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Article

Influence of Varieties and Mulching on the Quality and Quantity of Vegetable Pepper Yield

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Abstract: The influence of the cultivation method on green pepper fruits was investigated. Six pepper cultivars were planted using soil covered by brown mulching foil and in uncovered soil. Cultivation was maintained for two years providing the equivalent conditions of cultivation. The ascorbic acid content, total antioxidant capacity, total polyphenol content, soluble solids content and yield were observed and compared to mulching foil application, year of cultivation, pepper variety and order of harvest. The obtained results proved a statistically significant effect of mulching film in all tested varieties; the effects of year of cultivation and plant variety were also confirmed. The mulching film had a positive effect on pepper yield. The highest yield of peppers was grown on mulching foil in the variety 'Lungy'. The vitamin C content, total antioxidant capacity, total phenolic content and soluble solids content were demonstrably higher in the variant without mulching film. The highest levels of total polyphenol content and total antioxidant capacity were determined in the 'Yolo wonder' variety, the darkest colored cultivar. The highest content of vitamin C and soluble solids content were found in the 'Semaroh' variety grown without mulching film, however, this variety achieved the lowest yield growing with mulching foil.

Keywords: antioxidant capacity; mulching; pepper fruits; polyphenols; vitamin C

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1. Introduction

Peppers are considered one of the most favored and valuable vegetables. Their fruits are commonly eaten both fresh and processed. Fresh peppers are frequently eaten as a side dish either with cooked or cold meals. On the other hand, processed peppers are often a part of canned meals or ready-to-eat meals. Besides their specific taste, which makes them attractive for culinary purposes, their fruits also contain many bioactive compounds [1].

Ripe red colored fruits contain significant amounts of vitamin C, β-carotene and other valuable substances [2]. While monitoring the constituents of peppers, it is necessary to highlight especially the components that greatly affect biological value. In peppers, antioxidant components play an important role [3]. The pepper components with antioxidant activity can be included in groups such as carotenoids, vitamins and phenolic compounds. These phytochemicals can influence not only antioxidant activity but moreover the color, taste and aroma of the fruits [4]. Ascorbic acid and tocopherols (especially α-tocopherol) are considered as vitamins with the main antioxidant activity and they are responsible for reducing the amount of free radicals in the human body. Moreover, provitamin A is responsible for protection against age-related macular degeneration and its role in lung cancer prevention is also often mentioned [5]. The main phenolic compounds with antioxidant activity are presented as ferulic acid, quercetin, luteolin, apigenin derivatives and many others [6]. Spicy Capsicum species also contain capsaicin, dihydrocapsaicin and nordihydrocapsaicin [4]. Except the mentioned phytochemicals, the enzymatic systems with antioxidant function are important as well. These enzymes are mostly active in sweet peppers where the superoxide dismutase, catalase or ascorbate-glutathion system should be obviously emphasized [7].

The final content of all mentioned antioxidant systems and their variability is closely related to the cultivar, genotype, ripeness, growing and postharvest conditions that is widely documented in many studies [4]. Elizondo-Cabalceta et al. (2017) [8] evaluated the quality and yield of 12 sweet pepper genotypes grown under greenhouse conditions in Alajuela, Costa Rica. The highest number of first-class fruits (6.88 to 7.63 fruits/plant) and the highest commercial yield (70.96 to 78.35 t/ha) were produced by Cortes, Jumbo and V-701 genotypes. In the research by Rocha et al. (2018) [9], the production, physiological and phytotechnical characteristics of capsicum were evaluated under different irrigation strategies, in soil with mulch (polyethylene film, black below, white above) and without mulch. Mulching produced higher fruit numbers compared to plants grown in bare soil, and the soil yielded higher productivity using less water, thus increasing water use efficiency.

In our research, we focused on vitamin C content, soluble solids content, antioxidant capacity, total polyphenol content and yield of pepper fruits, depending on the varieties and method of cultivation (mulching). Mulching is generally considered a cultural practice that increases yield and improves fruit quality worldwide. The less water needed for irrigation, earlier harvest and larger plant size are among the main benefits associated with mulching. However, the shelf life after harvest is reduced (Melgarejo et al., 2012) [10].

The aim of the work was to set up experiments with the cultivation of different varieties of pepper in open ground and to compare the yield and quality when using a mulching film and without mulching.

2. Materials and Methods

2.1. Plant Material

A field experiment with annual sweet peppers—*Capsicum annuum* L.—was established in the Botanical Garden of the Slovak University of Agriculture (SUA) in Nitra in 2014 and 2015. The forerunner was peas. Vegetable peppers of the varieties Amy, Granova, Lungy, Semaroh, Slávy and Yolo wonder were used for the experiment. The Slava and Lungy varieties are F1 hybrids and the other varieties are simple progenies. The seeds of all varieties were purchased from the company Semo Smržice in Czech Republic, except for the variety Yolo wonder, which was purchased from the company Claus Tézier. The size, taste and color of pepper fruits are presented in Table 1.

Table 1. Properties of pepper fruits.

Cultivar	Width of Fruits (mm)	Length of Fruits (mm)	Thickness of the Pericarp (mm)	Taste	Color in Technical Maturity
Amy	60	125	7	not spicy	Light green
Granova	77	106	5	not spicy	Light green
Lungy	76	125	6	not spicy	Green
Slavy	71	114	5	not spicy	Green
Semaroh	41	130	4	not spicy	Green
Yolo wonder	70	130	6	not spicy	Dark green

2.2. Cultivation

Vegetable pepper seedlings were grown from sowing, which took place on 7 March 2014 and 11 March 2015 in the greenhouses of the SUA Botanical Garden. Germinated plants were transplanted on 24 April 2014 and 23 April 2015. Meteorological data (average temperature (°C) and total precipitation (mm) in individual months) for the location of Nitra, Slovakia, for 2014 and 2015 are shown in Table 2.

Table 2. Meteorological data (average temperature (°C) and total precipitation (mm) in individual months) for the location Nitra, Slovakia, for the year 2014 and 2015.

Year	Data	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
2014	Temperature (°C)	2.7	4.3	9.3	12.4	15.2	19.3	21.8	18.9	16.8	12.1	7.5	3.1	11.9
	Precipitation (mm)	38.2	37.5	15.4	48.9	57.6	52.5	64.1	55.9	122.0	34.6	21.5	42.0	590.2
2015	Temperature (°C)	1.6	1.2	6.3	10.4	15.1	19.9	23.6	23.5	17.5	10.5	6.0	2.6	11.5
	Precipitation (mm)	52.0	28.9	35.4	25.0	69.5	10.2	17.2	57.7	33.2	54.8	24.2	10.1	418.2

In the experiment, we used a mulching foil of brown color, the analogy one as was tested by Golian et al. (2016) [11]. They tested mulch films of various colors for growing field peppers. They state that mulching with dark mulch foils has a more positive effect on growth than bright mulch foils [11].

In our experiment, the same type of dark foil was used, which was applied in the work by Golian et al., 2016 [11]. The mulching foil was placed on a pre-prepared and leveled plot on 12 May 2014 and 11 May 2015. We planted the seedlings on 14 May 2014 and 13 May 2015. The cultivation area with and without mulch film is shown in Figure 1. The spacing of plants was 0.40×0.50 m.

Figure 1. The cultivation area with and without mulch film.

There was a high supply of phosphorus and potassium in the soil (Table 3). For this reason, autumn stock fertilization with phosphorus and potassium was not used. In the spring, we fertilized with nitrogen. We used LAD 27 fertilizer, with a content of ammonium nitrate and dolomite (the composition of LAD 27 fertilizer is: 27% N, 4% MgO, and 7% CaO). On a plot area of 10×12 m, 8.5 kg of LAD 27 fertilizer was used every year in three doses. In the year 2014, fertilization was applied on April 24 at a dose of 5.1 kg, on June 12 at a dose of 1.7 kg and on July 8 at a dose of 1.7 kg. In 2015, fertilization was applied on April 27 at a dose of 5.1 kg, on June 11 at a dose of 1.7 kg and on July 7 at a dose of 1.7 kg. The experiment was based on soil dominated by clay. The percentage of sand, silt, clay and EC was not evaluated during the soil analysis.

Table 3. Soil nutrients content in the plot.

The Nutrient Content in mg·kg^{-1} Soil in 2014						
$N\text{-}NH_4^+$	$N\text{-}NO_3^-$	P	K	S	Ca	Mg
28	18	130	575	32.5	7300	663
pH/KCl 6.96, humus 3.79%						
The Nutrient Content in mg·kg^{-1} Soil in 2015						
$N\text{-}NH_4^+$	$N\text{-}NO_3^-$	P	K	S	Ca	Mg
27	19	135	584	30.2	7200	634
pH/KCl 6.92, humus 3.81%						

In both variants (with and without mulch), the number of varieties was 6. The number of repetitions was 3. In each repetition, 9 plants were planted for each variety. In each year of the experiment, a total of 324 plants were planted.

2.3. Evaluation of Quantity and Quality

The fruits were harvested gradually three times in the stage of technical (green) maturity and then for the fourth time they were harvested in transient maturity (period between technical and botanical maturity). The harvest dates were as follows: 1st harvest, 23 July 2014, 28 July 2015; 2nd harvest, 5 August 2014, 4 August 2015; 3rd harvest, 14 August 2014, 13 August 2015; 4th harvest, 24 September 2014, 23 September 2015.

The fruits were classified into market fruit (%) and non-standard (%). The grading parameters were as follows: the width of the sweet pepper must not be less than 20 mm in the case of a pointed variety, less than 40 mm in the case of a square variety or square with a point and 55 mm in the case of a flat or tomato pepper [12]. When harvested, 9 pieces of pepper fruits were taken from each variety and mulching variant composing an average sample for analysis.

The vitamin C content was determined according to the method by Miki (1981) [13] modified by Rop et al. (2010) [14]. It was calculated as mg·kg^{-1} of FW (fresh mass).

The soluble solids content was measured with a digital refractometer of mark Kruss DR201-95 in the Laboratory of SUA in Nitra [15].

The total antioxidant capacity of the pepper extracts was determined by a DPPH method by Thaipong et al. (2006) [16] using free radical 2,2-diphenyl-1-picrylhydrazyl (DPPH). The calibration curve was used to transfer absorbance results as g ascorbic acid equivalents per kg of fresh weight (g AAE·kg^{-1} FW) [17].

Total phenolic content of the pepper extract was determined using the Folin–Ciocalteu procedures. The results were obtained in duplicates and were expressed as g gallic acid equivalents per kg of fresh weight (g GAE·kg^{-1} FW) [18].

Pretreatment of samples for extract preparation was provided by the method based on Kim et al. (2003) [18].

2.4. Statistical Analysis

Each experiment was performed in triplicate. The data were analyzed using Excel 2013 (Microsoft Corporation, Redmond, WA, USA) and STATISTICA CZ version 12 (StatSoft, Inc., Tulsa, OK, USA) and expressed as means ± standard deviations (M ± SD).

The procedure for the statistical analysis was the following: the Shapiro–Wilk test of normality (α = 0.05) was performed within all monitored samples. The test of homogeneity was performed with Levene's test and Brown–Forsythe test. Furthermore, a specific analysis procedure was chosen according to the number of compared groups of data. If the conditions for a parametric test complied (Shapiro–Wilk test and Levene's test or Brown–Forsythe test were met, α = 0.05), a specific parametric test was executed—F-test and a two-tailed t-test (α = 0.05) in the case of comparison of only two groups of samples (e.g., with and without mulch film for one variety) and ANOVA and Tukey HSD test in the case of comparison of several groups (comparison of varieties with each other). Otherwise, the nonparametric test (α = 0.05) was used—the Mann–Whitney U test (α = 0.05) in the case of comparison of only two groups of samples and Kruskal–Wallis test (α = 0.05) and multiple comparisons of *p* values (two-sided) (α = 0.05) based on Mann–Whitney U test in the case of comparison of several groups.

3. Results

3.1. Vitamin C Content

Table 4 and Figure 2 show that in our experiments the monitored varieties achieved a higher content of vitamin C in the variant of cultivation without mulching foil. The two-year average shows the lowest average content (709.45 mg·kg^{-1}) was found for the 'Yolo wonder' variety and the highest (901.84 mg·kg^{-1}) for the 'Semaroh' and (898.70 mg·kg^{-1}) 'Slávy' variety. In the mulching variant, the overall vitamin C values were lower. They ranged from 631.47 mg·kg^{-1} for the 'Granova' variety and 772.62 mg·kg^{-1} for the 'Amy' variety (Figure 2).

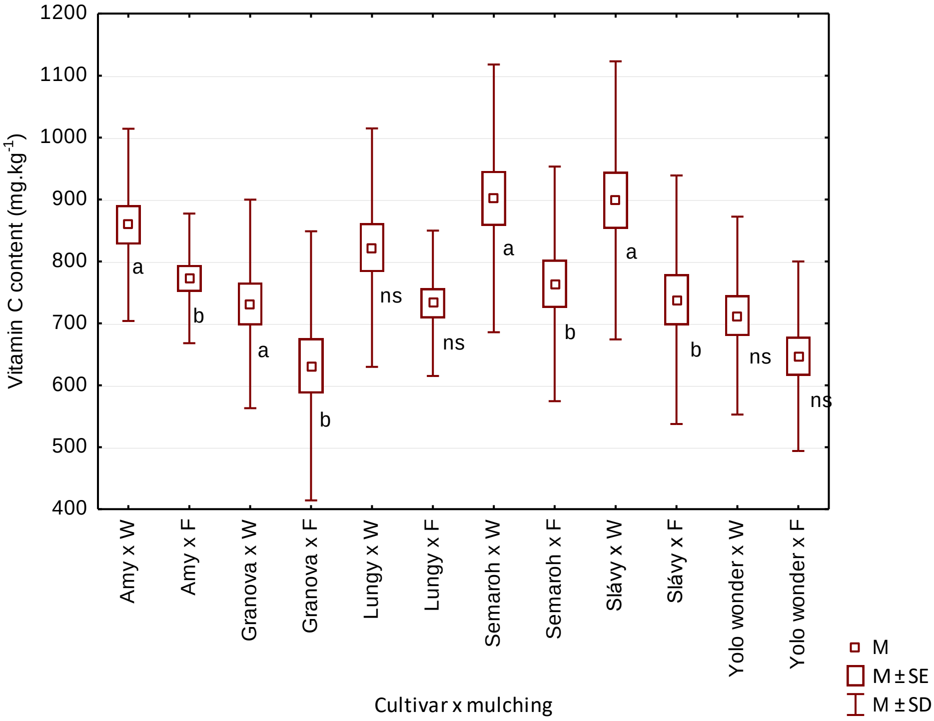

Figure 2. Vitamin C content (mg·kg^{-1}) in pepper cultivars under different treatments (W—Without mulching foil, M—mulching foil)—average value from all years and harvests. The result of the t-Student test between treatments is indicated in small letters next to the box (if there are differences, the higher average is lettered "a" and the lower average is lettered "b"; "ns" indicates no statistical difference).

Table 4. Vitamin C content according to collections, variants and years ($mg \cdot kg^{-1}$).

Cultivar	Soil Treatment	1. Harvest 2014	1. Harvest 2015	2. Harvest 2014	2. Harvest 2015	3. Harvest 2014	3. Harvest 2015	4. Harvest 2014	4. Harvest 2015
		Mean ± SD	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**
Amy	W	706 ± 32 $^{ns;ns}$	713 ± 18 $^{ns;ns}$	747 ± 20 $^{*;a}$	795 ± 10 $^{**;a}$	954 ± 211 $^{ns;ns}$	976 ± 215 $^{ns;ns}$	984 ± 55 $^{ns;a}$	999 ± 59 $^{ns;a}$
	M	682 ± 20 $^{ns;ns}$	680 ± 28 $^{ns;ns}$	659 ± 8 $^{*;b}$	713 ± 25 $^{**;b}$	848 ± 107 $^{ns;ns}$	868 ± 107 $^{ns;ns}$	858 ± 37 $^{ns;b}$	874 ± 40 $^{ns;b}$
Granova	W	599 ± 28 $^{ns;ns}$	609 ± 32 $^{ns;ns}$	660 ± 49 $^{ns;a(MW)}$	693 ± 44 $^{ns;a}$	677 ± 68 $^{ns;a}$	624 ± 155 $^{ns;ns}$	989 ± 39 $^{ns;ns}$	1001 ± 41 $^{ns;ns}$
	M	610 ± 48 $^{ns;ns}$	608 ± 45 $^{ns;ns}$	448 ± 29 $^{ns;b(MW)}$	466 ± 32 $^{ns;b}$	471 ± 27 $^{ns;b}$	485 ± 27 $^{ns;ns}$	971 ± 35 $^{ns;ns}$	992 ± 40 $^{ns;ns}$
Lungy	W	655 ± 35 $^{ns;ns}$	658 ± 36 $^{ns;ns}$	1079 ± 29 $^{ns;a}$	1139 ± 63 $^{ns;a}$	771 ± 175 $^{ns;ns}$	781 ± 171 $^{ns;ns}$	743 ± 48 $^{ns;ns}$	753 ± 47 $^{ns;ns}$
	M	595 ± 38 $^{ns;ns}$	598 ± 40 $^{ns;ns}$	821 ± 19 $^{ns;b}$	854 ± 17 $^{ns;b}$	764 ± 153 $^{ns;ns}$	775 ± 154 $^{ns;ns}$	719 ± 86 $^{ns;ns}$	733 ± 82 $^{ns;ns}$
Semaroh	W	651 ± 86 $^{ns;a}$	659 ± 84 $^{ns;a}$	863 ± 41 $^{ns;a}$	887 ± 38 $^{ns;ns}$	848 ± 11 $^{ns;a}$	860 ± 19 $^{ns;a}$	1215 ± 91 $^{ns;a}$	1231 ± 94 $^{ns;a}$
	M	477 ± 26 $^{ns;b}$	519 ± 23 $^{ns;b}$	736 ± 40 $^{ns;b}$	831 ± 105 $^{ns;ns}$	763 ± 18 $^{ns;b}$	776 ± 17 $^{ns;b}$	996 ± 39 $^{ns;b}$	1012 ± 41 $^{ns;b}$
Slávy	W	804 ± 28 $^{ns;a}$	808 ± 29 $^{ns;a}$	1026 ± 41 $^{ns;a}$	1059 ± 52 $^{ns;a}$	680 ± 351 $^{ns;ns}$	691 ± 353 $^{ns;ns}$	1052 ± 111 $^{ns;ns}$	1068 ± 111 $^{ns;ns}$
	M	675 ± 39 $^{ns;b}$	684 ± 47 $^{ns;b}$	634 ± 12 $^{ns;b}$	651 ± 17 $^{ns;b}$	577 ± 187 $^{ns;ns}$	597 ± 182 $^{ns;ns}$	1037 ± 49 $^{ns;ns}$	1050 ± 50 $^{ns;ns}$
Yolo wonder	W	670 ± 61 $^{ns;ns}$	764 ± 37 $^{ns;a}$	549 ± 19 $^{ns;ns}$	562 ± 23 $^{ns;ns}$	652 ± 34 $^{ns;ns}$	667 ± 33 $^{ns;ns}$	914 ± 18 $^{ns;ns}$	922 ± 185 $^{ns;ns}$
	M	594 ± 93 $^{ns;ns}$	649 ± 59 $^{ns;b}$	493 ± 36 $^{ns;ns}$	520 ± 34 $^{ns;ns}$	596 ± 143 $^{ns;ns}$	608 ± 142 $^{ns;ns}$	850 ± 73 $^{ns;ns}$	866 ± 72 $^{ns;ns}$

Comment: W—variant with uncovered soil, M—variant with mulching film. Statistically significant differences: (1) between years (first position): *,** statistically significant difference for the same cultivar with the same treatment and the same collection number, ^{ns} indicates no statistical difference; (2) between soil treatment (second position): ^{a,b} statistically significant difference for the same cultivar at the same collection number in the same year, ^{ns} indicates no statistical difference; (3) $^{(MW)}$ indicates calculation using the Mann–Whitney U test.

In the group of plants without mulch film, differences were found between the varieties 'Granova' vs. 'Slávy', 'Granova' vs. 'Semaroh', 'Yolo wonder' vs. 'Slávy' and 'Yolo wonder' vs. 'Semaroh'. Only one difference was found in the group of plants with mulch film, and that was between the varieties 'Amy' and 'Granova'.

Figure 2 also shows a statistically significant difference between treatments (W—Without mulching foil, M—mulching foil) for the same pepper variety, which was performed using the *t*-Student test. This statistically significant difference was found for all varieties except 'Lungy' and 'Yolo wonder' varieties.

The content of vitamin C in pepper cultivars treated with mulch film was lower than in the case without mulch film. A similar trend was found by Valšíková et al. (2018) [19] in tomatoes, who documented a decrease in the content of ascorbic acid in fruits treated with mulching film.

Dumaset et al. (2003) [20] and Gautieret et al. (2009) [21] documented that a reduction in direct sunlight can directly affect the content of ascorbic acid (in general, it leads to a decrease in bioactive compound levels and antioxidant capacity).

The changes in vitamin C content of the pepper variety ´Fresno de la Vega´ as a function of ripeness were studied [22]. The ascorbic acid content increases in peppers as they ripen. For green mature, breaker and red peppers, average values of 107.39, 129.69 and 154.39 mg/100 g edible portion were found. In our experiment, we also noticed an increase in vitamin C content from the first to the fourth harvest.

In the research of Agostini-Costa et al. (2017) [23], the peppers of 'yellow jalapeño lineage' (*C. annuum*) and of the red bode cultivar (*C. chinense*) also stood out for their high levels of vitamin C (152 ± 5 and 123 ± 1 mg/100 g). These pungent varieties had a higher vitamin C content than our varieties of sweet peppers.

3.2. Content of Soluble Solids

When evaluating the soluble solids content (Table 5) in the variant without mulching, the value of the average for individual varieties ranged from 2.72% for the variety 'Slávy' to 3.65% for the variety 'Semaroh'. The variant with cultivation on mulching foil had lower values of soluble solids content for each variety. The lowest soluble solids content was measured in the varieties 'Amy' and 'Slávy' with a value of 2.38% and the most in the varieties 'Semaroh' (3.54%) and 'Yolo Wonder' (3.13%). The average values of the soluble solids content for individual harvests are shown in Table 5.

Table 5. Content of soluble solids in % (Means ± Standard error) for individual harvests.

Cultivar	Soil Treatment	1. Harvest	2. Harvest	3. Harvest	4. Harvest
Amy	W	2.38 ± 0.16 $^{*;ns}$	1.68 ± 0.23 $^{*;ns}$	1.99 ± 0.55 $^{*;ns}$	5.83 ± 0.20 $^{**;a}$
	M	1.88 ± 0.17 $^{*;ns}$	1.52 ± 0.10 $^{*;ns}$	1.51 ± 0.53 $^{*;ns}$	4.60 ± 0.03 $^{**;b}$
Granova	W	2.29 ± 0.08 $^{*;ns}$	2.23 ± 0.17 $^{*;ns}$	2.53 ± 0.20 $^{*;ns}$	6.43 ± 0.25 $^{**;a}$
	M	2.14 ± 0.19 $^{*;ns}$	1.97 ± 0.40 $^{*;ns}$	2.49 ± 0.15 $^{*;ns}$	5.16 ± 0.06 $^{**;b}$
Lungy	W	2.42 ± 0.07 $^{ns(KW);ns}$	2.09 ± 0.71 $^{ns(KW);ns}$	2.47 ± 0.15 $^{ns(KW);ns}$	6.83 ± 0.12 $^{ns(KW);a}$
	M	2.43 ± 0.09 $^{*;ns}$	1.85 ± 0.16 $^{*;ns}$	2.43 ± 0.20 $^{*;ns}$	5.70 ± 0.09 $^{**;b}$
Slavy	W	2.31 ± 0.15 $^{ns(KW);ns}$	1.72 ± 0.19 $^{ns(KW);ns}$	1.72 ± 0.56 $^{ns(KW);ns}$	5.13 ± 0.02 $^{ns(KW);a}$
	M	2.39 ± 0.22 $^{*;ns}$	1.54 ± 0.10 $^{*;ns}$	1.64 ± 0.44 $^{*;ns}$	3.96 ± 0.38 $^{**;b}$
Semaroh	W	2.80 ± 0.14 $^{*;a}$	2.41 ± 0.08 $^{*;a}$	3.32 ± 0.50 $^{*;ns}$	6.06 ± 0.07 $^{**;ns}$
	M	2.39 ± 0.03 $^{*;b}$	2.03 ± 0.02 $^{**;b}$	2.64 ± 0.11 $^{*;ns}$	5.90 ± 0.07 $^{***;ns}$
Yolo wonder	W	2.44 ± 0.23 $^{*;ns}$	2.54 ± 0.16 $^{*;ns}$	2.89 ± 0.14 $^{*;ns}$	6.43 ± 0.23 $^{**;a}$
	M	2.17 ± 0.14 $^{*;ns}$	2.41 ± 0.08 $^{*;ns}$	2.70 ± 0.27 $^{*;ns}$	5.26 ± 0.01 $^{**;b}$

Comment: W—Soil without mulching, M—Soil with mulching. Statistically significant differences: (1) between harvest (first position): *,** statistically significant differences, ^{ns} indicates no statistical difference; (2) between soil treatment (second position): ^{a,b} statistically significant differences, ^{ns} indicates no statistical difference; (3) $^{(KW)}$ indicates calculation using the Kruskal–Wallis test (α = 0.05).

Similar results were obtained in the research conducted by Valšíkova et al. (2017) [24]. The soluble solids content of six pepper varieties in the experiment tended to increase during the vegetation period. In the stage of technical (green) maturity, the average content of soluble solids was 3.97%. In transitional maturity, it was 4.83% and in botanical (red) maturity it was 6.16%.

The changes in total soluble solids (°Brix) with harvesting time followed alterations of the sugar content, as may be expected [25]. Neocleous and Nikolaou (2019) [25] found that the accumulation of reducing sugars and soluble solids in fruit is influenced by photosynthesis (light and temperature in the optimal range). This is indicated by the results in this work, where the average value of the content of soluble solids was lower when treated with mulch film (less amount of direct light) than in the case without mulch film treatment.

3.3. Total Polyphenol Content

As was mentioned before, apart from vitamin C, other antioxidant characteristics were determined as well. The amount of total polyphenol content and total antioxidant capacity of pepper fruits are presented in Tables 6 and 7. As can be observed from Table 6, all monitored cultivars achieved a higher content of total phenolic compounds in the variant of cultivation without mulching foil in both monitored periods (2014 and 2015). Moreover, it is clearly documented that in the second monitored period in year 2015, all varieties reached higher values of total polyphenols, which correspond with higher content of vitamin C in the second year of cultivation (see Table 4). The highest level of total polyphenol content showed in the 'Yolo wonder' variety (0.90 g GAE·kg^{-1} FW, 1.13 g GAE·kg^{-1} FW in year 2015). Other cultivars showed quite similar values of polyphenols, which ranged from 0.76 to 0.81 g GAE·kg^{-1} FW in the first year of cultivation and from 0.81 to 0.92 g GAE·kg^{-1} FW in the second year of cultivation both without using mulching film. In the variant where the mulching film was applied, the overall levels of total polyphenolic compounds were lower. They ranged from 0.64 to 0.73 g GAE·kg^{-1} FW in 2014 and from 0.75 to 0.87 g GAE·kg^{-1} FW in 2015 for most tested cultivars, the highest value showed in the 'Yolo wonder' variety (0.84 g GAE·kg^{-1} FW, resp. 1.05 g GAE·kg^{-1} FW in the second year of cultivation, however, in this case it is not a statistically significant difference compared to uncovered soil cultivation).

Table 6. Total polyphenol content (g GAE·kg^{-1} fresh weight).

Cultivar	Soil Treatment	Year 2014	Year 2015
		Mean ± SD	**Mean ± SD**
Amy	W	0.77 ± 0.03 $^{ns;a(MW)}$	0.81 ± 0.05 $^{ns;ns}$
	M	0.66 ± 0.01 $^{*;b(MW)}$	0.78 ^{a} ± 0.03 $^{**;ns}$
Granova	W	0.76 ± 0.02 $^{*(MW);a}$	0.84 ± 0.05 $^{**(MW);a(MW)}$
	M	0.64 ± 0.04 $^{*(MW);b}$	0.75 ± 0.01 $^{**(MW);b(MW)}$
Slavy	W	0.78 ± 0.03 $^{*;a}$	0.84 ± 0.06 $^{**;a}$
	M	0.69 ± 0.02 $^{*(MW);b}$	0.75 ± 0.06 $^{**(MW);b}$
Semaroh	W	0.81 ± 0.03 $^{*;a}$	0.92 ± 0.05 $^{**;a}$
	M	0.73 ± 0.03 $^{*;b}$	0.87 ± 0.03 $^{**;b}$
Yolo wonder	W	0.90 ± 0.03 $^{*(MW);a}$	1.13 ± 0.25 $^{**(MW);ns}$
	M	0.84 ± 0.02 $^{*(MW);b}$	1.05 ± 0.10 $^{**(MW);ns}$

Comment: W—variant with uncovered soil, M—variant with mulching film. Statistically significant differences: (1) between years (first position): *,** statistically significant differences, ^{ns} indicates no statistical difference; (2) between soil treatment (second position): ^{a,b} statistically significant differences, ^{ns} indicates no statistical difference; (3) $^{(MW)}$ indicates calculation using the Mann–Whitney U test.

Table 7. Total antioxidant capacity (g AAE·kg^{-1} fresh weight).

Cultivar	Soil Treatment	Year 2014	Year 2015
		Mean ± SD	Mean ± SD
Amy	W	1.06 ± 0.03 $^{ns;a(MW)}$	1.14 ± 0.09 $^{ns;a(MW)}$
	M	0.93 ± 0.01 $^{*(MW);b(MW)}$	1.04 ± 0.02 $^{**(MW);b(MW)}$
Granova	W	1.12 ± 0.06 $^{*;a}$	1.24 ± 0.07 $^{**;ns}$
	M	0.93 ± 0.03 $^{*(MW);b}$	1.20 ± 0.12 $^{**(MW);ns}$
Slavy	W	1.07 ± 0.04 $^{ns;a}$	1.13 ± 0.12 $^{ns;a(MW)}$
	M	0.93 ± 0.05 $^{ns;b}$	0.99 ± 0.05 $^{ns;b(MW)}$
Semaroh	W	1.16 ± 0.01 $^{*;a(MW)}$	1.34 ± 0.10 $^{**;ns}$
	M	0.94 ± 0.01 $^{*(MW);b(MW)}$	1.28 ± 0.07 $^{**(MW);ns}$
Yolo wonder	W	1.31 ± 0.03 $^{*;a}$	1.42 ± 0.06 $^{**;a}$
	M	1.15 ± 0.02 $^{*(MW);b}$	1.24 ± 0.07 $^{**(MW);b}$

Comment: W—variant with uncovered soil, M—variant with mulching film. Statistically significant differences: (1) between years (first position): *,** statistically significant differences, ^{ns} indicates no statistical difference; (2) between soil treatment (second position): ^{a,b} statistically significant differences, ^{ns} indicates no statistical difference; (3) $^{(MW)}$ indicates calculation using the Mann–Whitney U test.

Similar results were presented for other fruits. Higher levels of total polyphenol content and total antioxidant activity in tomato fruits in the case of cultivation in uncovered soil compared to using mulching film were presented by Valšíková et al. (2018) [19].

The decrease in total polyphenol content in Konservolia Olive trees due to polyethylene mulching foil treatment compared with the mulch-free condition was reported by Gholami et al. (2020) [26]. After the application of the mulch film, there was a decrease in the average value of total polyphenol content or total antioxidant capacity also in Japanese plum grown under polyethylene film, as documented by Melgarejo et al. (2012) [10]. These conclusions correlate with the participation of the phenolic compounds in the plant defense mechanism. On the other hand, the application of reflective mulching film during blueberry cultivation resulted in higher levels of total polyphenol content due to increased light intensity [27].

The values of total polyphenols content depending on variety are contrary to the vitamin C content. The highest values of phenolic compounds were achieved in the ´Yolo wonder´ variety in both periods without mulching film, however, this cultivar showed one of the lowest amounts of ascorbic acid (see Table 4).

Assigned to the cultivar color, the green pepper had a higher level of phenolics than red and yellow ones, and the red pepper had a higher content of ascorbic acid than green and yellow peppers as was found by Zhang et al. (2003) [28]. Our conclusion is the same focusing only on green-colored varieties. We observed the highest content of polyphenols in fruits of the 'Yolo wonder' variety, which were dark green and this variety showed the lowest content of vitamin C. The fruit color of other monitored cultivars varied from light green to green (Table 1).

3.4. Total Antioxidant Capacity

The decreasing trend of polyphenol content as a result of using mulching film corresponds with the values of total antioxidant capacity that are shown in Table 7. Higher levels of total antioxidant capacity were assessed in the variant with uncovered soil during planting in both time periods 2014 and 2015. Moreover, all cultivars showed higher values in 2015 compared with year 2014. When tested cultivars were compared to each other, the 'Yolo wonder' variety achieved the highest levels of total antioxidant capacity: 1.42 g AAE·kg^{-1} FW in 2015 without mulching, and 1.31 g AAE·kg^{-1} FW in 2014. Other cultivars achieved levels ranging from 1.13 to 1.34 g AAE·kg^{-1} FW in 2015, and from 1.06 to 1.16 g AAE·kg^{-1} FW in 2014 with uncovered soil cultivation. The mulching film application during cultivation caused on average a 15% decrease in total antioxidant activity in

2014, and on average 11% in 2015. These results correspond with the values of total phenol content that were discussed before.

The decreasing trend of total antioxidant capacity as a result of using mulching film corresponds with the trend observed in a study reported by Valšíková et al. (2018) [19] where the effect of mulching was studied on tomatoes. The total antioxidant capacity was similarly reduced also in [10], where average lower values of the total antioxidant capacity were found after the application of the mulch film. In a study by Martí et al. (2011) [29], the differences in the total antioxidant activity contributed to the different cultivars. In conclusion, they did not find significant differences between green and red colored peppers. However, as stated by Guilherme et al. (2020) [30], green peppers had significantly higher DPPH activity in comparison with red cultivars, which was attributed to the higher total phenolic content. This corresponds with our results. The highest level of total antioxidant capacity was observed in case of the ´Yolo wonder´ cultivar with dark green colored fruits. Furthermore, the ´Yolo wonder´ variety showed the highest polyphenol content.

3.5. Total Yield of Pepper Fruits

In the experiments, we also focused on the yield of vegetable peppers. We found differences due to varieties and mulching. In our experiment, the mulch film had a positive effect on the pepper yield. Varieties grown without mulching achieved lower yields compared to variants grown with mulching of the soil (Table 8). In the case of the Semaroh variety without mulching film, the yield was up to 60% lower compared to the group treated with mulching film. The largest total yield of peppers was obtained when grown on a mulching film, and that was with the variety Lungy (37.4 t·ha^{-1}). The yield was the lowest for the 'Semaroh' variety (9.30 t·ha^{-1}) without mulch film treatment.

Table 8. Total yield of peppers at gradual harvests (t·ha^{-1}) and difference of total yields between soil treatment.

Varieties	Soil Treatment	1. Harvest	2. Harvest	3. Harvest	4. Harvest	Total	Difference of Total Yields
Amy	W	10.3	4.3	3.1	3.1	20.1	5.1
	M	14.9	6	3.4	3.4	25.2	
Granova	W	11.8	10.3	5.6	5.6	32.5	1.5
	M	7.8	9.5	7.5	7.5	34	
Lungy	W	10.2	12.1	4.6	4.6	31.6	5.8
	M	16.7	8.5	6.9	6.9	37.4	
Slavy	W	13.7	6.2	3.5	3.5	26	0.1
	M	11.9	5.3	5.3	5.3	26.1	
Semaroh	W	5.1	1.5	1.5	1.5	9.3	14.9
	M	9.9	5.3	4.4	4.4	24.2	
Yolo wonder	W	13.2	7.6	4.8	4.8	28.3	3.5
	M	10.5	7.4	6.3	6.3	31.8	

Comment: W—variant with uncovered soil, M—variant with mulching film.

The mulching effects on the growth and yield of peppers were studied by Bogevska et al. (2021) [31]. Straw wheat mulch and red film were less suitable for growing peppers. The black film followed by white on black film can be recommended for pepper kapiya type production in open fields.

According to more authors [32–34], on open ground peppers commonly reach a yield of 10-30 t·ha^{-1}, but can also achieve higher yields. When grown in greenhouses, 50 to 100 fruits are produced per 1 m^2.

Dhaliwal et al. (2019) [35] found that the highest fruit number, fruit weight, early yield, marketable yield and total yield were obtained when the pepper crop was planted under black polythene. Similarly, Edgar et al. (2016) [36] addressed the impact of the use of organic and inorganic mulch materials to increase the productivity of horticultural crops.

Based on the experimental results, the black polythene mulches had the greatest effects on the growth and yield of sweet peppers. The black polythene mulch when growing green peppers also helps for better conservation of soil moisture and nutrients for good crop growth. Their results are consistent with the results in this work regarding higher yields.

Khan et al. (2016) [37] studied mulching materials (wheat straw, sawdust, clear plastic and black plastic) when growing chili peppers. The minimum weed density on m^2 (19) and the maximum yield (3.07 $t{\cdot}ha^{-1}$) were found when black plastic was used, while the maximum weed density on m^2 (209) was found when using transparent plastic. Khan et al. documents that areas without the mulch film had the lowest yield. Areas with any mulch film had a higher yield (up to 4x higher with black plastic film). Habtamu et al. (2016) [38] investigated tomato mulching. They used black plastic mulch, white plastic mulch, grass mulch and no mulch with two varieties ('Cochoro' and 'Miya'). They found that the significantly highest number of fruits per cluster and percent fruit set was registered when the Miya variety was grown on grass and black plastic mulch. Even when growing pumpkin varieties 'Surya' on black foil there was a demonstrable increase in yield [39].

The application of mulching foils during cultivation has become often used as a water conservation practice. Mulching material reduces evaporation, protects soil surface from sunlight and helps to adjust altering soil temperature. Moreover, the different optical properties of colored plastic foils influence the growth rate and canopy distribution of plant. Black plastic mulch is the most popular because of its simple handling, lightness and best efficiency in keeping water and nutrients in the plant root zone. However, the plastic foil has a negative impact on the environment and soil ecosystem, therefore, new materials for mulching are still being explored and should be biodegradable, cost-effective and efficient [40,41].

3.6. Harvest and Proportion of the 1st Quality Class of Pepper Fruits

The yield of 1st class fruits was higher in the variants grown on mulch foil, from 18.15 $t{\cdot}ha^{-1}$ ('Semaroh') to 34.90 $t{\cdot}ha^{-1}$ ('Lungy'). In the variants grown on free soil, the yields of the 1st class reached from 8.03 to 28.60 $t{\cdot}ha^{-1}$, depending on the varieties. The smallest yield was produced by the variety with small fruits ('Semaroh' 8.03 $t{\cdot}ha^{-1}$) and the highest yields were provided by the variety 'Lungy' with the 1st class fruits yield 28.60 $t{\cdot}ha^{-1}$.

We expressed the shares of the 1st class harvest in the total harvest in %. When grown without mulching, the highest shares of the 1st class had the varieties 'Slávy' (92.81%) and 'Amy' (92.14%). The lowest % of the 1st class was found in the varieties 'Granova' (83.75%) and 'Semaroh' (86.34%).

The variant with mulching foil had the best results with the share of the 1st class in the varieties 'Slávy' (93.87%) and 'Lungy' (93.32%). In this case, the worst was the Semaroh variety, whose share of 1st class fruits reached only 75%.

According to the USDA Agricultural Marketing Service, the rules determine, among other things, the quality and condition for peppers of 1st class quality (USDA 2016) [42]. For European States, the (CIR) Commission implementing regulation (EU) No 543/2011 of 7 June 2011 lays down detailed rules for the application of Council Regulation (EC) No 1234/2007 fruit and vegetables sectors [43]. A consolidated text is set out in Annex I; Part 8 of Part B Marketing standard for sweet peppers. This regulation defines that the 1st class of sweet peppers must be of good quality. They must be characteristic of the variety and/or commercial type. It also determines possible accurately described slight allowed defects.

4. Conclusions

The content of vitamin C, total antioxidant capacity, total phenolic content and soluble solids content was demonstrably higher in the variant without mulching film.

The highest content of vitamin C was found in pepper fruits grown without mulching in the 'Semaroh' variety and the lowest in the 'Yolo wonder' and 'Granova' varieties. Moreover, the highest levels of total antioxidant capacity and total phenolic content was observed in the variant without mulching as well. The cultivar with the highest amount of total phenolic content was the 'Yolo wonder' variety, the same as for the highest level of total antioxidant capacity. The average content of soluble solids was highest in the cultivation without mulching film on ground in the 'Semaroh' variety and lowest in the variety of 'Slávy'. For the mulching foil, the lowest values of soluble solids were found in the varieties 'Amy' and 'Slávy', and the most in the varieties 'Semaroh' and 'Yolo wonder'. The mulching film had a positive effect on the pepper yield. The high statistical evidence was manifested between the varieties and also between the variants. The largest yield of peppers was grown on mulch foil, in the variety 'Lungy'. Even in this variant, the 'Semaroh' variety achieved the lowest yield.

The method of cultivation clearly did not affect the quantity of 1st class crops. The difference between the total harvest and the 1st class harvest is non-standard. Throughout the experiment, the amount of non-standard fruit ranged from 1.27 to 6.32 t·ha^{-1}.

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