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Influence of Mulching on Replantation Disease in Sour Cherry Orchard

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Abstract: Increasingly, in orchards around the world that are planted one after another, disturbances are observed, and these issues with growth and development are called replantation disease. It is manifested mainly by poor tree growth after planting and poor ripening. One way to reduce replantation disease is to improve soil fertility after many years of fruit tree cultivation. The aim of the work was to evaluate the growth and yield of cherries after replantation and to compare this with a site where fruit trees had not grown before. The trees were planted at two sites: after the replantation of the cherry orchard (OR1) and in a site where fruit trees had not been cultivated before (OR2). Two combinations were used in each orchard: boiler without mulching (C), mulch—after planting mulching with a substrate after growing mushrooms (M). The trees at the site after replantation grew and bore less fruit than in the position where fruit trees had not grown before. The disease also affected some of the quality characteristics of the fruit. This resulted in an increase in fruit weight and a darker color (L*) and a higher value of hue fruit color. Mulching, which is often recommended in orchards planted after previous cultivation, did not provide the expected improvement. It did not significantly affect tree growth and yield. Only an effect on the content of components in the soil was observed, but it affected the condition of the trees. In addition, we analyzed how experimental combinations responded to climatic conditions by calculating the correlations between the SAT (sum of active temperatures) and the stages of tree development.

Keywords: replantation; *Prunus cerasus*; firmness; mulching; total soluble solids; titratable acidity; color; sum of active temperatures

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1. Introduction

Poland is one of the largest producers of fruit in the Europe and in the world. Apples are dominant, but it is also one of the largest producers of cherry fruits, which annually ranges from 150 to 200 thousand tons [1–5]. The area of cultivation of this species is large; however, due to decreasing profitability, it has been reduced [1,6,7]. The basic cultivar in Poland is Łutówka (Chatenmorelle), and its share in commodity production is 80–85% [8].

The production of cherries is burdened with a high environmental risk [9] related to the course of the weather during flowering and fruit setting. Ground frosts or unfavorable conditions for pollination and fertilization cause a large fluctuation in yield [3,10]. Low temperatures in winter are already rare, and now the threat of not having a sufficiently long dormant period is becoming more and more frequent. The length of winter supercooling is important for the proper development of generative organs of horticultural plants [11–14]. So far in Poland, the topic of cold in winter has been marginal, and the topic was known only from the literature [15–17], but global warming means that the problem is growing and it will be necessary to conduct this type of research.

In addition, a significant problem in cherry cultivation is high sensitivity to replantation disease. It is manifested by poor growth of trees planted in conditions of replantation [18–21]. It is recommended to plant trees in new locations, as well as carefully prepare the site before planting. However, if it is not possible to set up an orchard on a site previously used for agricultural crops, it is recommended to leave a several years interval in the cultivation of this species. This allows you to regulate the pH of the soil, supplement nutrients, and enrich in organic matter or improve the structure of the soil. However, the break is most often limited to one year [22–25].

In addition, agrotechnical methods are being sought that will improve the adverse properties of the soil [26–28] This is mainly achieved by implementing organic matter into the soil and mulching. The soil is enriched with matter of different reaction, water properties, and richness in mineral substances. In orchard crops, sawdust of various tree species, straw, shredded bark, manure, and substrate used to cultivate mushrooms are used. The use of organic mulches requires their regular replenishment, because it is constantly decomposed. The rate of biodegradation depends on the degree of fragmentation and composting [29–32].

The use of organic matter such as straw, bark, sawdust, or wood chips [33] where the C:N ratio is high, requires the use of additional mineral nitrogen fertilization [34]. Soil micro-organisms that decompose organic material take up some of the nitrogen that becomes inaccessible to trees [35] which means that fertilizing recommendations for this component should be increased by 50 to 100%. In addition, it is advisable to analyze the matter used for mulching so as not to disturb the balance between minerals or increase soil salinity and, consequently, weaken the growth of trees [35].

There is a need to maintain a high soil culture and reduce weed populations in order to properly maintain soil fertility and moisture with increasing water shortages during the growing season [36]. So far, there have been few studies on the use of compost from growing mushrooms as mulch in cherry cultivation. The use of compost from mushroom cultivation in an apple orchard allowed the controlling of weed infestation, but at the same time limited the yield after two seasons of research [37]. Similar results were obtained in orchards where mushroom compost was added to the soil at the time of planting or used as mulch in apple trees [38]. The use of compost in a plum orchard had a positive effect on yield [39], where yields did not differ from the control combination.

The literature on soil fatigue in orchards is quite poor, and the problem seems to be growing, which is why the authors decided to conduct research using fields in the university's experimental station, where orchard crops have been used for many years. The main objective of the study was to assess the growth and yield of cherry trees (*Prunus cerasus* L.) after replantation of the cherry orchard compared to a site where fruit trees had not been grown before. As a treatment aimed at mitigating the effects of replantation, mulching with compost obtained from the substrate obtained after growing mushrooms was used. Additionally, the influence of climatic factors on flowering, ripening, and fruit quality was studied.

2. Materials and Methods

The experiment was carried out in the years 2007–2016 in a cherry orchard (*Prunus cerasus* L.) with the Łutówka cultivar grafted on a wild cherry rootstock (*Prunus mahaleb* L.). The trees were planted in 2007 in the orchard of an experimental farm at the Poznań University of Life Sciences. The distance between the rows was 4.0 m and in the row it was 2 m.

A turf strip was maintained between the rows of trees. In the initial period (the first three years), mechanical fallow land was maintained. In the following years, weeds were controlled with glyphosate (Roundup 360 SL, Monsanto Europe N.V., Antwerpen, Belgium). Depending on the weather and the intensity of weed growth, chemical control was performed 2–3 times. Protection against diseases and pests was carried out based on current recommendations for production in commercial cherry orchards.

The orchard was established on fawn soil proper, made of clay sands, lying on light order clay. The upper layer of 0–50 cm is light clay sand, to strong clay sand, which is lined with light clay. The share of floated parts is 20%. The organic matter in the topsoil was in the range of 1.2–1.25%. The groundwater level was at a depth of 140–180 cm. The sites were located next to each other (a distance of 10 m) and did not differ in the type of soil, the level of groundwater or terrain. The rows of trees at the OR1 and OR2 sites were planted in the same field. The evaluation of mineral content and soil reaction before experimentation is given in Table 1.

Table 1. Physicochemical properties of soil at OR1 and OR2.

Planting Area	mg 100 g^{-1} DW Soil								pH in KCl	*p*
	P	*p*	K	*p*	Mg	*p*	K/Mg	*p*		
Depth 0–20 cm										
OR1	9.3	0.147	14.4	0.131	11.9	0.202	1.3	0.099	6.5	$p = 0.246$
OR2	10.0		11.7		12.6		0.9		6.7	
Depth 21–40 cm										
OR1	5.7	0.482	11.3	0.240	9.7	0.052	1.2	0.082	6.1	$p = 0.971$
OR2	6.6		8.7		11.1		0.8		6.2	

The trees were planted at two sites that differed in the risk of replantation disease. Additionally, the sites differed in the way the soil was prepared prior to planting. However, it should be emphasized that the fields were directly adjacent to each other, were homogeneous in terms of soil, and flat without depressions or slopes.

Site 1 (OR1), where sweet cherries were grown from spring 1984 to fall 2005.

Site preparation before planting:

- In autumn 2005 liming 2 t·ha^{-1}.
- Spring 2006, submerging and ploughing.
- In 2006, three times in April, June, and August, green manure in the form of mustard was sown, which, before flowering, was ploughed to a depth of 20–25 cm.
- In the autumn of 2006, manure was applied in a dose of 40 t ha^{-1} and plowing was carried out to a depth of 20 cm.
- In the spring of 2007, before planting trees, fibering, cultivating, and harrowing were carried out.

Site 2 (OR2) where, before planting, only agricultural crops were grown.

Use of the field before planting:

- Agricultural crop rotation (rapeseed, cereals)
- In the years before the trees were planted, legumes were grown for green manure and soil was grown.

The experiment was established in two places (OR1 and OR2) where mulching was applied.

Orchard 1—control (OR1–C)—trees planted in replanted soil in a place where for 21 years cherries had been grown,

Orchard 1—mulching treatment 2 (OR1–M)—as in combination 1, but with compost mulching with substrate from mushroom *Agaricus bisporus* cultivation used. Compost was applied in the belt of tree rows, under the crowns of trees using an area of 1 m^2 80 L·tree^{-1} compost under each tree. The parameters of the compost used for mulching are shown in Table 2.

Table 2. Physicochemical properties of the litter used in the experiment.

Contents of Macro-Elements [mg·100 g^{-1}]				pH	Organic Matter [%]	Contents Micro-Elements [mg·kg^{-1}]				
P	K	Mg	S			B	Mn	Cu	Zn	Fe
144.5	59.5	35.6	37.8	6.71	29.8	7.9	256.8	11.3	145.6	4800.0

Orchard 2—control treatment 3 (OR2–C)—trees planted in soil on which fruit plants were not previously grown,

Orchard 2—mulching (OR2–M)—like in treatment 3, but with applied mulching with compost obtained after growing mushrooms like in treatment no 2.

The experiment was assumed in 4 repetitions (Figure 1). Mulch treatments were randomly assigned to the 4-tree plots. In each repetition there were 4 trees, for a total of 16 trees per combination. Each plot had a visible area of 20 m^2. Between each plot, there were 2 trees of insulation gap. In total, 64 trees were covered by the entire experiment. Sixteen plots were arranged in 2 rows, one in each station.

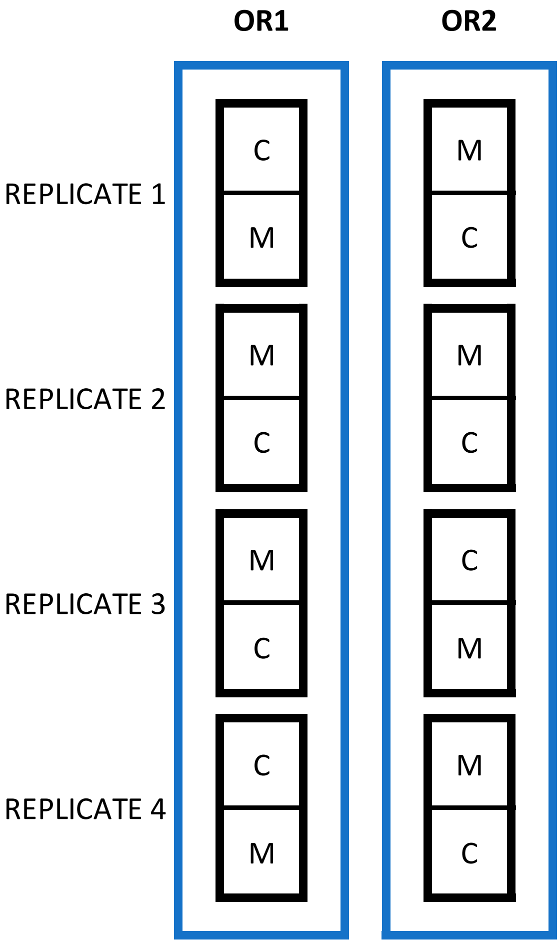

Figure 1. Diagram of an experimental system, where each rectangle represents an experimental plot. OR1—site 1 (after replantation), OR2—site 2 (before planting, only agricultural crops were grown), C—control, M—with compost mulch after mushroom (*Agaricus bisporus*) production.

Before planting, potassium (200 kg·ha^{-1} K_2O), phosphorus (185 kg·ha^{-1} P_2O_5), and 60 t·ha^{-1} manure were applied in each orchard.

In the first year of running the orchard, mechanical fallow land was maintained. In the second year, herbicide fallow was applied under trees and turf in the inter-rows.

2.1. Measurements, Observations and Analyses

2.1.1. Tree Growth, Productivity and Yield Efficiency

The date of harvest was determined on the characteristic basis of the color of the fruit of the cultivar and the ease of moving away from the peduncle. Fruits were harvested from each tree separately. The result was presented as the average yield per tree and the sum of the yield per tree in the years 2008–2016. The unit yield per tree (kg·$tree^{-1}$) was converted into the yield per hectare (t·ha^{-1}). Each year, after the end of vegetation, the diameter of the trunk was measured in two directions (perpendicular to the row lines and along the row lines) with a caliper at a height of 10 cm above the place of budding), and the average of the measurements was calculated. On the basis of the obtained results, the cross-sectional area of the trunk (TCSA) in cm^2 was calculated. Every year, based on the obtained results, the tree yield efficiency coefficient ($kg \cdot cm^{-2}$ trunk cross-sectional area) was calculated.

2.1.2. Fruit Quality

Fruits for evaluation were collected in the harvest maturity. A single sample consisted of 200 fruits. A single mixed sample was collected from each repetition separately. The fruits on the tree of the 'Łutówka' cultivar ripen evenly. Therefore, in order to ensure that the sample for quality tests was representative, the fruit was collected from half the height of the crown and the outer lots.

- The fruit quality assessment was carried out on the basis of the following five measures:
- Fruit weight—The weight of the fruit was defined as the collective pr. A total of 10 fruits were weighed 10 times with an accuracy of 0.1 g, and then the result was divided. From each combination, 100 fruits were collected.
- Fruit firmness—determined individually for 100 fruits from each repetition using a firmness tester model FT 02 (Facchini Srl, Alfonsine, Italy), which was fixed on a tripod. This test consists of piercing the fruit (whole fruits with peel) with a stem with a diameter of 2.5 mm. Results were expressed in newtons (g) with an accuracy of 1 g.
- Total soluble solids (TSS)—the same fruits that were previously used to measure firmness and determine the mass of the fruit were taken for analysis. The measurement was made using the PR-101a electronic refractometer (Atago Co., Ltd., Tokyo, Japan). The measurement value was expressed in °Brix accuracy of 0.1 °Brix.
- Titratable acidity (TA) of the fruit was measured with a pH meter (pH 538, WTW, Germany) calibrated with pH 4 and 7 buffers. From each repetition, 50 fruits were taken, and 150 mL of juice was squeezed. In total, 5 mL was taken for analysis, 50 mL of distilled water was added, and 0.1 N NaOH was titrated, neutralizing the acid solution to achieve pH 8.1. On the basis of the amount of NaOH consumed, the acidity was calculated and the result was converted into the percentage of malic acid.
- The color of the fruit skin was measured in one place with a manual Minolta CR-100 colorimeter (Minolta Corp., Ramsey, NJ, USA) and recorded using the uniform CIE L* a* b* color space. The value of L* reflects the brightness of the color, a* specifies the proportions of red (positive values) and green (negative values), while b* determines the proportion of yellow (positive values) and blue (negative values). Parameters a* and b* define the chromaticity of a color, whereas the parameter L* defines its luminance, related to the size of the luminous flux that reflects from the object and reaches the eye of the observer. The numeric values a* and b* have been converted to a Hue_{ab} angle value ($h^\circ = \tan^{-1} b^*/a^*$), chroma ($C^* = ((a^*)^2 + (b^*)^2)^{0.5}$) [40,41], tomato color index ($COL = (2000 \times a)/(L \times (a^2 + b^2)^{0.5})$) [9,42], and index red grapes $CIRG = (18O - h)/(L^* + C)$ [9,43–45].

Phenological Development

During the investigation, observations were made of the impact of the experimental factor of cultivation and mulching on the date of reaching individual phenological phases, especially on the course of flowering and fruiting of trees.

2.1.3. Soil Sampling

The evaluation of the pH content of P, K, Mg, and soil was carried out at the Department of Pomology at the Poznan University of Life Sciences. From each repetition of the herbicide belt, four soil samples were taken from two layers of soil: an arable layer of 0–20 cm and an arable layer of 21–40 cm. The samples of each layer were poured separately into a container, where they were thoroughly mixed. For analysis, 500 mL of soil was taken. From each combination of experiments, 4 samples with a volume of 500 mL were taken. The mineral content in the soil was determined using the methods of Egner–Riehm (P and K) and Schachtschabel (Mg) [46].

2.2. Weather Conditions

Climatic conditions (mean monthly air temperature and precipitation) were recorded using the automatic meteorological station iMetos (Pessl Instruments, Weiz, Austria), which was located in the orchard. Temperatures were measured at a height of 2 m above ground level (Table 3).

Table 3. Air temperatures on the experimental plot in April and May in 2008–2016.

	2008	2009	2010	2011	2012	2013	2014	2015	2016
				Air temperature in April					
Mean	7.9	11.2	8.8	11.5	8.9	7.9	10.7	11.6	8.6
Min	−0.6	−4.5	−3.0	0.5	−4.5	−6.7	−1.8	−2.7	−1.9
Max	20.1	25.4	33.0	25.0	29.8	25.0	24.7	23.4	24.0
				Air temperature in May					
Mean	13.6	12.4	11.9	14.2	15.2	14.6	13.2	12.6	15.6
Min	0.0	−0.4	2.1	−2.9	1.5	3.5	−1.1	−0.1	4.0
Max	26.8	23.8	24.1	29.7	31.2	27.1	30.3	24.0	29.2

In 2008 and 2011, there were spring frosts, which caused damage to flowers and fruit buds. In the spring of 2009, the conditions were optimal, but hailstorms reduced the yield and quality of the fruit. In other years, the climatic conditions were conducive to pollination and fertilization of fruits (Figure 2).

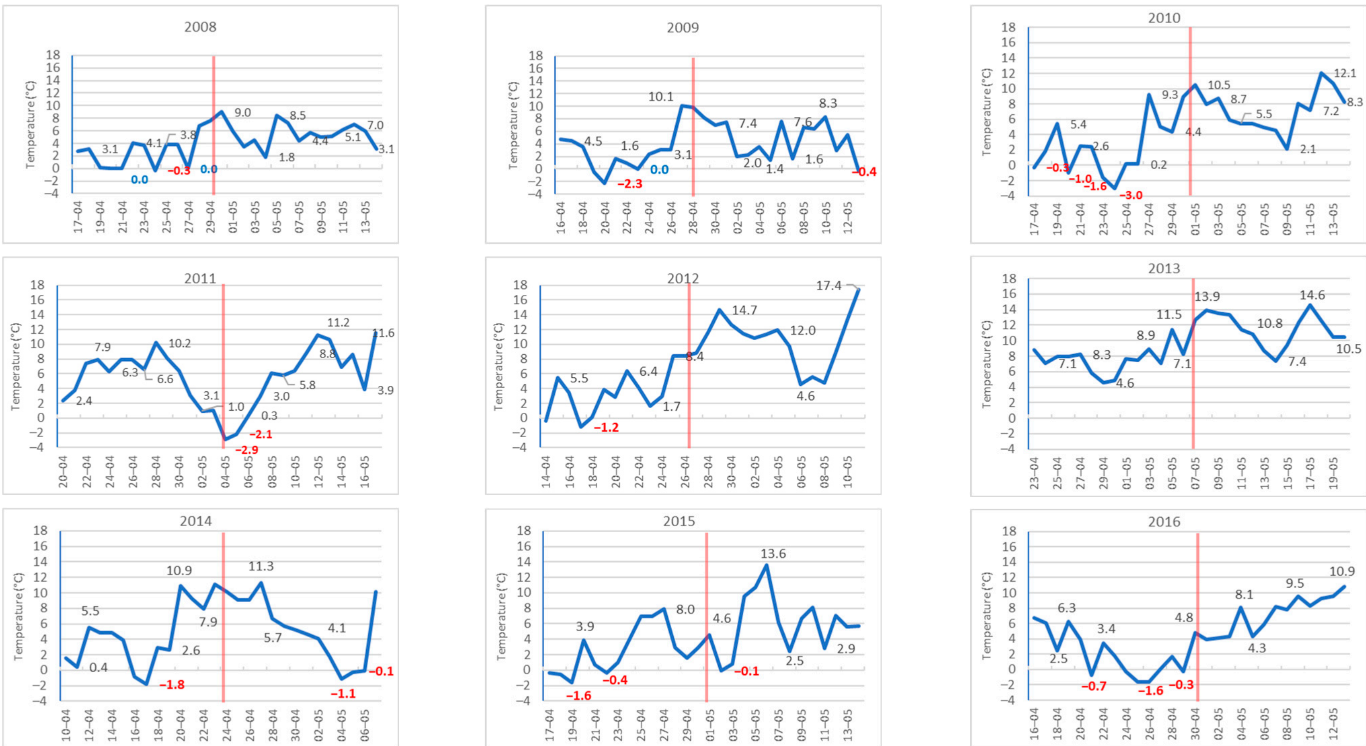

Figure 2. Temperature profiles corresponding to the 2 weeks before and after full flowering in the years 2008–2016.

The amount of rain during the study period varied widely. The lowest rainfall was in 2015 and the highest in 2019. The distribution of precipitation was very uneven. The lowest rainfall was in the winter month, when the monthly rainfall did not exceed 40 mm.

In spring, there were frequent periods of rain for several weeks, while in summer there was often high rainfall (Table 4).

Table 4. Total precipitation recorded in 2008–2016.

Month	Total Rainfall (mm)									Mean
	2008	2009	2010	2011	2012	2013	2014	2015	2016	
January	65.3	22.4	23.5	37.5	34.2	44.8	41.1	37.1	30.4	37.4
February	7.2	19.8	15.2	33.0	21.2	1.2	8.6	9.0	36.0	16.8
March	36.1	54.2	42.6	27.6	7.6	10.2	48.3	45.3	50.8	35.9
April	56.2	19.6	19.0	9.2	9.8	85.2	53.6	20.5	37.6	34.5
May	9.0	85.4	110.1	32.8	57.0	99.4	75.8	27.0	27.4	58.2
June	15.2	160.0	13.0	56.2	127.8	46.0	39.5	77.7	132.8	74.2
July	62.0	79.4	111.4	182.4	121.8	37.6	76.8	83.5	124.6	97.7
August	116.4	32.8	124.1	32.4	39.0	38.2	68.1	23.4	41.4	57.3
September	27.0	52.4	72.4	27.8	24.6	81.0	46.2	22.5	13.0	40.8
October	57.2	68.4	5.3	27.4	64.4	23.8	36.3	20.9	100.8	44.9
November	26.6	17.8	114.9	3.2	22.8	49.4	15.1	34.8	43.4	36.4
December	33.4	16.6	46.5	53.2	46.6	20.0	53.1	25.8	46.2	37.9
Total	511.6	628.8	698.0	522.7	576.8	516.8	562.5	427.4	684.4	569.9

2.3. Statistical Analysis

The normality of the distributions and the uniformity of the variances obtained were checked with the Shapiro–Wilk and Levene tests. Data were subjected to a one-way and two-way ANOVA separately for OR1 and OR2 using Statistica 13.3 (TIBCO Software Inc., Palo Alto, CA, USA). Experimental results are presented as mean ± standard deviation. The t-Student test ($p < 0.05$) was used to compare mean values between the combination of control and mulching. Multiple comparisons of means were performed with the Duncan test ($p = 0.05$).

To limit the possible negative impact on fruit yield, a covariance analysis (ANCOVA) was carried out, taking the trunk circumference as a covariate variable.

The Pearson correlation coefficient was also calculated.

3. Results and Discussion

3.1. Mineral Content in the Soil

The mineral content at both sites was in the high-abundance class [47]. In the arable layer of the soil at the OR1 site, the pH of the soil, the phosphorus, and the magnesium were at a similar level. Only potassium levels were higher at OR2. In the subarable layer at the OR1 site, there was a higher potassium content and a lower magnesium P, while the pH and content were at a similar level (Table 1).

The content of the components in the soil in the years 2007–2011 depended on the soil layer and the location where the cherries were grown (Tables 5 and 6).

The pH of the soil was at a similar level in both orchards, and there was no significant difference between soil layers, sites, and soil mulching. In apple production, mixing ash substrate with the soil and then mulching with the same material after planting the trees resulted in an increase in pH compared to fallow and mechanical cultivation [38].

The content of available phosphorus in the soil was at a similar level in the arable and subarable layers at the site after replantation. There were also no big differences between the use of mulching and its absence. On the other hand, the use of soil mulching with a substrate obtained after mushroom cultivation was found to result in significant differences between layers. In the arable layer, the phosphorus content was significantly higher, especially after mulching the soil with mushroom substrate, which was characterized by a high phosphorus content (Table 2). An increase in the content in the arable layer was observed only in OR1–M in the first and second year after mulching. In subsequent years, the content remained at a similar level (Figure 3). In the subarable layer, there was a slight increase in the OR1–M content, and in OR2–M, there was a tendency to decrease the assimilable phosphorus (Figure 4). The higher phosphorus content in the upper soil may be due to better soil fertility and structure [48] and in part as a result of mixing the mushroom substrate with the top soil. On the site, after many years of cherry cultivation, despite the thorough preparation of the site, the fertility and soil structure did not allow the mushroom substrate to mix in the upper layer of the soil. This is confirmed by research carried out in the apple orchard, where a significant increase in phosphorus content was possible in the arable layer of the soil when the mulch was mixed with the soil [38]. An increase in the phosphorus content in the soil was evident in the arable and subarable layers under the influence of nitrogen fertilization [49].

Table 5. Content of minerals in the soil in the cherry orchard in the years 2007–2011 in the soil layer 0–20 cm.

Treatment	mg 100 g^{-1} DW Soil			K/Mg	pH
	P	K	Mg		
			OR1		
C	8.16 ± 0.82 [1]	14.16 ± 1.65	10.54 ± 1.13	1.35 ± 0.12	6.46 ± 0.10
M	12.15 ± 0.92	20.35 ± 2.93	11.60 ± 1.34	1.75 ± 0.21	6.64 ± 0.12
			p Value		
	0.000 [2]	**0.000**	0.071	**0.000**	**0.002**
			OR2		
C	10.42 ± 1.06	11.69 ± 0.77	11.61 ± 0.82	1.01 ± 0.09	6.65 ± 0.07
M	16.98 ± 2.25	19.61 ± 1.61	12.88 ± 1.20	1.53 ± 0.10	6.91 ± 0.07
			p Value		
	0.000	**0.000**	**0.013**	**0.000**	**0.000**

[1] Mean ± SD, [2] Bold format intends to highlight significance when the *p* value is less than 0.05 (Student *t*-test), OR1—orchard after replantation, OR2—orchard on virgin soil, C—control without mulching, M—mulching.

Table 6. Content of minerals in the soil in the cherry orchard in the years 2007–2011 in the soil layer 21–40 cm.

Treatment	mg 100 g^{-1} DW Soil			K/Mg	pH
	P	K	Mg		
			OR1		
C	5.75 ± 0.53 [1]	8.96 ± 2.74	8.40 ± 0.90	1.06 ± 0.24	6.11 ± 0.10
M	5.58 ± 0.61	9.38 ± 2.17	9.59 ± 1.09	1.02 ± 0.24	6.25 ± 0.09
			p Value		
	0.528 [2]	0.708	**0.016**	0.714	**0.004**
			OR2		
C	7.63 ± 0.60	7.68 ± 1.67	9.40 ± 1.07	0.81 ± 0.12	6.28 ± 0.19
M	8.20 ± 0.62	9.90 ± 1.62	10.0 ± 1.31	1.00 ± 0.14	6.60 ± 0.13
			p Value		
	0.520	**0.004**	0.258	**0.006**	**0.001**

[1] Mean ± SD, [2] Bold format intends to highlight significance when the *p* value is less than 0.05 (Student *t*-test), OR1—orchard after replantation, OR2—orchard on virgin soil, C—control without mulching, M—mulching.

The potassium content available in the soil depended on the level of sampling, the site, and the soil mulch applied.

There was no significant difference in potassium content in the arable layer depending on the site where cherries were grown. A significant difference in K content was found between the mulch control and the application of mulch in the arable layer, where the available K was significantly higher at 20.0 mg 100 g^{-1}. Both in the arable and subarable layers at the OR1–M site, a decrease in potassium content was observed. In the OR2–M combination, potassium levels remained at a similar level (Figures 3 and 4). This is confirmed by the results of experiments in apple orchards, where the use of mixing the mushroom substrate and the mulching itself increased the potassium content in arable soil [38]. Similar results have been obtained in many years of experience, where nitrogen fertilization caused an increase in potassium content in the topsoil [49,50].

The magnesium content available in the soil depended on the site and the soil mulching used. A significantly higher magnesium content was found at the site where fruit trees had not grown before, where, in both the arable and subarable layers, much higher contents were determined than at the site after replantation. Treatment with the mushroom substrate had a significant effect on the magnesium content. Magnesium levels decreased in both soil layers between 2007 and 2011. In the subarable layer, the rate of Mg decline was faster in OR2–M than in OR1–M, especially in the first year after mulching (Figures 3 and 4). The mushroom substrate used increased the K: Mg ratio in the arable layer of the soil. The effect on the K:Mg ratio was evident in the top soil (Table 5). The higher K:Mg ratio resulted from the significantly higher content of K than Mg in the mushroom substrate.

The use of an ash substrate led to an increase in the content of P, K, and Mg, and this effect was observed mainly in the topsoil as a result of the high content of these components in the mulch used.

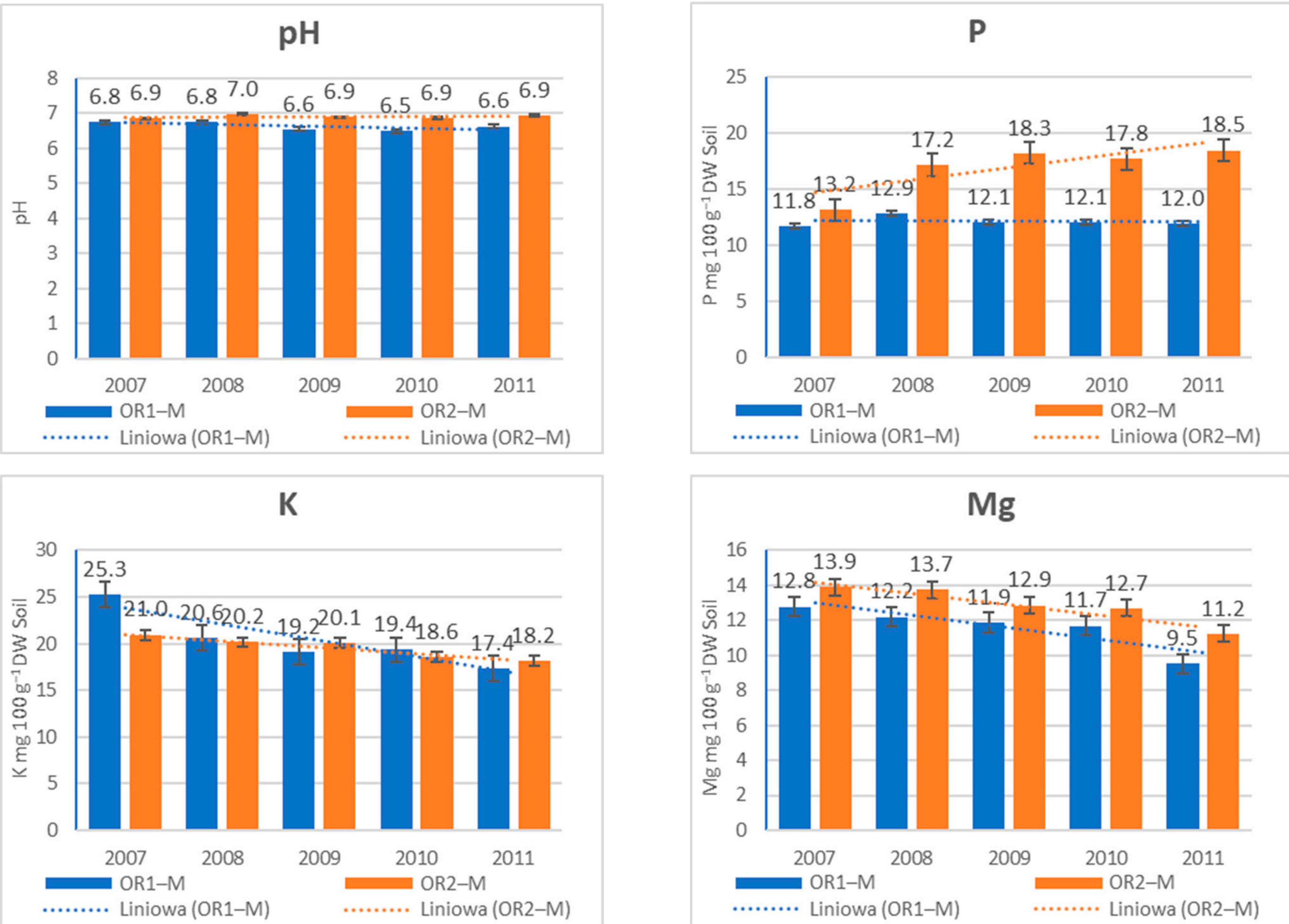

Figure 3. The effect of mulching on soil reaction and mineral content in the arable layer 0–20 cm.

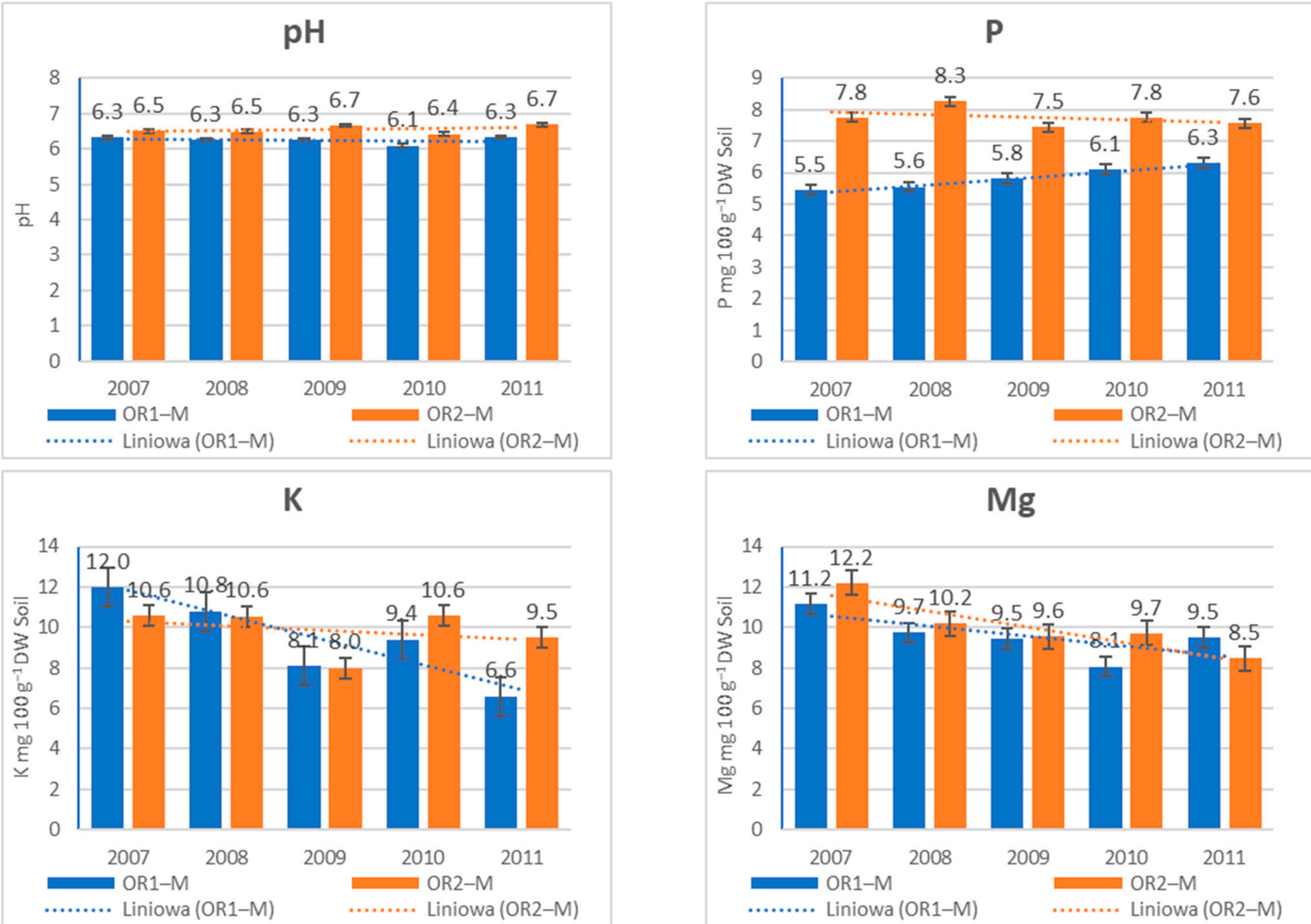

Figure 4. The effect of mulching on the pH of the substrate and the content of minerals in the subarable layer 21–40 cm.

3.2. Tree Growth

The growth of trees measured by the cross-sectional area of the trunk was significantly higher in the field which, before planting trees, was used for the cultivation of agricultural plants (Tables 7 and 8). Annual plant cultivation and agrotechnical treatments, such as plowing and application of organic matter as green manure or animal manure, significantly improved tree growth during the research period. The use of a one-year break between cherry cultivation had an impact on the weaker growth of vegetative trees measured by cross-sectional area. The use of mushroom substrate did not have a significant impact on growth, and in the area where the cherry orchard grew, growth was significantly weaker. The compost after mushroom cultivation did not affect the growth of the trees on the site which was previously used for agriculture and on which fruit plants were not grown. Mushroom substrate is a rich source of phosphorus, potassium, and organic matter; however, it can lead to an increase in soil salinity [38]. Therefore, the use of high doses of the mushroom substrate or growing directly in compost can lead to a weakening of the growth of cherries that are sensitive to salinity [51]. The growth of sweet cherries after the replantation of the apple and cherry orchard limited the growth of trees. The growth restriction occurred despite the fumigation of the cherry site with methyl bromide. However, the cherry orchard site caused greater growth restriction in cherries compared to the soil after apple replantation, probably due to different populations of bacteria and fungi carried through the soil [2,52,53].

Table 7. The influence of the site and the mulching with compost from the mushroom substrate on the cross-sectional area of the trunk in the years 2008–2016 (cm^2 mean ± SD).

Year	Mulching	Planting Area	
		OR1	**OR2**
2008	C	5.98 ± 1.46 [1]	5.77 ± 0.45
	M	4.86 ± 0.66	5.91 ± 1.58
2009	C	11.76 ± 3.81	14.57 ± 4.63
	M	9.06 ± 2.18	12.58 ± 3.22
2010	C	16.75 ± 3.09	20.90 ± 4.01
	M	12.88 ± 3.10	18.14 ± 4.18
2011	C	23.36 ± 2.99	27.55 ± 5.13
	M	19.31 ± 2.59	25.54 ± 6.98
2012	C	30.97 ± 3.01	36.20 ± 9.79
	M	26.73 ± 3.58	36.13 ± 8.72
2013	C	39.72 ± 3.44	46.22 ± 15.66
	M	35.38 ± 4.91	48.64 ± 11.39
2014	C	43.95 ± 1.88	52.98 ± 12.52
	M	40.10 ± 5.54	54.50 ± 11.82
2015	C	48.44 ± 0.46	60.53 ± 9.26
	M	45.13 ± 6.23	60.73 ± 12.50
2016	C	52.83 ± 2.56	66.07 ± 9.59
	M	52.29 ± 7.32	69.73 ± 19.03
Treatment		*p* Value	
Year		**0.000** [2]	**0.000**
Mulching		**0.001**	0.957
Year × Mulching		0.969	0.999

[1] Mean ± SD, [2] Bold format intends to highlight significance when the *p* value is less than 0.05, OR1—orchard after replantation, OR2—orchard on virgin soil, C—control without mulching, M—mulching.

Table 8. Effect of the site and compost mulching after mushroom cultivation on the cross-sectional area of the trunk in the years 2008–2016 (cm^2 mean ± SD).

Treatment	TCSA	
	OR1	**OR2**
C	30.42 ± 2.32 [1]	36.75 ± 7.67
M	27.30 ± 1.04	36.88 ± 8.68
	p Value	
	0.050 [2]	0.982

[1] Mean ± SD, [2] Bold format intends to highlight significance when the *p* value is less than 0.05 (Student *t*-test), OR1—orchard after replantation, OR2—orchard on virgin soil, C—control without mulching, M—mulching.

The increase in trunk cross-sectional area was variable during the study period (Tables 9 and 10). Since both the preparation before planting and fertilization during cultivation were at the same level, the reasons for variability probably lie in the course of the weather [54,55]. Undoubtedly, the availability of nutrients in the soil is not the main factor that determines the intensity of tree growth. Organic mulches can improve nutrient uptake at nutrient-poor sites in the future as the need for P, K, and Mg uptake by larger trees increases [56]. However, the availability of water in the soil plays a key role in tree growth. This factor can also be affected by mulching, as the water content in the soil decreases much more slowly in mulched soil than in mechanical cultivation [57]. On the other hand, however, drying the organic mulch and the soil beneath it requires much more rainfall to supply water to the root system.

Table 9. The influence of the stand and the mulching with compost after mushroom cultivation on the growth of the increment trunk cross-sectional area in the years 2008–2016 (cm^2 mean ± SD).

Year	Mulching	Planting Area	
		OR1	**OR2**
2008	C	2.38 ± 0.42 [1]	2.44 ± 0.49
	M	1.78 ± 0.14	2.34 ± 0.73
2009	C	5.78 ± 0.55	8.80 ± 0.09
	M	4.10 ± 0.65	6.67 ± 0.53
2010	C	3.82 ± 0.84	6.32 ± 0.51
	M	4.99 ± 0.40	5.56 ± 0.21
2011	C	6.61 ± 0.89	6.65 ± 0.55
	M	6.44 ± 0.93	7.39 ± 0.07
2012	C	7.61 ± 0.52	8.65 ± 0.65
	M	7.42 ± 0.40	10.59 ± 1.00
2013	C	8.75 ± 0.66	10.16 ± 0.26
	M	8.65 ± 0.56	12.34 ± 0.62
2014	C	4.23 ± 0.42	6.76 ± 0.29
	M	4.73 ± 0.29	5.86 ± 1.25
2015	C	4.49 ± 0.54	7.54 ± 0.28
	M	5.03 ± 0.35	6.23 ± 0.37
2016	C	4.29 ± 0.22	5.55 ± 0.31
	M	7.16 ± 0.13	8.92 ± 0.36
Treatment		*p* Value	
Year		**0.000** [2]	**0.000**
Mulching		0.814	**0.004**
Year × Mulching		**0.000**	**0.000**

[1] Mean ± SD, [2] Bold format intends to highlight significance when the *p* value is less than 0.05, OR1—orchard after replantation, OR2—orchard on virgin soil, C—control without mulching, M—mulching.

Table 10. Influence of stand and compost mulching after mushroom cultivation on the increase in trunk cross-sectional area in years 2008–2016.

Treatment	Increase in the Cross-Sectional Area of the Trunk	
	OR1	**OR2**
C	5.52 ± 1.94 [1]	6.99 ± 2.16
M	5.39 ± 2.09	7.32 ± 2.87
	p Value	
	0.949 [2]	0.577

[1] Mean ± SD, [2] Significance when the *p* value is less than 0.05 (Student *t*-test), OR1—orchard after replantation, OR2—orchard on virgin soil, C—control without mulching, M—mulching.

3.3. *Yielding*

During the study, the yield was very variable (Figure 5, Table 11). Other researchers who had field experiments in the same years also observed a high variability in fruit plant yield [58–61]. We observed that until the fourth year, the yield of trees depended mainly on the size of the trees and then on the course of the climatic conditions. In older trees, weather conditions and growing conditions played an important role. Therefore, statistical analyses were performed separately for juvenile trees (the first four years) and separately for trees in the four consecutive years when the trees no longer increased significantly in size (Figure 5). There were no differences in yield between 2009 and 2010 despite the increase in the volume of tree crowns, because in 2010 there were spring frosts. Also in the following year, 2011, in the period of 7 days after full flowering, a temperature of −2.9 °C was recorded. However, fruit trees withstand minor frosts without major losses and also have the ability to regenerate damage [62]. Probably for the above reasons, as well as the larger size of the crowns, the average yield of a single tree was 100% higher than the year before.

Table 11. Impact of the site and compost mulching after mushroom cultivation on yield in the years 2008–2016.

Year	Mulching	Yield		Productivity Coefficient	
		OR1	OR2	OR1	OR2
2008	C	0.74 ± 0.29 [1]	1.18 ± 0.21	0.13 ± 0.06	0.21 ± 0.04
	M	0.71 ± 0.13	0.88 ± 0.16	0.15 ± 0.03	0.15 ± 0.02
2009	C	3.66 ± 2.14	2.38 ± 0.91	0.29 ± 0.09	0.18 ± 0.09
	M	2.24 ± 0.43	2.28 ± 1.28	0.25 ± 0.02	0.18 ± 0.08
2010	C	1.90 ± 0.74	2.88 ± 1.18	0.11 ± 0.03	0.13 ± 0.03
	M	1.64 ± 0.74	3.28 ± 1.71	0.13 ± 0.04	0.17 ± 0.07
2011	C	4.94 ± 1.43	3.54 ± 0.58	0.21 ± 0.04	0.13 ± 0.04
	M	4.00 ± 2.59	2.76 ± 1.37	0.21 ± 0.15	0.12 ± 0.08
2012	C	14.44 ± 2.44	6.00 ± 1.93	0.46 ± 0.04	0.17 ± 0.04
	M	11.50 ± 0.91	7.25 ± 1.44	0.43 ± 0.04	0.21 ± 0.08
2013	C	4.81 ± 2.38	4.31 ± 1.71	0.12 ± 0.05	0.10 ± 0.05
	M	5.25 ± 1.15	4.25 ± 0.96	0.15 ± 0.02	0.09 ± 0.03
2014	C	2.27 ± 0.41	5.56 ± 1.80	0.05 ± 0.01	0.11 ± 0.03
	M	1.35 ± 0.30	7.38 ± 2.17	0.03 ± 0.01	0.13 ± 0.01
2015	C	17.03 ± 2.79	23.34 ± 5.62	0.35 ± 0.06	0.38 ± 0.04
	M	16.88 ± 2.90	29.25 ± 6.62	0.38 ± 0.08	0.48 ± 0.01
2016	C	12.80 ± 8.42	9.00 ± 1.15	0.25 ± 0.17	0.14 ± 0.02
	M	11.50 ± 6.81	11.50 ± 5.26	0.22 ± 0.13	0.19 ± 0.11
Treatment		*p* Value			
Year		**0.000** [2]	**0.000**	**0.000**	**0.000**
Mulching		0.242	0.069	0.868	0.130
Year × Mulching		0.985	0.330	0.978	0.319

[1] Mean ± SD, [2] Bold format intends to highlight significance when the *p* value is less than 0.05, OR1—orchard after replantation, OR2—orchard on virgin soil, C—control without mulching, M—mulching.

In 2013, despite the lack of negative temperatures during the flowering period, yields were poor, probably due to the high variability of weather during the flowering period, making pollination and ignition difficult. Low temperature, wind, and rainy weather limit flower pollination by pollinators, especially honeybees [63,64]. In addition, the warming climate and increasingly warmer winters may result in a lack of a sufficiently long period of cold, but this type of research has not yet been carried out in Poland. The following year, the yield was low again, but the reason for this was spring frosts in the period before and after flowering. The 2015 yield was record-breaking despite minor frosts during the flowering period. Minor frosts generally cause a decrease in yield [9] because, for abundant fruiting, it is enough if 30% of flowers are tied [65–67]. However, the occurrence of severe spring frosts during flowering can cause not only destruction of all flowers, but also damage to the shoots and leaves [9,10,68].

The highest yield was harvested in 2015, when an average of 21.6 kg was obtained from one tree. The yield in subsequent years depended on the course of climatic conditions. Both spring frosts and unfavorable conditions during the flowering period had a significant impact on yield in individual years.

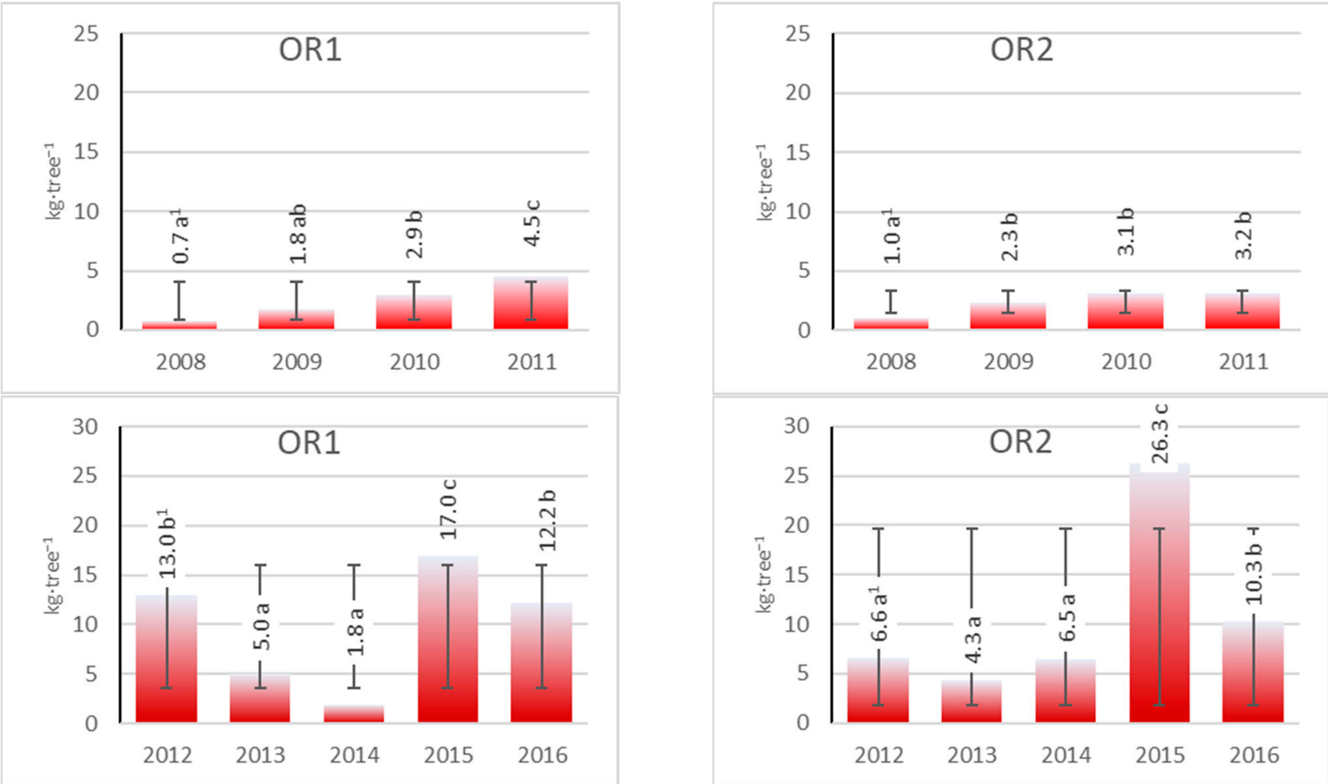

Figure 5. The general yielding average of all treatments of cherry trees over the years. [1] means that the same letters are not significantly different at $\alpha = 0.05$ (Duncan's test).

In addition to weather, the yield was significantly influenced by experimental factors. From trees planted in the soil where cherries had previously been grown (replantation), a much lower yield was harvested than at the site where fruit plants had not been grown before (Tables 12 and 13).

Table 12. ANCOVA results for total yield and productivity coefficient with trunk circumference as a covariate.

		SS	df	MS	F	*p*
			Total yield			
OR1	Mulching	0.73	1	0.73	0.009	0.927 *
	Residuals	396.42	5	79.28		
OR2	Mulching	67.90	1	67.90	0.681	0.447
	Residuals	498.59	5	99.72		
			Productivity coefficient			
OR1	Mulching	0.00008	1	0.00008	0.09	0.775
	Residuals	0.00454	5	0.00091		
OR2	Mulching	0.00057	1	0.00057	1.46	0.281
	Residuals	0.00196	5	0.00039		

SS = sum of squares, df = degree of freedom, MS = mean square, * p values > 0.05 indicate no significant differences.

Another factor, i.e., mulching with a mushroom substrate, did not have a significant impact on the increase in yield regardless of the orchard location. Although the use of mushroom compost provides a rich source of phosphorus, potassium, and organic matter, it can also increase salinity [38], which is a stressor and restricts tree growth and yield [69]. Among fruit plants, cherries are sensitive to salt stress [70]. Plants suffer from an increased osmotic effect in the soil, which keeps water in the soil solution, and accumulates Na and Cl in tissues to toxic levels [71]. Salinity negatively affects flowering and fruit set, reducing the final yield and quality of fruits [72]. This is confirmed by the results of studies evaluating the effect of using the mushroom substrate in an apple orchard, where the result was poor fruit environment, which led to a low level of yield [38].

Table 13. Total yield and productivity coefficient sour cherries of the Łutówka cultivar in 2008–2016.

Total Yield in Years 2008–2016 (kg·tree^{-1})		
	OR1	OR2
C	50.8 ± 3.6 [1] n.s. [2]	71.0 ± 5.0 n.s.
M	51.8 ± 11.4 n.s.	77.1 ± 11.9 n.s.
Mean	51.3	74.1
Productivity coefficient (kg·cm^{-2})		
	OR1	OR2
C	0.165 ± 0.020 n.s.	0.236 ± 0.012 n.s.
M	0.173 ± 0.035 n.s.	0.249 ± 0.027 n.s.
Mean	0.169	0.242

[1] Mean ± SD, [2] no statistical significance when the p value is less than 0.05 (Student t-test), OR1—orchard after replantation, OR2—orchard on virgin soil, C—control without mulching, M—mulching.

Results of the analysis of ANCOVA covariance with trunk circumference as a covariate variable indicated a significant impact of the site on the total yield obtained during the research period (Table 12). The impact of the site was clear after cumulating the yields throughout the study period (Table 13). In multi-year fruit production studies, total yield is often a much more sensitive indicator than the average of individual years [73–75]. In the orchard growing in soil previously used for agriculture, the cumulative production per tree was 73.1 kg, while in the orchard planted after cherry orchard cultivation, the cumulative production per tree was 51.1 kg. However, there was no significant effect of applied mulch on the total yield of trees during the research period.

The productivity coefficient that combined tree growth and its yield showed the importance of the site, where the soil previously used for fruit farming did not reduce this feature by 50%. The fertility index also did not show an effect of mulching on yield. Similar results were obtained earlier in the apple orchard, where the use of mushroom substrate compost mulch also did not have a significant effect on apple yield during the four years of research [33].

The results were certainly significantly influenced by the high variability of the yield in individual years caused by the course of the climatic conditions. The occurrence of spring frosts during flowering and fruit setting limited the yield of trees. Rainfall during the growing season also had a negative impact on tree yield [9]. The occurrence of rain makes it difficult for insects to pollinate flowers, which require warm and sunny weather [76]. Precipitation in May had a negative impact on the yield of cherries. However, the increase in rainfall in June caused an increase in yield.

3.4. Quality of Cherry Fruits

3.4.1. Fruit Weight

Weight is the basic quality parameter in all species of fruit plants [3,67,77,78]. In the experiment, the weight of the sour cherries was variable in subsequent years (Table 14). In a young orchard, only in one year, in 2009, was the weight of 100 fruits greater than 500 g and significantly higher than in the other three years. However, in the "adult orchard", the fruits were larger, always weighing more than 500 g, and in the best year, 2012, the mass of 100 fruits was more than 600 g (Figure 6).

Table 14. Influence of planting area and mulching on the fruit mass in the years 2008–2016.

Year	Mulching	Localization	
		OR1	OR2
2008	C M	513.10 ± 28.18 [1] 432.17 ± 27.73	480.58 ± 10.71 460.44 ± 20.86
2009	C M	528.56 ± 14.01 542.86 ± 7.53	504.00 ± 14.73 495.02 ± 9.49
2010	C M	440.88 ± 7.97 446.38 ± 16.13	513.40 ± 37.99 464.72 ± 20.90
2011	C M	494.04 ± 15.92 495.96 ± 35.61	428.58 ± 14.32 392.01 ± 3.25
2012	C M	629.42 ± 2.92 603.57 ± 34.99	602.68 ± 15.52 586.45 ± 7.81
2013	C M	559.68 ± 18.29 565.76 ± 20.01	484.26 ± 5.47 492.16 ± 11.7
2014	C M	556.84 ± 14.89 532.89 ± 12.90	479.89 ± 10.01 480.43 ± 23.23
2015	C M	584.56 ± 13.10 581.20 ± 30.00	511.17 ± 15.67 565.38 ± 19.82
2016	C M	571.37 ± 26.59 602.98 ± 38.34	591.24 ± 16.66 606.02 ± 44.75
Treatment		*p* Value	
Year		**0.000** [2]	**0.000**
Mulching		0.127	0.208
Year × Mulching		**0.001**	**0.000**

[1] Mean ± SD, [2] Bold format intends to highlight significance when the *p* value is less than 0.05, OR1—orchard after replantation, OR2—orchard on virgin soil, C—control without mulching, M—mulching.

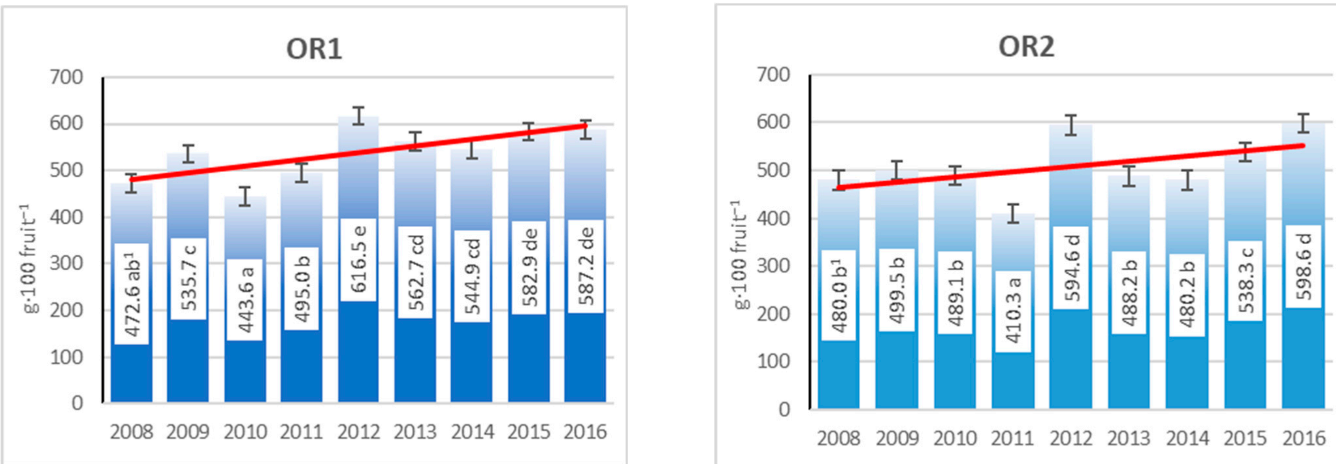

Figure 6. The weight of 100 sour cherries in the years 2008–2016. [1] means that the same letters are not significantly different at α = 0.05 (Duncan's test).

A higher yield harvested from trees growing on a site where trees had not been grown before resulted in a reduction in the weight of a single fruit. The weight of 100 fruits at the site after replantation was significantly higher and was 537.9 g. On the other hand, in trees where fruit plants had not been grown before and crop rotation of fruit plants was used, the weight of 100 fruits was 507.7 g (Table 14). With a higher yield of trees, the mass of fruits decreases. This relationship is particularly visible in cherries [79], peaches, or pome fruits, such as apples or pear [80,81]. Therefore, to achieve better quality and greater fruit weight, fruit thinning is used [10,67].

The use of mulch did not have a significant effect on the weight of the fruit (Tables 14 and 15).

Table 15. The weight of fruits of the sour cherry cv. 'Łutówka' in the years 2008–2016.

Treatment	Mass of 100 Fruit (g)	
	OR1	OR2
C	542.05 ± 54.98 [1] n.s.[2]	510.64 ± 54.98 n.s.
M	533.75 ± 65.28 n.s.	504.73 ± 68.29 n.s.
Mean	537.9	507.7

[1] Mean ± SD, [2] no statistical significance when the p value is less than 0.05 (Student t-test), OR1—orchard after replantation, OR2—orchard on virgin soil, C—control without mulching, M—mulching.

3.4.2. Fruit Firmness

The firmness of the fruit changed over the years of research (Tables 16 and 17, Figure 7). The highest was in 2014 and 2015. Lower firmness was probably due to higher fruit weight ($r = -0.46$, $p < 0.001$). Other factors that affected the reduction in fruit firmness were the size of the increase in the cross-sectional area of the trunk ($r = -0.69$, $p < 0.001$) and the course of climatic conditions during the growing season, in particular the intensity of precipitation during the growing season ($r = -0.48$, $p < 0.001$) and the soil temperature ($r = 0.7$, $p < 0.001$) (Table 17). The highest values of fruit firmness were in 2014 and 2015, when they were, respectively, 220.2 g cm^{-2} i 217.1 g cm^{-2} (Figure 7).

However, no effect of replantation and mulching on fruit firmness was observed (Tables S1 and S2). Similar results were obtained using different organic mulches in apple cultivation, where mulching did not affect apple firmness [82].

3.4.3. Total Soluble Solids Content

The total soluble solids (TSS) content varied from year to year (Table 18). The highest contents were found in 2008 and 2010. The lowest values were in 2009, 2012, 2015, and 2016. With the age of the trees, the content of TSS in the fruit (Figure 8) decreased. This is confirmed by studies on citrus fruits, where the sugar content was lower in older trees [83]. Similar results were obtained in an apple orchard, where fruits in 9-year-old trees had a higher TSS than fruits on 15-year-old trees [84].

There were no differences in the TSS of the fruit harvested in different orchards. Similar results were obtained in other studies in which organic mulches such as wood chips, pine bark, and sawdust did not have a significant effect on SSC [57,82,85,86]. On the contrary, the use of compost in peach cultivation resulted in a decrease in the TSS content of fruits [87]. There were some differences between orchards but these were variable in different years (Table 18, Figure 8). There is a high correlation coefficient between yield, fruit weight, and TSS content in fruits (Table 19). The use of the mushroom substrate was important in the first year. The greatest effect was found in virgin soil, where the TSS content was lower under the influence of mulching. The substrate contained a high content of K, which in high doses in the apple orchard caused a decrease in the TSS content [88]. A similar reaction of trees was observed in a cherry orchard, where a dose greater than 400 g of K_2O tree $^{-1}$ caused a decrease in the TSS content [89]. A factor that could have a negative impact on the extract content was probably high salinity. Most plants are sensitive to high levels of salt in the soil. Sensitive plants, such as stone and pome fruits, require conductivity below 4 dS/m [51].

Table 16. Influence of planting area and mulching on the firmness in the years 2008–2016 (g, mean ± SD).

Year	Mulching	Localization	
		OR1	**OR2**
2008	C	200.25 ± 15.02 [1]	200.00 ± 13.44
	M	201.50 ± 8.66	189.25 ± 13.96
2009	C	193.50 ± 27.93	205.75 ± 22.83
	M	217.50 ± 12.63	220.25 ± 20.29
2010	C	209.38 ± 12.20	188.25 ± 8.85
	M	199.13 ± 8.38	200.13 ± 7.65
2011	C	204.36 ± 9.79	201.12 ± 5.03
	M	201.01 ± 4.56	183.89 ± 8.79
2012	C	194.11 ± 7.73	188.43 ± 3.74
	M	199.25 ± 10.15	184.58 ± 3.93
2013	C	210.21 ± 3.42	190.92 ± 5.14
	M	205.34 ± 4.20	191.14 ± 6.67
2014	C	214.63 ± 14.03	220.38 ± 9.69
	M	217.50 ± 8.80	228.38 ± 9.04
2015	C	231.88 ± 25.04	221.50 ± 30.95
	M	206.25 ± 11.09	208.63 ± 26.41
2016	C	187.50 ± 5.58	184.38 ± 8.41
	M	197.00 ± 24.16	182.56 ± 10.83
Treatment		*p* Value	
Year		**0.006** [2]	**0.000**
Mulching		0.964	0.696
Year × Mulching		0.067	0.304

[1] Mean ± SD, [2] Bold format intends to highlight significance when the p value is less than 0.05, OR1—orchard after replantation, OR2—orchard on virgin soil, C—control without mulching, M—mulching.

Table 17. Influence of selected parameters on fruit firmness.

	Firmness
MOF	–0.47 *
ITCSA	–0.69 *
PRECV	–0.49 *
TSOIL	–0.70 *
TMAY	–0.62 *
>15	–0.55 *

* Significant levels $p < 0.001$. Explanations: MOF—mass of fruit, ITCSA—increase in trunk cross-sectional area, PRECV—precipitation in vegetation period, TSOIL—temperature soil, TMAY—average air temperature in May, >15—sum temperature until harvest.

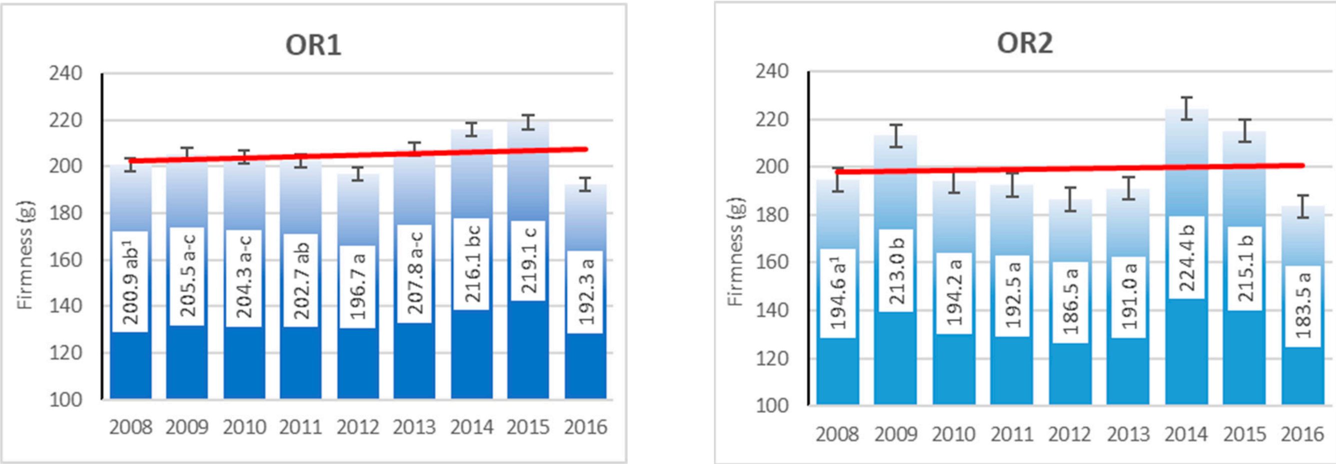

Figure 7. Firmness of the fruits. [1] means that the same letters are not significantly different at $\alpha = 0.05$ (Duncan's test).

Table 18. The influence of the stand and the composting after mushroom cultivation on the content of fruit extract in the years 2008–2016 (°Bx, mean ± SD).

Year	Mulching	Localization	
		OR1	OR2
2008	C	18.22 ± 1.16 [1]	17.31 ± 0.63
	M	17.00 ± 0.62	16.64 ± 0.70
2009	C	12.89 ± 0.69	13.53 ± 0.63
	M	13.21 ± 0.45	12.78 ± 0.38
2010	C	17.51 ± 0.58	14.60 ± 0.70
	M	17.50 ± 1.03	15.50 ± 1.38
2011	C	16.53 ± 0.95	16.35 ± 0.53
	M	16.58 ± 0.05	15.98 ± 0.30
2012	C	13.53 ± 0.39	14.08 ± 0.25
	M	13.40 ± 0.34	13.98 ± 0.29
2013	C	15.38 ± 0.67	16.15 ± 0.19
	M	14.83 ± 0.97	15.83 ± 1.27
2014	C	13.20 ± 0.50	14.20 ± 0.74
	M	14.58 ± 0.51	14.73 ± 1.07
2015	C	13.85 ± 0.93	12.53 ± 1.83
	M	13.20 ± 0.66	13.38 ± 0.83
2016	C	14.03 ± 0.57	14.20 ± 0.36
	M	13.63 ± 1.21	14.03 ± 0.34
Treatment		*p* Value	
Year		**0.000** [2]	**0.000**
Mulching		0.451	0.944
Year × Mulching		0.079	0.339

[1] Mean ± SD, [2] Bold format intends to highlight significance when the *p* value is less than 0.05, OR1—orchard after replantation, OR2—orchard on virgin soil, C—control without mulching, M—mulching.

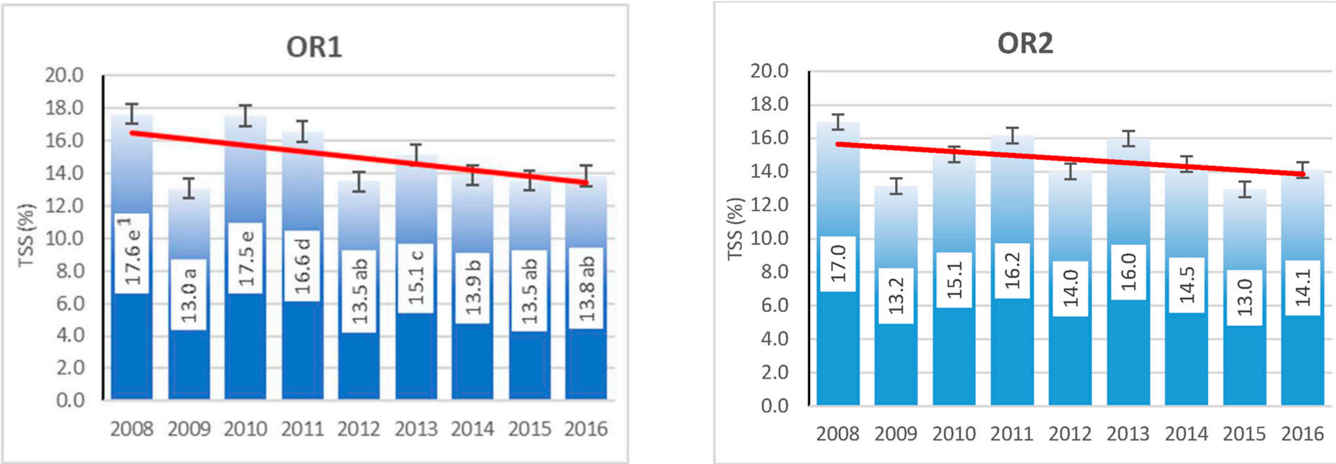

Figure 8. The general average of all treatments total soluble solids (TSS) content in the years 2008–2016. [1] means that the same letters are not significantly different at $\alpha = 0.05$ (Duncan's test).

Table 19. Influence of selected parameters on the content of soluble solids (TSS).

	TSS
MOF	–0.51 *
YIELD	–0.49 *
TCSA	–0.43 *
TMINV	0.73 *
TSOILV	–0.51 *
TJUN	–0.62 *
NODFH	–0.73 *
PJUN	–0.62 *

* Significant levels $p < 0.001$. Explanations: MOF—fruit mass, ITCSA—trunk cross-sectional area, TMW—maximum average temperature; TSOILV—temperature soil in vegetation period, TMAY—average air temperature in June, NODFH—number of days from flowering to harvest, PJUN—precipitation in June.

3.4.4. Titratable Acidity

The acidity of cherry fruits is an important element in processing, in which high acidity is sought [90–93]. There was a high variability of this feature in the first five years, when the spread of results was more than 25%. In the subsequent years, the acidity stabilized at a level close to 1.6% (Table 20, Figure 9). The results obtained confirm previous studies, where hydrolytic acidity was variable in individual years of research. During three years of research, Schattenmorelle IR-2′ obtained acidity in the range of 1.2% to 1.7% [94]. An important factor that affects the acidity of fruits is the course of climatic conditions, that is, in colder climates, the acidity is higher [9]. In other studies, with the appearance of spring frost and damage to some generative buds, larger fruits were obtained, whose acidity was much lower and was 1.4%, while with a larger number of fruits and a lower weight in the previous year, it reached 2.2% [95]. In our studies, a significant relationship was also found between fruit size and acidity ($r = -0.48$). The acidity of fruits is influenced by the course of climatic conditions [96]. The greatest impact on the increase in acidity of fruits was a result of the minimum temperature during the growing season, solar radiation, and the average temperature in June (Table 21). This is confirmed by studies in which the content of organic acids in sweet cherries with a late ripening date is determined by the climatic conditions in May and June [97]. Weather conditions during the growing season and two weeks before harvest have a significant impact on the chemical composition of cherry fruits [98].

Table 20. The influence of the stand and the composting after mushroom cultivation on titratable acidity of sour cherry the years 2008–2016 (% malic acid in, mean ± SD).

Year	Mulching	Localization	
		OR1	**OR2**
2008	C	2.26 ± 0.08 [1]	2.09 ± 0.01
	M	2.23 ± 0.15	1.89 ± 0.08
2009	C	1.68 ± 0.35	1.97 ± 0.12
	M	1.77 ± 0.06	1.34 ± 0.19
2010	C	2.01 ± 0.36	1.93 ± 0.09
	M	1.65 ± 0.06	1.89 ± 0.06
2011	C	2.02 ± 0.08	1.89 ± 0.10
	M	2.06 ± 0.07	1.89 ± 0.09
2012	C	1.81 ± 0.05	1.27 ± 0.06
	M	1.43 ± 0.16	1.61 ± 0.03
2013	C	1.64 ± 0.12	1.78 ± 0.12
	M	1.61 ± 0.06	1.78 ± 0.14
2014	C	1.55 ± 0.14	1.62 ± 0.08
	M	1.64 ± 0.15	1.57 ± 0.13
2015	C	1.64 ± 0.03	1.62 ± 0.19
	M	1.61 ± 0.16	1.64 ± 0.19
2016	C	1.71 ± 0.09	1.72 ± 0.12
	M	1.62 ± 0.02	1.54 ± 0.09
Treatment		*p* Value	
Year		**0.000** [2]	**0.000**
Mulching		**0.036**	**0.003**
Year × Mulching		**0.015**	**0.000**

[1] Mean ± SD, [2] Bold format intends to highlight significance when the *p* value is less than 0.05, OR1—orchard after replantation, OR2—orchard on virgin soil, C—control without mulching, M—mulching.

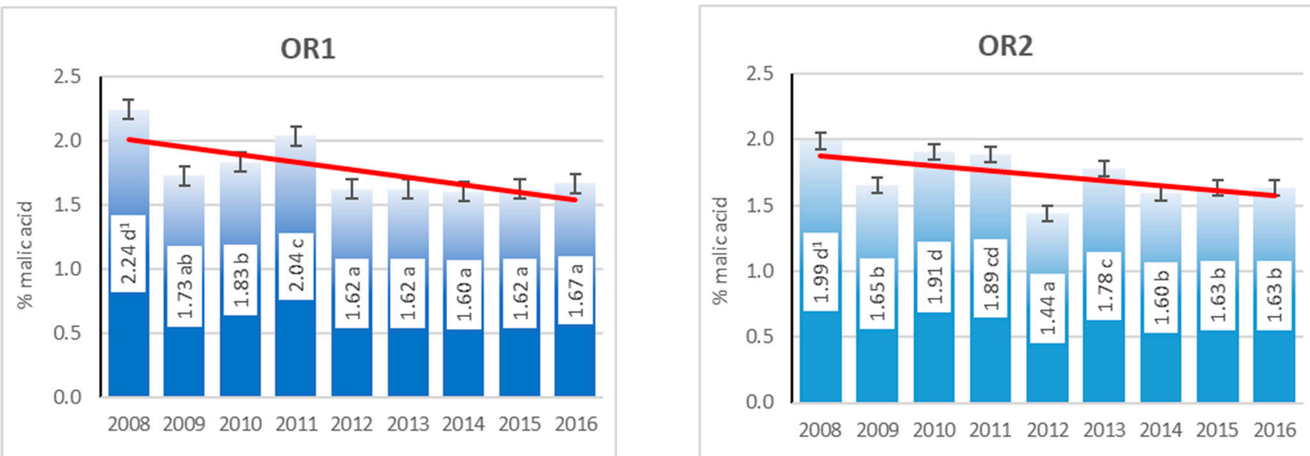

Figure 9. Influence of year on titratable acidity of sour cherry (% malic acid). [1] means that the same letters are not significantly different at α = 0.05 (Duncan's test).

Table 21. Influence of the selected features on titratable acidity (TA) of sour cherry.

	TA
TminV	0.64 *
SOLR	0.46 *
TJUN	0.39 *
NODFH	−0.57 *

* Significant levels $p < 0.001$. Explanations: TminV—average minimum temperature during the growing season, SOLR—solar radiation, TJUN—average temperature in Jun; NODFH—number of days from flowering to harvest.

Similar to the firmness and extract content, the acidity did not change under the influence of the research factors used (Tables S3 and S4).

3.4.5. Fruit Color

During the ripening of cherry fruits, the color changes from green to red, which is the result of biochemical changes during which the synthesis of color-modifying anthocyanins [99] occurs, the content of simple sugars increases, the acid content decreases, and the taste and other quality characteristics change [99]. All these changes are caused by changes in the structure of cell walls due to an increase in the solubility of pectic substances, which are the main component of the middle part and the primary cell walls of fruit tissues [100,101]. On a site where an orchard had not been cultivated before, significantly higher values of L* and COL were observed (Table 22). A higher L* value indicates that the fruit was less ripe compared to soil where the fruit trees had not grown before. This is confirmed by the higher value of h°, which in cherries was always higher in less ripe fruits [102,103]. In the cherry orchard, under the influence of nitrogen fertilization, the fruits were brighter [9] because nitrogen fertilization delays ripening [104,105]. This is confirmed by studies conducted on grapes and apples, where excessive fertilization with N stimulated vegetative growth, delayed ripening, and reduced anthocyanin synthesis [106,107]. However, the negative effects of high fertilization with N on maturation and anthocyanin content can be reduced by balanced fertilization with K [108]. The use of mulch with a mushroom substrate only had an impact on the color tone parameter h°, which was higher when mulching. It can be concluded that the application of the mushroom substrate delays the ripening of the fruits. This is confirmed by studies on Kelleris cherry, where this parameter decreased during fruit ripening [109]. The site, as well as the mulching used, had no significant effect on the parameters a*, b*, C*, and the color index for the red grapes, CIRG. Only the color index for tomatoes, COL, was significantly higher at the site after the replantation of the cherry orchard (OR1). The value of the COL color index used for tomatoes increased under the influence of nitrogen fertilization. Lower values were observed in older trees and a high correlation coefficient with cell sap pH [9]. Higher values of this indicator in tomatoes indicated an increase in red [110].

The parameters of fruit coloring changed during the years of research (Table 23). The brightness of L* increased with increasing yield and increasing trunk cross section area. On the contrary, the intensity of photosynthetic radiation affects the decrease in color brightness (Table 24). The a* parameter was negatively correlated with trunk cross-sectional area growth and evapotranspiration during the growing season. Photosynthetic radiation mainly reduced the brightness of the color and the proportion of yellow. Increasing the number of sunny days and the sum of temperatures affects the increase in the firmness and yield of cherry trees [9]. The use of black nets in apple production reduced PAR (photosynthetically active radiation) by reducing the color of the fruit and extract content [111]. The greater firmness of fruits may result from better sunlight and better conditions for calcium uptake, which is a component of cell walls responsible for their firmness [112,113].

Table 22. Influence of orchard site on the color space.

Treatment		Color Components and Indices						
		L*	**a***	**b***	**C***	**h°**	**COL**	**CIRG**
OR1	C	21.24 ± 2.96 [1]	6.22 ± 1.91	3.07 ± 1.10	7.10 ± 1.82	21.53 ± 8.62	84.00 ± 19.31	4.65 ± 2.64
	M	21.38 ± 2.73	6.37 ± 2.12	2.66 ± 1.56	7.21 ± 2.00	53.20 ± 8.63	88.60 ± 12.66	4.75 ± 1.68
		p Value						
Year		**0.000** [2]	**0.000**	**0.000**	**0.000**	**0.042**	**0.000**	**0.000**
Mulching		0.276	0.614	**0.001**	0.731	**0.034**	0.076	0.613
Year × Mulching		**0.009**	**0.000**	**0.011**	**0.000**	**0.000**	0.308	**0.002**
OR2	C	22.86 ± 3.17	6.18 ± 1.71	2.80 ± 1.15	6.96 ± 1.58	22.39 ± 13.30	80.39 ± 12.93	4.35 ± 2.53
	M	23.14 ± 3.43	7.06 ± 2.21	2.95 ± 1.03	7.84 ± 2.08	25.93 ± 35.71	82.16 ± 1.53	4.72 ± 1.44
		p Value						
Year		**0.000**	**0.000**	**0.000**	**0.000**	**0.024**	**0.000**	**0.000**
Mulching		**0.010**	**0.001**	**0.000**	**0.000**	0.553	0.284	0.059
Year × Mulching		0.059	0.910	**0.045**	0.762	0.611	0.248	**0.000**

[1] mean ± SD, [2] Bold format intends to highlight significance when the *p* value is less than 0.05, OR1—orchard after replantation, OR2—orchard on virgin soil, C—control without mulching, M—mulching. Explanations: L* indicates darkening of fruit at the time of harvest; a* indicates chromaticity on a green (−) to red (+) axis; b* chromaticity on a blue (−) to yellow (+) axis; C*—Chroma = $((a^*)^2 + (b^*)^2)^{0.5}$); h°—($\tan^{-1}$ b*/a*); COL = $(2000 \times a)/(L \times (a^2 + b^2)^{0.5})$; CIRG = (18O − h)/(L* + C).

Table 23. Color space of the skin of sour cherry depending on the year.

Year	Color Components and Indices						
	L*	**a***	**b***	**C***	**h°**	**COL**	**CIRG**
				OR1			
2008	19.8 bc [1]	8.1 e	1.8 b	8.3 c	9.0 a	97.5 cd	2.5 b
2009	21.1 d	6.7 c–e	2.4 c	7.2 c	19.6 ab	81.1 b	0.0 a
2010	19.0 a	6.3 cd	2.9 cd	6.9 bc	17.1 ab	103.9 d	5.8 d
2011	20.8 d	4.7 ab	3.1 d	5.7 ab	25.6 b	85.8 bc	6.0 d
2012	20.1 c	7.6 de	0.3 a	7.8 c	157.0 c	94.4 cd	5.8 d
2013	23.1 e	3.6 a	2.8 cd	4.7 a	31.1 b	79.6 b	5.6 d
2014	19.9 bc	7.0 c–e	3.8 e	8.0 c	21.6 ab	88.1 bc	5.9 d
2015	19.5 b	6.0 bc	4.1 e	7.4 c	26.6 b	88.8 bc	6.1 d
2016	28.4 f	6.8 c–e	4.7 f	8.4 c	28.6 b	57.5 a	4.7 c
				OR2			
2008	21.3 d	9.6 e	1.8 b	9.8 g	7.5 a	81.4 cd	0.1 a
2009	22.5 e	8.1 d	2.4 c	8.5 ef	12.5 a	86.9 de	4.5 c
2010	19.8 b	6.6 c	2.9 d	7.2 cd	16.4 a	100.0 f	5.5 de
2011	20.2 c	4.8 b	2.8 d	5.6 b	23.1 a	89.4 e	6.1 e
2012	24.2 g	6.4 c	1.1 a	6.8 c	56.4 b	77.1 c	5.1 cd
2013	23.2 f	3.4 a	2.6 cd	4.4 a	30.1 a	82.3 c–e	5.4 de
2014	19.2 a	6.3 c	3.6 e	7.4 cd	23.0 a	86.8 de	6.2 e
2015	28.7 i	6.4 c	4.3 f	7.8 de	26.1 a	59.6 a	4.7 cd
2016	27.9 h	7.9 b	4.4 f	9.2 fg	22.4 a	68.0 b	3.1 b

[1] The same letters in the column are not significantly different at α = 0.05 (Duncan's test). OR1—orchard after replantation, OR2—orchard on virgin soil, C—control without mulching, M—mulching. Explanations: L* indicates darkening of fruit at the time of harvest; a* indicates chromaticity on a green (−) to red (+) axis; b* chromaticity on a blue (−) to yellow (+) axis; C*—Chroma = $((a^*)^2 + (b^*)^2)^{0.5}$); h°—($\tan^{-1}$ b*/a*); COL = $(2000 \times a)/(L \times (a^2 + b^2)^{0.5})$; CIRG = (18O − h)/(L* + C).

Table 24. Influence of the selected features on color space of skin of sour cherry.

Feature	Color Components and Indices						
	L*	**a***	**b***	**C***	**h°**	**COL**	**CIRG**
YIELD	0.51 ***	−0.09	0.44 **	0.06	0.33 *	−0.49 ***	0.25
TCSA	0.59 ***	−0.27 *	0.63 ***	−0.08	0.61 ***	−0.56 ***	0.41 **
ITCSA	0.36 **	−0.59 ***	−0.04	−0.56 ***	0.35 **	−0.23	0.47 ***
TMW	0.22	−0.60 ***	0.25	−0.50 ***	0.52 ***	−0.20	0.62 ***
PREC	−0.10	−0.05	−0.42 **	−0.16	−0.33 *	0.28 *	0.08
TSOIL	0.02	0.51 ***	0.17	0.52 ***	−0.20	−0.11	−0.50 ***
ETW	0.08	−0.57 ***	0.54 ***	−0.43 **	0.68 ***	−0.04	0.73 ***
WB	−0.03	0.27	−0.61 ***	0.13	−0.70 ***	0.14	−0.13
PAR	−0.76 ***	−0.01	−0.70 ***	−0.20	−0.52 ***	0.67 ***	−0.08

* Significant levels $p < 0.001$, ** $p < 0.01$, *** $p < 0.05$. Explanations: L*—indicator of darkening of fruit at the time of harvest; a* indicates chromaticity on a green (−) to red (+) axis; b* chromaticity on a blue (−) to yellow (+) axis; C^*_{ab}—Chroma = $(a^{*2} + b^{*2})^{1/2}$; H_{ab}—($h^\circ = \tan^{-1} b^*/a^*$); CIRG = (18O − h)/(L* + C); TCSA—trunk cross-sectional area, ITCSA—increase in trunk cross-sectional area, TMW—average maximal temperature; PREC—precipitation, TSOIL—temperature soil, ETW—evapotranspiration, WB—water balance, PAR—photosynthetically active radiation.

4. Conclusions

The orchard where no fruit plants were grown before but agricultural cultivation was used was the place where the best results were obtained, both in terms of yield and tree growth (Table 25). Replanting cherries requires at least a few years before the next tree planting. Despite supplementing nutrients, regulating soil pH, and enriching the soil with organic matter, differences in growth and yield were observed. It can be concluded that the biological processes that occur in the soil that affect fertility are important processes and it is difficult to replace them with proper soil after intensive cultivation in one year. The interval between the removal and planting of a new orchard should be 3–5 years to reduce the risk of growth and quality loss. At the same time, it is recommended to grow cruciferous vegetables, legumes, and cereals. For *Prunus* spp. without the use of additional treatments, the return to the same position should be after 5–8 years.

The use of the mushroom substrate as a treatment that will increase soil fertility has not been proven to be effective. This substrate is a rich source of phosphorus and potassium, but it can increase soil salinity and negatively affect tree growth, especially in the first years after planting. Therefore, before application, the substrate should be analyzed and composted. The application of herbicides in large amounts in herbicide belts is also not recommended, especially for plants sensitive to soil salinity. Salinity and the high content of some components have a great impact on topsoil, even when using a substrate surface-based mulch in herbicide belts. Therefore, in practice, the application of high-salinity organic matter should be used in small doses, which will not increase soil salinity and affect the weakening of growth and yield.

The trees growing in a place where the fruit plants had not been grown before and after the replantation of the old cherry orchard did not differ in terms of the development of the trees. Mulching the soil with a mushroom substrate also did not affect tree development.

Table 25. Impact of stand and mulching.

Characteristic	Influence	
	Planting Area	**Mulching**
Growth (TCSA)	↑	↘
Total Yield	↑	↗
Productivity Coefficient	↑	↗
Mass of fruit	↓	↘
Firmness	↗	↘

Table 25. *Cont.*

Characteristic	Influence	
	Planting Area	**Mulching**
Soluble solid content	↘	↘
Titratable Acidity	↗	↘
Color		
L*	↑	↗
a*	↗	↗
b*	←→	↗
C*	↗	↗
h°	↘	↑
COL	↑	↗
CIRG	↘	↗
Mineral content in soil		
Leyer of soil 0–20 cm		
P	↑	↑
K	↓	↑
Mg	↑	↑
K/Mg	↓	↑
pH	↗	↗
Leyer of soil 21–40 cm		
P	↑	↗
K	↘	↑
Mg	↑	↑
K/Mg	↘	↗
pH	↗	↗

↑ statistically significant positive or ↓—statistically significant negative impact of the site where fruit trees did not grow before (OR2) or mulching with a mushroom substrate $\alpha = 0.05$ (Duncan's test). ↘ negative impact but not or statistically significant ↗—positive impact of the site where fruit trees did not grow before (OR2) or mulching with a mushroom substrate statistically insignificant $\alpha = 0.05$ (Duncan's test), ←→—no differences.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/agriculture13081587/s1, Table S1: The influence of the position and composting after mushroom cultivation on fruit firmness in 2008–2016; Table S2: Firmness of the Łutówka cultivar in 2006–2013; Table S3: The influence of the site and mulching on the hydrolytic acidity of fruit in 2008–2016; Table S4: The influence of the site and mulching on titratable acidity of fruit in 2008–2016.

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