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The Effect of Mulch Materials on Selected Soil Properties, Yield and Grape Quality in Vineyards under Central European Conditions

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Abstract: The results of this study provide overall information on the verification of the effect of applying two different mulching materials of an organic origin to the soil surface in the area between rows of grape vines in vineyards on selected physical and chemical properties of the soil and, at the same time, on the yield and quality parameters of the grape vines (*Vitis vinifera* L.). During the period under study, 2018–2020, the effect of shredded cereal straw (CS) and compost from garden waste (CO) was investigated. The control variant (CWC) was left without any cover and was regularly cultivated with a coulter cultivator to a depth of 60 mm. During the experiments, meteorological data were monitored and recorded along with soil temperature and soil moisture for each variant. The results show that the lowest temperature was measured for the straw cover variant (11.10–11.87 °C), while the highest soil temperature was measured for compost (11.93–13.16 °C). Under the straw, the moisture level in the soil was higher compared to the other variants, and there was a gradual increase (of 3%) in soil bulk density values compared to the baseline. By contrast, the compost variant showed a decrease (of 1%) in bulk density values. The differences in nutrient content were slight among the variants. The only statistically significant difference was identified for the compost variant with respect to the content of total nitrogen and phosphorus. Further results demonstrated a positive effect of both mulch material variants on grape yield, which was 6–19% higher in the variants with a cover layer. In addition, the use of mulch also had a positive effect on grape quality. For example, the sugar content—one of the main quality parameters—increased by 1–7% due to the mulch layer. Based on these results, the use of mulching materials can be recommended for areas with low total rainfall during the growing season, as well as when growing varieties with irregular yields and uneven grape quality.

Keywords: mulch cover; organic mulch materials; soil physical properties; sustainable farming

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1. Introduction

On a global scale, the common grape vine is the most abundant fruit species. It is extensively cultivated in many different areas with a wide range of soil and climatic conditions. In connection with global warming, water scarcity is now becoming a limiting factor in the cultivation of vines. The growth and development of common grape vines require from 300–700 mm of rainfall each annual cycle [1].

For these reasons, the proportion of vineyards where supplementary irrigation is being introduced is increasing. However, even such irrigation will not be able to fully cover the requisite water consumption in the future. As a result of a lack of rainfall and excessive water consumption in many sectors associated with anthropogenic activities, surface water resources are increasingly becoming depleted, and groundwater levels and supplies are declining [2].

In the coming period, making viticultural production more competitive will thus be tied to innovating the technological processes applied in the cultivation of the common grape vine, while respecting environmental and economic aspects. In this context, one promising solution may be sustainable soil management practices [3], which is a complex three-phase system the properties of which may be influenced by a number of factors [4,5].

Therefore, vine growers are looking for progressive methods of soil surface treatment in vineyards, which include the application of mulch materials near the plants being grown. Synthetic and, in particular, natural mulch materials can be used in this respect [6]. The application of mulch materials of an organic origin is considered a potential solution with a high sustainability potential. A mulch cover layer contributes to better management, soil water use and alleviation of water stress in the plants grown [7]. Mulching with organic materials contributes to changes in soil microbiome and enzyme activity by providing carbon and nutrients [8]. At the same time, mulching affects the intake of nutrients by plant roots and changes the release of root exudates, which leads to strengthening the variability of the soil environment [9]. Mulch materials capture the heat energy of the incident solar radiation based on the principle of the greenhouse effect. In this case, the sun's energy passes through the mulch layer and heats the air underneath. In turn, the temperature significantly affects the physicochemical, biological and interspheric processes that affect gas exchange between the soil and the surrounding atmosphere [10,11]. Soil temperature influences the rate of decomposition and subsequent mineralization of organic substances contained in the soil [12]. It substantially affects soil moisture, conductivity and water availability to plants [4,5]. Additionally, Li et al. [13] state that the covering surface layer of mulch helps to retain soil moisture much better, due to the reduction of water evaporation and increased infiltration. A number of studies also point to the creation of better conditions for optimizing vine growth, grape production quality and yield [14–16]. In addition, mulching can be a good solution for reducing water erosion and weed growth, while improving soil fertility and nutrient cycling. The use of long-term mulching can help to increase the content of organic matter and nutrients in the soil due to the degradation of the mulching materials [17,18]. Suitable types of mulching materials can reduce the toxicity and leaching of applied herbicides into the groundwater [19]. A number of relevant reports from Asia [20], Europe [21], Africa [22] and America [23] point to the effectiveness of mulch in reducing soil and water loss on non-agricultural as well as agriculturally used land, in different climatic conditions around the world. Some papers suggest that the use of organic mulch materials also represents a suitable means for recycling waste materials in a circular economy system [19,24,25].

According to ISA [26], the recommended thickness of mulch material of an organic origin is between 30 and 80 mm. The suitability of specific types of mulch materials depends on the type of plants grown and the climatic conditions of the local environment. In terms of other aspects, Wang et al. [27] mention the color of the material used, the thickness of the layer, seasonality and availability, transport costs and application at the site. It is for these reasons that field trials need to be carried out.

Within this context, the main objective of this paper was to assess the effect of two different mulch materials of an organic origin (cereal straw, compost) applied between rows of grape vines under Central European conditions, as compared to an uncovered cultivated control variant, on selected physical and chemical soil properties, including an evaluation of the yield and quality of grapes of the common grape vine (*Vitis vinifera* L.).

2. Materials and Methods

2.1. Characteristics of the Experimental Area

The experimental measurements were carried out in the Czech Republic, in the Moravia wine-growing region, the Velké Pavlovice subregion (Figure 1), at a vineyard in the village of Rakvice (48°51′29′′ N 16°48′48′′ E). The experimental measurements were taken in the 2018–2020 period.

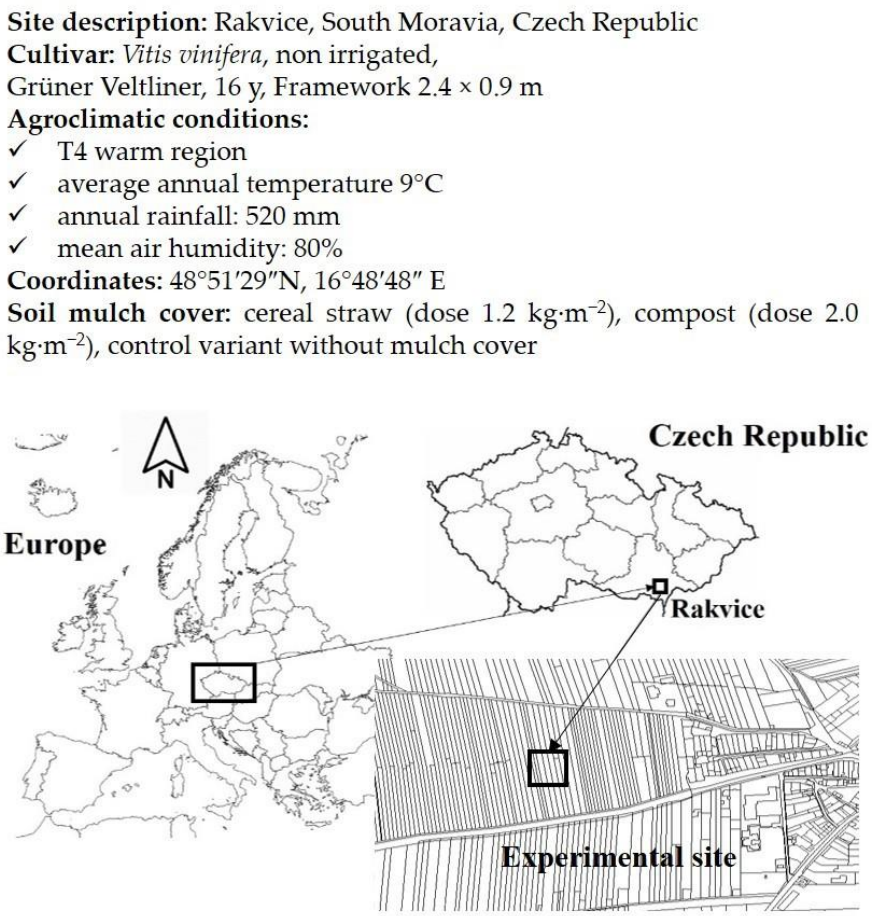

Figure 1. Map showing the location and characteristics of the experimental area. Experimental site is located in the Czech Republic, in the Moravia wine-growing region, the Velké Pavlovice subregion, at a vineyard in the village of Rakvice.

The altitude of the vineyard is 164 m above sea level, and the experimental area is located in a T4 warm region, a warm district, dry with a moderate and dry winter. The average annual temperature is 9 °C, the average total annual precipitation is 520 mm, the average relative humidity is about 80%. Geologically, the area belongs to the Bohemian Massif–superficial deposits and post-variscan magmatites, the Vienna Basin region (the Moravian part), Quaternary, the rock type is unconsolidated sediment, the rock is sandy-clay to clay-sandy sediment, the rock grain size is sandy-clay to clay-sandy, and the dominant soil unit is modal chernozem (CEm).

The experimental vineyard is 16 years old. The variety assessed was Grüner Veltliner on Kober 5BB rootstock. The individual rows of the vineyard are oriented towards the south-east, with row spacing of 2.4 m. The vines within the rows are spaced 0.9 m apart. The vines are grown on a high wire (trunk height 1.0 m) and are pruned, leaving a single cane. The slope of the land is up to 5%. Over the long term on this site, the vines begin to sprout in mid-April, flowering starts in the first half of June and ripening and harvesting of the grapes occurs in the first half of October.

2.2. Experimental Variants and Mulch Materials Used

To assess the effects of mulch materials, raw materials that are easily available and have different surface colors were selected. These were: shredded cereal straw (CS, density 100 kg·m^{-3}, in terms of grain size distribution the greatest proportion of particles (75.50%) was in the 40–60 mm fraction) and compost from garden waste (CO, density 560 kg·m^{-3}, in terms of grain size distribution, the greatest proportion of compost particles (77.72%)

was in the 0–10 mm fraction). Each raw material was applied to the soil surface between the rows using the random block method, and each of the experimental variations was set up in 3 replicates (Figure 2).

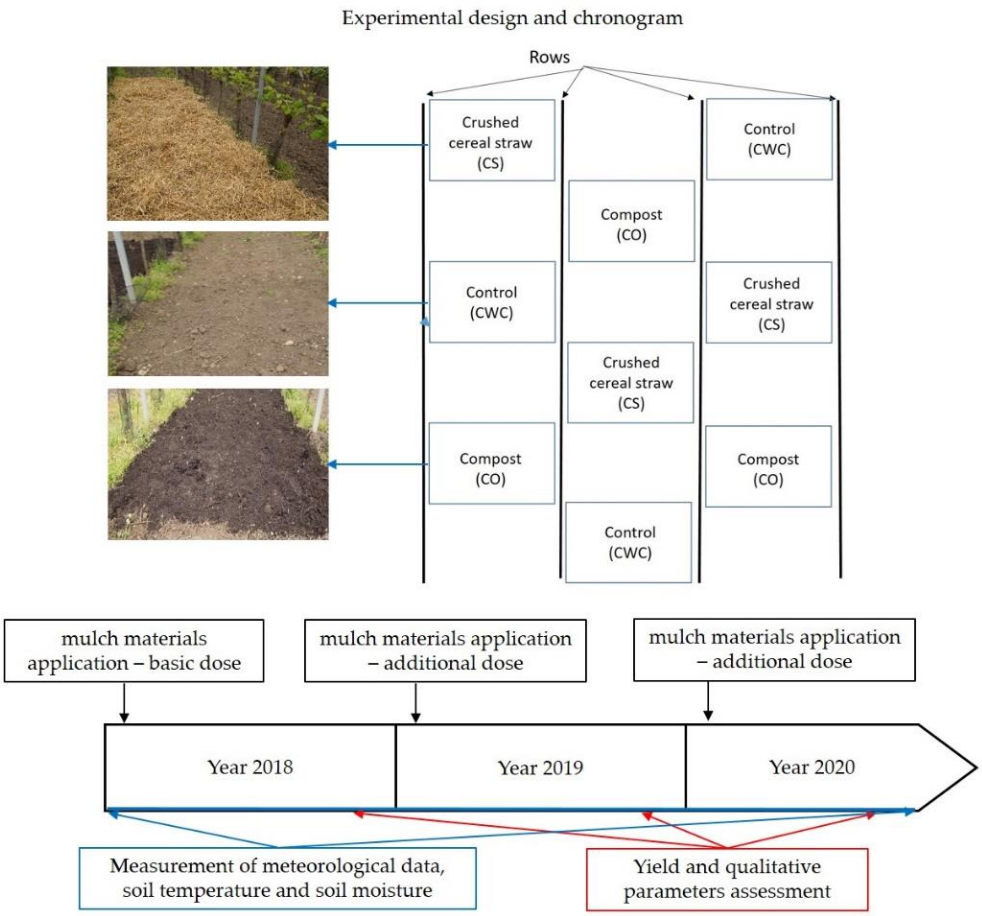

Figure 2. Schematic diagram of the design of the experiment using the random block method.

The experimental blocks for the control variant were left without any cover (CWC) and were regularly cultivated with a coulter cultivator to a depth of 60 mm. Overall, the experimental blocks were situated in the central part of the vineyard; the remaining inter-row area served as a buffer. Each of the experimental blocks included 10 vines.

The application rates of the mulch materials were chosen with reference to the methodology introduced by Ziegler [28]. In the case of cereal straw, the rate was 1.2 kg·m^{-2}, while in the case of compost, the rate was 2 kg·m^{-2}, and the control variant remained without any mulch cover. These rates were applied when setting up the experiment in 2018 and the mulch layer was renewed regularly in subsequent years.

2.3. Measurement of Meteorological Data, Soil Temperature and Soil Moisture

For the purpose of measuring meteorological data, a weather station with remote data transmission (type: AMET, Velké Bílovice, Czech Republic) was installed at the experimental site. Figure 3 shows the average monthly minimum and maximum temperatures, along with monthly rainfall totals for the period under study, 2018–2020.

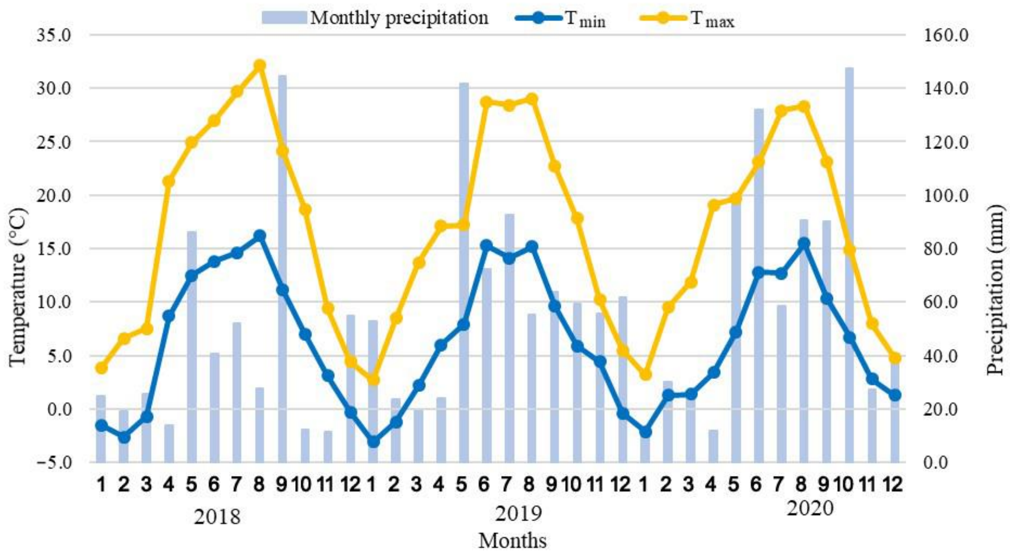

Figure 3. An overview of the average monthly minimum and maximum temperatures, monthly rainfall totals.

In addition to measuring the trends in meteorological factors, the station made it possible to continuously measure and record data including soil temperature and soil moisture. For all experimental variants, temperature was measured using a digital thermometer with a platinum temperature sensor (model: PT100-XM, AMET, Velké Bílovice, Czech Republic). The measurements were taken daily at regular fifteen-minute intervals, and a depth of placement of 0.1 m. Soil moisture was measured using "VIRRIB" (AMET, Velké Bílovice, Czech Republic) volumetric soil moisture sensors. These are mechanical sensors with a circular design, with a diameter of 280 mm, which were located at a depth of 0.1 m. Soil humidity was recorded during the growing season every day at regular fifteen-minute intervals. In order to eliminate the influence of edge effects, soil temperature and moisture measurements were always taken in the central part of the experimental block.

2.4. Assessment of Physical and Chemical Soil Properties

On the site, soil samples were always taken at the beginning of the growing season for assessing the chemical and physical properties of the soil. Samples were collected from a depth of 0.00–0.30 m in five replicates.

In terms of chemical analyses, the soil samples were analyzed according to Mehlich III for the content of: P, K, Mg, and Ca, while total nitrogen content Ntotal was determined by mineralization using the distillation method according to Kjeldahl [29]. The soil exchange reaction pH was determined potentiometrically from KCl leachate, and carbon content Cox was determined by oxidimetric titration according to Nelson and Sommers [30].

The physical properties of the soil were monitored using rollers according to Kopecký [31], which included the following determinations: reduced bulk density, total porosity, instantaneous water and air content, maximum capillary water capacity and minimum air capacity.

2.5. Assessment of Grape Yield

The grape harvest, regarding the ripeness of grapes, was mainly based on meteorological conditions of the given year. The grapes were harvested on 2 October 2018, 12 October 2019 and 9 October 2020. The grapes were placed in harvest containers and transported to the laboratory where they were weighed by using a digital scale. The grapes were harvested separately for the individual experiment variant (from 10 shrubs per variant), weighed by using KERN KB 10,000 laboratory scale (Kern & Sohn GmbH, Balingen, Germany) and the average yield of grapes (per 1 shrub) was determined, which was subsequently converted to the average yield of grapes expressed in tonnes per a hectare of vineyard. A total of

40 average berries were separated from different parts of the harvested grapes to make the result as objective as possible. The berries were chosen not to distort the results, so the results were as realistic as possible. Subsequently, the berries were mechanically ground, and the produced mash was stirred. From the resulting mash, a sample of must was taken and the analytical values were determined according to standardized laboratory methods.

2.6. Assessment of the Main Qualitative Parameters of Grapes

The following analytical values were determined: sugar content (°NM–kg of total sugar in 100 L of juice), the content of all titratable acids ($g \cdot L^{-1}$), pH (−) and the amount of assimilable nitrogen ($mg \cdot L^{-1}$). The berries from the harvested grapes were mechanically crushed and the resulting mash was stirred. From the resulting mash, a sample of must was taken and the analytical values were determined according to standardized laboratory procedures. Sugar content was measured using a PAL-1 digital refractometer (ATAGO Co., Ltd., Tokyo, Japan). The content of titratable acids was determined by titration with an automatic TitroLine Easy titrator (Schott Instruments GmbH, Mainz, Germany) on NaOH. The pH value was determined based on the potential of a glass electrode, which is dependent on the activity of hydrogen cations, relative to the reference calomel electrode. The potential was measured with a PH 526 pH meter from WTW, with a combined glass and argent chloride gel electrode using calibrated buffer solutions with a known pH. The amount of assimilable nitrogen was determined by formaldehyde titration. Each measurement was performed in three replicates.

2.7. Statistical Analysis

The obtained results were reported as the mean and standard deviation. Analysis of variance (ANOVA) and Tukey's honestly significant difference (HSD) tests were conducted to determine the differences among the means, using the "Statistics 12.0" (StatSoft Inc., Tulsa, OK, USA) software package. Analysis of variance was conducted, and the results were compared using Tukey's multiple range assay at a significance level of $\alpha = 0.05$.

3. Results and Discussion

The results presented correspond to one year with low rainfall (2018) and two years (2019 and 2020) with higher rainfall compared to the long-term average for the area in question, as shown in Figure 3. In terms of distribution throughout the year, total rainfall during the growing season (1 April–31 October) was 377 mm in 2018, 509 mm in 2019 and 630 mm in 2020.

The following Table 1 provides an overview of the average monthly soil temperatures and soil moisture levels for each experimental variant, respecting the type of mulch material used in the period under study.

Table 1. Average temperatures and soil moisture levels in the period under study, 2018–2020.

Month	Variant	Average Value of the Observed Trait					
		Soil Temperature (°C)			Soil Moisture Level (wt%)		
		2018	2019	2020	2018	2019	2020
January	CS	2.38 ± 1.19	1.61 ± 1.02	1.56 ± 0.36	35.49 ± 0.96	35.39 ± 0.85	41.07 ± 0.72
	CO	2.45 ± 1.30	1.87 ± 1.06	1.31 ± 0.38	30.14 ± 0.50	28.12 ± 1.23	28.13 ± 0.39
	CWC	2.62 ± 0.84	2.27 ± 0.96	2.19 ± 0.28	29.98 ± 0.48	27.80 ± 1.77	28.43 ± 0.60
February	CS	2.61 ± 1.14	2.29 ± 0.95	4.09 ± 1.01	34.41 ± 0.57	35.78 ± 0.61	42.37 ± 0.66
	CO	2.87 ± 1.26	2.53 ± 1.09	4.36 ± 1.20	28.95 ± 0.19	29.09 ± 0.59	28.48 ± 0.42
	CWC	2.74 ± 1.23	2.86 ± 1.07	4.72 ± 0.95	29.42 ± 0.32	29.44 ± 0.48	29.31 ± 0.38

Table 1. *Cont.*

Month	Variant	Average Value of the Observed Trait					
		Soil Temperature (°C)			Soil Moisture Level (wt%)		
		2018	2019	2020	2018	2019	2020
March	CS	6.20 ± 1.16	6.29 ± 1.04	6.07 ± 1.29	33.57 ± 0.71	36.23 ± 0.39	42.57 ± 0.72
	CO	6.28 ± 1.17	6.60 ± 0.84	6.69 ± 1.32	28.32 ± 1.44	27.94 ± 0.69	28.32 ± 0.21
	CWC	6.42 ± 1.86	6.94 ± 0.98	6.73 ± 1.13	27.02 ± 0.42	28.37 ± 0.76	29.10 ± 0.60
April	CS	10.81 ± 2.05	10.37 ± 1.48	9.36 ± 1.39	36.49 ± 0.87	33.90 ± 1.56	40.40 ± 0.94
	CO	11.26 ± 2.08	10.94 ± 1.57	11.08 ± 2.03	27.36 ± 2.75	22.61 ± 1.65	27.26 ± 0.43
	CWC	11.06 ± 2.85	11.23 ± 1.66	10.64 ± 1.93	27.25 ± 2.47	21.45 ± 1.83	23.89 ± 2.62
May	CS	17.07 ± 2.21	13.01 ± 2.01	12.97 ± 1.22	37.31 ± 1.46	37.39 ± 3.69	39.01 ± 3.66
	CO	19.18 ± 2.35	14.07 ± 2.45	15.01 ± 1.21	20.89 ± 0.38	22.91 ± 4.61	22.92 ± 1.57
	CWC	17.23 ± 1.49	13.51 ± 1.74	14.36 ± 1.03	20.23 ± 0.96	21.76 ± 5.46	19.59 ± 2.26
June	CS	19.44 ± 0.98	19.36 ± 1.33	17.26 ± 1.58	31.17 ± 2.60	42.24 ± 1.18	46.71 ± 1.96
	CO	22.32 ± 1.21	23.07 ± 1.79	18.43 ± 1.48	20.84 ± 0.80	29.94 ± 1.51	24.94 ± 4.10
	CWC	20.85 ± 1.09	20.71 ± 1.66	17.74 ± 1.47	18.38 ± 0.09	25.50 ± 3.68	26.49 ± 3.64
July	CS	19.93 ± 1.08	19.73 ± 1.11	20.14 ± 1.29	30.09 ± 1.47	43.08 ± 2.54	46.78 ± 1.18
	CO	22.62 ± 1.53	22.80 ± 1.48	21.33 ± 1.33	20.50 ± 0.81	24.24 ± 0.72	28.21 ± 1.07
	CWC	21.27 ± 1.34	21.20 ± 1.18	20.32 ± 1.08	18.10 ± 0.11	20.30 ± 0.30	21.83 ± 2.37
August	CS	21.15 ± 1.20	21.10 ± 0.67	21.52 ± 1.30	26.02 ± 0.80	40.66 ± 5.78	40.52 ± 3.06
	CO	24.96 ± 2.00	22.03 ± 0.99	22.36 ± 1.55	19.47 ± 0.21	23.49 ± 0.22	26.39 ± 0.77
	CWC	23.85 ± 1.52	21.80 ± 0.71	21.85 ± 1.10	18.05 ± 0.07	20.08 ± 0.19	19.83 ± 0.40
September	CS	17.95 ± 2.05	17.22 ± 1.74	17.58 ± 1.87	34.47 ± 2.50	34.07 ± 4.92	38.51 ± 5.29
	CO	19.38 ± 2.60	17.99 ± 2.11	18.18 ± 1.76	27.60 ± 2.41	23.74 ± 0.70	28.18 ± 0.69
	CWC	18.94 ± 2.18	18.30 ± 1.86	18.01 ± 1.54	21.34 ± 2.59	19.29 ± 0.31	19.46 ± 0.29
October	CS	12.89 ± 0.99	12.80 ± 1.32	11.65 ± 2.02	29.61 ± 0.85	32.73 ± 3.15	42.33 ± 4.55
	CO	13.80 ± 1.15	13.22 ± 1.50	12.19 ± 2.05	22.95 ± 0.66	23.08 ± 0.22	29.23 ± 2.15
	CWC	13.85 ± 1.13	13.55 ± 1.40	12.40 ± 1.96	17.79 ± 0.96	18.78 ± 0.05	26.25 ± 5.68
November	CS	8.64 ± 2.80	8.54 ± 1.12	7.22 ± 2.52	27.92 ± 0.23	38.92 ± 3.67	44.65 ± 1.60
	CO	9.09 ± 2.91	8.54 ± 1.26	7.94 ± 2.42	22.00 ± 0.28	23.82 ± 1.23	30.02 ± 0.79
	CWC	9.29 ± 2.85	9.14 ± 1.08	8.15 ± 2.37	17.40 ± 0.05	20.30 ± 1.54	30.91 ± 0.72
December	CS	3.41 ± 0.77	3.71 ± 1.02	3.74 ± 1.02	31.18 ± 2.62	40.76 ± 1.34	44.60 ± 1.26
	CO	3.71 ± 0.82	3.49 ± 1.10	4.31 ± 0.88	22.88 ± 1.68	26.50 ± 1.94	29.52 ± 0.56
	CWC	3.94 ± 0.75	4.38 ± 0.99	4.59 ± 0.82	18.74 ± 2.65	24.63 ± 2.60	30.87 ± 0.55

Legend: Data are expressed as means ± standard deviation; CS—cereal straw, CO—compost, CWC—control without any cover.

The following Table 2 shows the average annual values of temperature and soil moisture level, which were assessed by analysis of variance followed by a comparison of the differences using the HSD test. The results obtained show that the mulch materials had no statistically significant effect on soil temperature.

Table 2. An overview of average annual values of temperature and soil moisture level.

Variant	Average Value of the Observed Trait					
	Soil Temperature (°C)			Soil Moisture Level (wt%)		
	2018	2019	2020	2018	2019	2020
CS	11.87 ± 7.16^{a}	11.34 ± 7.00^{a}	11.10 ± 6.82^{a}	32.31 ± 3.53^{b}	37.59 ± 3.47^{b}	42.46 ± 2.76^{b}
CO	13.16 ± 8.34^{a}	12.26 ± 7.91^{a}	11.93 ± 7.14^{a}	24.33 ± 3.85^{a}	25.45 ± 2.68^{a}	27.63 ± 2.02^{a}
CWC	12.67 ± 7.72^{a}	12.15 ± 7.21^{a}	11.81 ± 6.67^{a}	21.98 ± 4.94^{a}	23.14 ± 3.82^{a}	25.49 ± 4.42^{a}

Legend: Data are expressed as means ± standard deviation; for each column, different letters "a, b" indicate significant differences among treatments according to the Tukey's test ($p < 0.05$); CS—cereal straw, CO—compost, CWC—control without any cover.

Nevertheless, it is clear from the values that the lowest temperature was measured for the CS cover variant (11.10–11.87 °C), while the highest soil temperature was measured under the CO cover (11.93–13.16 °C). Ham et al. and Fourie and Freitag [32,33] state that the intensity of heat conduction between the mulch layer and the soil surface affects the overall ability of the mulch layer to moderate soil temperature, which may be one of the reasons for the high cooling effect of the straw mulch layer. By contrast, the resulting soil moisture values show that the soil moisture level under the CS cover was higher compared to the other variants. Bussière and Cellier [34] assessed the effect of mulch on mass and energy exchanges between the soil and the atmosphere. Experimental results have shown that mulch cover affects soil moisture by limiting evaporation and also affects soil temperature due to heat transfer [35,36]. Dahiya et al. [37] state that an appropriate type of mulch material can contribute to reducing soil temperature, which has a positive effect on root growth and development. Gan et al. [38] state that more favorable soil microclimatic conditions are created under a mulch cover, which allow soil temperatures to be reduced to a depth of 100 mm while maintaining greater soil moisture during the warmest part of the growing season. Ham et al. [32] report that mulch materials that limit water evaporation and shade the soil surface from incident solar radiation generally have a cooling effect on the soil. At the same time, the results of their measurements demonstrate that midday soil temperatures are highest under mulch, which effectively transmits short-wave radiation and at the same time prevents the escape of long-wave radiation.

Table 3 presents the resulting values of the assessed physical properties of soil. These values also show that the instantaneous water content was higher for the mulched variants. At the same time, the CS cover variant showed a gradual increase in soil bulk density values compared to the baseline. By contrast, the CO cover variant experienced a decrease in bulk density values.

Additionally, Álvaro-Fuentes et al., Hansen et al. and Buesa et al. [3,39,40] reported an increase in soil bulk density values for land plots protected by a mulch cover, especially in the surface layers, due to compaction with no effective possibility to correct the situation by surface or deep loosening.

In general, the differences between the nutrient contents assessed were slight. The values presented in Table 4 show that the only statistically significant difference was in the total nitrogen and phosphorus content for the CO cover variant. The results of the papers by Yao et al. and Neilsen et al. [41,42] demonstrated an increase in the availability and content of P in mulched plots, with links to an increase in soil microbial biomass and an increase in phosphatase production.

Table 3. Resulting values of the physical analyses of the soil samples.

Year	Variant	Average Value of the Observed Trait					
		Bulk Density Red. (g·cm^{-1})	Total Porosity (%)	Instantaneous Content of		Max. Capillary Water Capacity (vol%)	Minimum Air Capacity (vol%)
				Water (vol%)	Air (vol%)		
2018	CS	1.39 ± 0.01 *	47.25 ± 0.57 *	19.72 ± 0.07 *	27.53 ± 0.64 *	33.45 ± 3.39 *	13.80 ± 3.96 *
	CO						
	CWC						
2019	CS	1.41 ± 0.02 ^{a}	46.51 ± 0.80 ^{a}	23.41 ± 1.61 ^{a}	23.10 ± 0.81 ^{a}	37.39 ± 1.36 ^{a}	9.12 ± 2.16 ^{a}
	CO	1.33 ± 0.02 ^{b}	49.41 ± 0.70 ^{b}	26.28 ± 1.39 ^{b}	23.13 ± 0.69 ^{b}	41.21 ± 4.01 ^{b}	8.20 ± 3.31 ^{b}
	CWC	1.40 ± 0.03 ^{a}	46.88 ± 1.14 ^{a}	21.04 ± 5.33 ^{a}	25.84 ± 4.19 ^{a}	34.02 ± 5.19 ^{a}	12.86 ± 4.05 ^{a}
2020	CS	1.42 ± 0.02 ^{a}	45.98 ± 0.83 ^{a}	26.42 ± 5.94 ^{b}	19.56 ± 5.12 ^{b}	23.90 ± 1.55 ^{b}	22.09 ± 0.72 ^{b}
	CO	1.38 ± 0.02 ^{a}	47.46 ± 0.58 ^{a}	21.43 ± 2.35 ^{a}	26.03 ± 1.77 ^{a}	36.97 ± 1.59 ^{a}	10.49 ± 1.01 ^{a}
	CWC	1.39 ± 0.03 ^{a}	47.03 ± 1.15 ^{a}	19.11 ± 0.41 ^{a}	27.92 ± 0.74 ^{a}	37.61 ± 3.84 ^{a}	9.41 ± 2.69 ^{a}

Legend: *—baseline; data are expressed as means ± standard deviation; for each column and each year, different letters "a, b," indicate significant differences among treatments according to the Tukey's test (p < 0.05); CS—cereal straw, CO—compost, CWC—control without any cover.

Table 4. Resulting values of the chemical analyses of the soil samples.

Year	Variant	Average Value of the Observed Trait						
		N_{total} (%)	P (mg·kg^{-1})	K (mg·kg^{-1})	Mg (mg·kg^{-1})	Ca (mg·kg^{-1})	pH_{KCl} (–)	C_{ox} (%)
2018	CS	0.21 ± 0.01 *	45.33 ± 0.99 *	471.67 ± 1.56 *	459.61 ± 1.96 *	4690.33 ± 0.96 *	7.30 ± 0.01 *	2.02 ± 0.01 *
	CO							
	CWC							
2019	CS	0.17 ± 0.01 ^{a}	48.03 ± 0.15 ^{a}	475.81 ± 0.77 ^{a}	454.79 ± 0.81 ^{a}	4591.73 ± 2.11 ^{a}	7.40 ± 0.03 ^{a}	2.05 ± 0.02 ^{a}
	CO	0.23 ± 0.01 ^{b}	49.09 ± 0.18 ^{b}	476.06 ± 0.06 ^{a}	458.55 ± 0.79 ^{a}	4738.55 ± 69.90 ^{a}	7.37 ± 0.02 ^{a}	2.05 ± 0.01 ^{a}
	CWC	0.20 ± 0.01 ^{ab}	47.78 ± 0.26 ^{a}	450.43 ± 7.33 ^{b}	452.39 ± 1.64 ^{a}	4592.68 ± 1.56 ^{a}	7.40 ± 0.02 ^{a}	2.02 ± 0.01 ^{a}
2020	CS	0.21 ± 0.02 ^{a}	50.70 ± 2.04 ^{a}	482.31 ± 0.92 ^{a}	447.25 ± 2.99 ^{a}	4499.32 ± 0.95 ^{a}	7.40 ± 0.01 ^{a}	2.06 ± 0.08 ^{a}
	CO	0.23 ± 0.01 ^{a}	50.75 ± 0.88 ^{a}	484.45 ± 1.88 ^{a}	452.30 ± 5.56 ^{a}	4571.07 ± 39.53 ^{a}	7.40 ± 0.02 ^{a}	2.14 ± 0.06 ^{a}
	CWC	0.21 ± 0.01 ^{a}	49.09 ± 2.88 ^{a}	480.67 ± 2.40 ^{a}	442.03 ± 2.96 ^{a}	4444.74 ± 50.37 ^{a}	7.40 ± 0.01 ^{a}	2.05 ± 0.06 ^{a}

>Legend: *—baseline; data are expressed as means ± standard deviation; for each column and each year, different letters "a, b," indicate significant differences among treatments according to the Tukey's test (p < 0.05); CS—cereal straw, CO—compost, CWC—control without any cover.

The measurements carried out and their results suggest that another benefit of the mulch materials applied may be the achievement of optimal grape yields and a positive influence on their qualitative parameters. Guerra and Steenwerth [14] stated that the resulting effectiveness of mulch materials was significantly influenced by their type, properties, application rate and their effects on soil nutrient content. Experiments involving the application of a mulch layer comprised of compost from garden waste have been conducted, for example, by Chan et al. [43]. The result was an increase in the potassium content and pH of the must. Sales and Chan and Fahey [44,45] reported that a sufficiently thick cover of mulch material affected soil moisture, while the effects on grape quality were not conclusive.

The results presented in Table 5 show a positive effect of mulch materials on grape yield. In all years, the highest yield was obtained for the CS cover variant, while the lowest yield was obtained for the uncovered CWC variant.

Table 5. Resulting values for the yields and quality parameters of the harvested grapes.

Year	Variant	Average Value of the Observed Trait				
		Grape Yield ($t \cdot ha^{-1}$)	Sugar Content (°NM)	All Titratable Acids ($g \cdot L^{-1}$)	pH (−)	YAN ($mg \cdot L^{-1}$)
2018	CS	12.42 ± 0.09 [c]	21.51 ± 0.01 [a]	5.78 ± 0.04 [b]	3.51 ± 0.00 [b]	153.35 ± 0.05 [b]
	CO	11.85 ± 0.06 [b]	21.52 ± 0.00 [a]	5.15 ± 0.03 [a]	3.54 ± 0.00 [c]	162.11 ± 0.06 [c]
	CWC	11.08 ± 0.10 [a]	21.31 ± 0.00 [b]	5.21 ± 0.02 [a]	3.22 ± 0.01 [a]	151.55 ± 0.05 [a]
2019	CS	13.22 ± 0.09 [c]	24.42 ± 0.00 [c]	5.39 ± 0.03 [b]	3.47 ± 0.00 [c]	152.63 ± 0.06 [b]
	CO	12.19 ± 0.09 [b]	24.51 ± 0.00 [b]	5.09 ± 0.02 [a]	3.33 ± 0.01 [a]	161.31 ± 0.02 [c]
	CWC	11.07 ± 0.16 [a]	22.83 ± 0.01 [a]	5.16 ± 0.03 [a]	3.36 ± 0.00 [b]	151.26 ± 0.04 [a]
2020	CS	10.93 ± 0.04 [a]	20.72 ± 0.02 [c]	6.67 ± 0.03 [b]	3.37 ± 0.01 [a]	341.71 ± 0.04 [b]
	CO	10.72 ± 0.09 [a]	20.24 ± 0.01 [b]	6.79 ± 0.02 [c]	3.36 ± 0.01 [a]	352.64 ± 0.09 [c]
	CWC	10.13 ± 0.11 [b]	20.10 ± 0.00 [a]	5.78 ± 0.02 [a]	3.28 ± 0.01 [b]	323.94 ± 0.05 [a]

Legend: Data are expressed as means ± standard deviation; for each column and each year, different letters "a, b, c" indicate significant differences among treatments according to the Tukey's test ($p < 0.05$); CS—cereal straw, CO—compost, CWC—control without any cover.

The results of the work reported by Coventry et al. [46] demonstrated the positive effect of a reflective mulch layer on the quality of harvested grapes. The main reason given was the regulation of the microclimate in the vine wall and better light penetration into the grape zone. The greater amount of incident solar radiation is therefore an important factor influencing the quality parameters of grapes, due to its positive photosynthetic effects and at the same time due to its influence on the expression of genes involved in the production of secondary metabolites that are important for grape quality. Smart et al. [47] state that radiation reflected from the topsoil or canopy can be an important part of the grapevine interception of total photo synthetically active radiation (PAR), which can affect grape composition. The density of the leaf area of the bushes also affects the reflectance of the soil surface in the vineyard. The reason is a change in the spectral quality of the light falling on the soil surface precisely as a result of its passage through the leaf surface. This condition is reinforced in vineyards with a north–south row orientation, as the bushes shade the inter-row area at midday [48]. In this context, Salomé et al. [49], for example, pointed to the wide variability and differences in the results reported in different studies, which are related not only to the variety being assessed, but also to the highly variable soil and climatic conditions. Similarly, Chan and Fahey [45] also reported that protecting the soil surface with organic mulch materials is not necessarily associated with a conclusive effect on the qualitative composition of the grapes.

Practical Implications of This Study

Site-specific agronomic evaluations provide valuable information for viticulture practice to integrate mulching materials of an organic origin into conventional technological procedures and for land managers and policy makers to develop. The obtained results support innovative technologies based on progressive ways of treating the soil surface in vineyards. At the same time, they enable the recycling of selected types of waste raw materials in a circular economy system.

The use of mulching materials may have other advantages that were not investigated or evaluated in this work, e.g., the reduction of water erosion, reducing the growth of weed plants, changes in nutrient cycling, the reduction of toxicity of applied plant protection products including their leaching into groundwater, the mitigation of water stress of shrubs, the release of greenhouse gas emissions, etc.

Based on the obtained results, it is clear that when choosing the best practice for a specific location, it will be necessary to respect the following factors in particular: the age and organization of the stand, soil properties, climatic conditions, the availability and properties of the mulching materials used, environmental regulations and the priority goals of viticulture. Further experiments should focus in more detail on assessing a wider range of mulch materials while respecting their availability, cost, durability and overall effects. Only comprehensive research in this area can provide vine growers with the knowledge required to strengthen efficient and sustainable viticulture.

4. Conclusions

The results of the experiments bring new knowledge aimed at understanding the effects of mulch materials on soil properties, grape yield and quality in vineyards under Central European and Czech Republic conditions. In this sense, it can be concluded that the use of organic mulch materials contributes to maintaining increased water content in the soil. This difference was most noticeable for the CS mulch cover, where it amounted to an increase of 46–60%. Where CO was applied, the increase in soil moisture was 9–12% compared to the control variant with no cover. Our experimental measurements did not show a statistically significant effect of mulch materials on reducing soil temperature, yet these effects were evident when a CS mulch cover was applied, namely a 6–7% difference compared to the uncovered control variant. Finding correlations between soil moisture and temperature and the growth of common grape vines could be an important management tool with broad environmental implications in the field of sustainable viticulture. However, negative developments in the field of physical soil properties may pose a risk. As shown by the results obtained, the CS cover variant experienced an increase in soil bulk density values over the period under study. This situation corresponds to the absence of cultivation work, which is difficult to perform due to the cover. The CO cover had the opposite effect, as it resulted in a decrease in soil bulk density values, especially in the surface layer of the soil. The results of the experiments carried out show a positive effect of both variants of mulch materials on grape yield (an increase of 6–19%) and grape quality (an increase of 1–7% in sugar content as one of the main quality parameters). On the basis of these results, the use of mulch materials can be recommended for drier regions with low total rainfall during the growing season, as well as for growing varieties with irregular grape yields and uneven grape quality. Further experiments should focus in more detail on assessing a wider range of mulch materials while respecting their availability, cost, durability and overall effects. Only comprehensive research in this area can provide vine growers with the knowledge required to strengthen efficient and sustainable viticulture.

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