sustainability

MDPI

Article

Deep Placement of Compost into Vineyard Soil Affecting Physical Properties of Soils, Yield and Quality of Grapes

Barbora Badalíková [1,*], Patrik Burg [2], Vladimír Mašán [2], Jakub Prudil [1,3], Ján Jobbágy [4], Alice Čížková [2], Koloman Krištof [4] and Martin Vašinka [1,5]

[1] Agricultural Research, Ltd., Zahradní 400/1, 664 41 Troubsko, Czech Republic; prudil@vupt.cz (J.P.); martin.vasinka@seznam.cz (M.V.)
[2] Department of Horticultural Machinery, Faculty of Horticulture, Mendel University in Brno, Valtická 337, 691 44 Lednice, Czech Republic; patrik.burg@mendelu.cz (P.B.); vladimir.masan@mendelu.cz (V.M.); alice.cizkova@mendelu.cz (A.Č.)
[3] Department of Agrochemistry, Soil Science, Microbiology and Plant Nutrition, Faculty of Agronomy, Mendel University in Brno, Zemědělská 1, 613 00 Brno, Czech Republic
[4] Institute of Agricultural Engineering, Transport and Bioenergetics, Faculty of Engineering, Slovak University of Agriculture in Nitra, Tr. A. Hlinku 2, 949 76 Nitra, Slovakia; jan.jobbagy@uniag.sk (J.J.); koloman.kristof@uniag.sk (K.K.)
[5] Department of Geological Sciences, Faculty of Science, Masaryk University, Kotlářská 2, 611 37 Brno, Czech Republic
* Correspondence: badalikova@vupt.cz; Tel.: +420-547138821

check for updates

Citation: Badalíková, B.; Burg, P.; Mašán, V.; Prudil, J.; Jobbágy, J.; Čížková, A.; Krištof, K.; Vašinka, M. Deep Placement of Compost into Vineyard Soil Affecting Physical Properties of Soils, Yield and Quality of Grapes. *Sustainability* **2022**, *14*, 7823. https://doi.org/10.3390/su14137823

Academic Editor: José Miguel Reichert

Received: 9 May 2022
Accepted: 23 June 2022
Published: 27 June 2022

Abstract: In recent years, research has focused on verifying various ways of dosing organic matter into the soil in Central European conditions. The main reason for this is to search for the optimal management methods for soils with permanent vegetation. In this article, we state and evaluate the results of experiments carried out at the Lednice experimental site (Sauvignon Blanc variety) and the Velké Bílovice experimental site (Pinot Gris variety) between 2018 and 2020. The experiments evaluated the deep placement of compost and compost enriched with lignohumax at a rate of 30 t·ha^{-1} in the areas around vineyard tree trunks on the basic physical properties of the soil and the yield and quality of grapes. Results proved the positive effect of compost heaps and compost combined with the applied lignohumax on improving soil density (2–10% difference compared with the unfertilized reference variant) and porosity, which ultimately resulted in improved soil moisture conditions at both experimental sites (8–25% difference compared with the unfertilized reference variant). At the same time, the results demonstrated the positive effect of the applied compost and the chosen method of application on the yield and quality of grapes. In the case of Sauvignon Blanc, the increase in yield in the fertilized variants was 12–34%, while, in the case of Pinot Gris, it ranged from 24 to 33%. Among qualitative indicators, the grapes of both varieties were evaluated for sugar content, total acidity, pH, and amount of yeast assimilable nitrogen. In this case, results were not unambiguous in favor of fertilized variants; however, in most cases, fertilization had a positive effect.

Keywords: viticulture; compost; grape quality; deep application; physical soil properties

1. Introduction

Viticultural production represents a dynamically developing sector which is accompanied by continual innovation and intensification of applied technological procedures. Efforts for optimization of the product and its qualities often lead to excessive use of soil, which represents the basic production resource. This trend may have the negative effect of decreasing soil fertility. This is caused by a complex interaction of factors, the main ones being the limited application of organic fertilizers, a high degree of mechanization of work operations associated with a high number of passes, and high doses of applied agrochemicals, etc. [1,2].

In terms of viticulture sustainability in recent years, research has focused on the problems of application and dosage of organic matter into the soil [3]. Organic matter in the soil plays an unmistakable role in creating and improving its physical properties, such as soil retention capacity, density, and capability to form soil aggregates, and it influences the soil water regime [4]. Diacono and Montemurro [5] state that organic matter significantly affects the development of soil edaphon—biological and chemical processes contributing to soil quality. In the case that regular application of organic matter into the soil is not ensured, a decrease in its fertility occurs [6].

In a vineyard, the loss of soil fertility may negatively affect the yield and quality of the grapes. According to recordings done by White et al. [7], soil properties represent one of the main factors directly affecting grape quality and, also, the organoleptic properties of the produced vine. In the context of addressing sustainable agriculture, in recent years, there has been an increasing focus on replacing traditional, and often unavailable, manure with other alternatives in the form of green manure or compost [8].

Composting is an aerobic process in which the action of microorganisms leads to the decomposition of various types of biodegradable wastes Partanen et al. [9] presented their effective transformation of compost with the possibility of reapplication to the soil [10,11]. However, only a limited number of papers have dealt with the application of compost in vineyards, with the main focus on vine growth, grape yield, grape quality, and the overlap into the field of wine production with the main focus on the growth of vines [12–14]. Roots play a key role in the nutrition of vegetation from the soil. It is well-known that the application of compost may affect the growth of roots by influencing the availability of nutrients in the soil [15]. While inorganic fertilisers are instantly available and acceptable to plants, compost decomposes gradually. Mineralized nutrients are released for many years depending on the origin and chemical composition of the applied compost and on the soil-climatic conditions [16,17]. In their papers, Nardi et al., Dougherty et al., and Cataldo et al. [18–20] state that the application of compost may stimulate the growth of roots by humic substances that are released into the soil from decomposing organic matter. These substances have a beneficial effect on the proliferation of roots and the total amount of plant biomass.

Optimising the effects of compost on the soil is closely connected to determining the necessary number of doses and the application methods themselves. From the correct viticultural-practice perspective, the selection of a proper application method and the cost of the application itself play important roles. Most of the time, existing systems use the application of compost to the inter-row surface with subsequent shallow incorporation [21]. However, the results of several papers by Hassanein and Abul-Soud, Navel et al., and Mugnai et al. [13,22,23] state that to reach the synergy effect of application of the organic matter, it is not enough to incorporate the organic matter at a depth of 100–150 mm, it is necessary to apply it deeper than 200 mm (250–300 mm if possible). Other application methods are also evaluated, e.g., into a pre-prepared furrow where the applied compost goes deeper to where the roots are actively absorbing the water and nutrients being distributed [15]. These, however, are very laborious. In contrast, a lateral application can be used, in which the organic matter is directed to the area around the tree trunks with a single, gradual incorporation. The above methods are characterized by considerable labor and are related to the ploughing of a furrow among fertilized rows, the dosing of the organic matter into the created furrow, and its subsequent covering connecting to the flattening of the soil surface [24].

The objective of this paper is to evaluate the effects of the proposed deep implementation of compost into the area around tree trunks in vineyards on the physical properties of the soil, as well as the yield and quality of the grapes.

2. Materials and Methods

2.1. Characteristics of Experimental Sites

The experimental measurements were carried out at the experimental sites of Lednice and Velké Bílovice between 2018 and 2020. Both locations are fertile vineyards which, in terms of the regional division of the Czech Republic, are located in the Morava viticulture region, Velkopavlovická subregion.

2.1.1. Lednice Experimental Site

With coordinates of 48°47′30″ north latitude and 16°47′56″ east longitude, the area of interest is located in a vineyard southwest of the Lednice village (Na Valtické vineyard track). It belongs to the T4 area of a very warm, dry region with mild and dry winters. The average annual temperature is 9 °C, and the long-term average sum of precipitation is 500 mm per year. The average relative humidity is around 80%. For the purpose of measuring meteorological data (monthly precipitation and temperature), a meteorological station with remote data transmission (type AMET, Czech Republic) was installed at the experimental sites. The measured values of precipitation and temperature during the monitored years at the Lednice site are shown in Figure 1. The predominant soil types are modal chernozem and carbonate chernozem; the parent substrate is loess. The soil is slitty; this is a moderately heavy, skeletonless, and very deep soil with a mainly favourable water regime. The depth of topsoil ranges from 0.3 to 0.4 m. The level of groundwater ranges from 0.9 to 1.2 m below the soil level. The land is flat. The Sauvignon Blanc variety is planted in the vineyard, grafted on the rootstock Kober 5BB, and shrubs are cultivated using high-culture training with a cut to a single cane. The plantation was established in 2012; shrubs are planted in a clutch of 2.5 × 1.0 m.

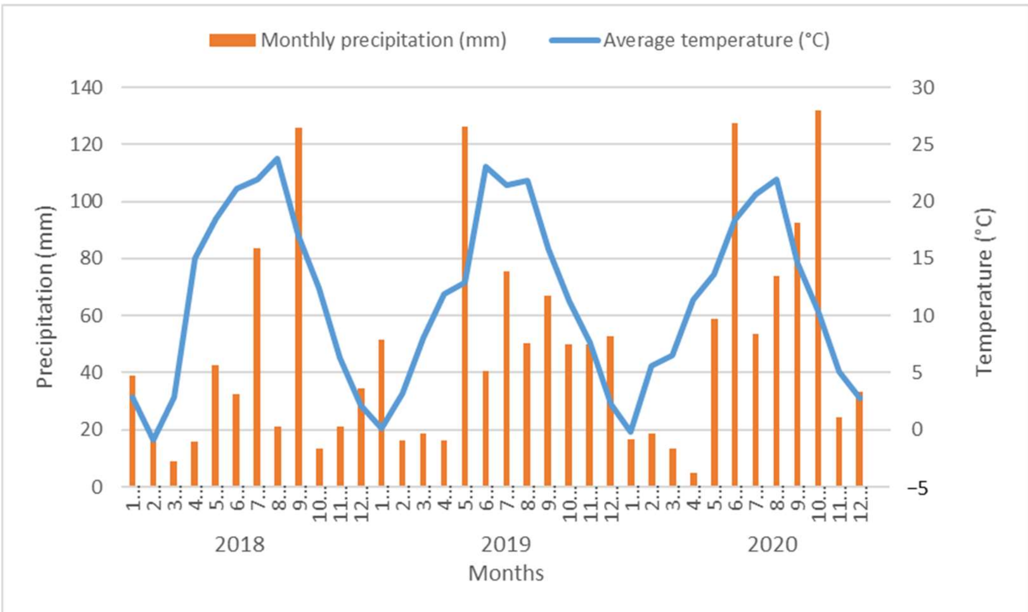

Figure 1. Average month temperature and the sum of precipitation (mm) recorded from January 2018 to December 2020 in Lednice.

2.1.2. Velké Bílovice Experimental Site

With coordinates of 48°52′59″ north latitude and 16°53′5″ east longitude, the area of interest is located northwest of the Velké Bílovice village (Úlehle vineyard track). It belongs to the T4, a warm, dry region with mild, dry winters. The average annual temperature is 8.5 °C, and the average annual sum of precipitation is 550 mm. The average relative humidity is around 80%. The measured values of precipitation and temperature during the monitored years at the Velké Bílovice site are shown in Figure 2. The predominant types of soil are chernozem and pelic chernozem; the parent substrate is loess. The soil is slitty; this is moderately heavy, skeletonless, and very deep soil with a mainly favourable water regime. The depth of topsoil ranges from 0.3 to 0.7 m. Soils are located in a very permeable subsoil, mainly skeletonless, medium-dry, and dependent on precipitation during the growing season. The land is located on a plain. The vineyard is planted with a variety of Pinot Gris, grafted on the rootstock SO_4, and shrubs are cultivated using high-culture training with a cut to a single cane. The plantation was established in 2007; shrubs are planted in a clutch of 2.7 × 1.0 m.

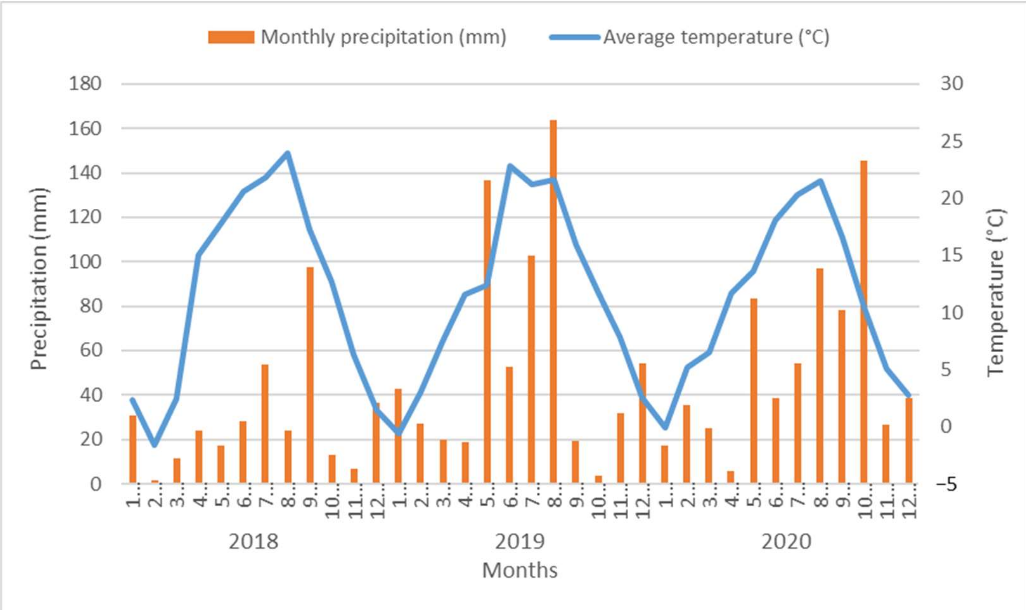

Figure 2. Average month temperature and the sum of precipitation (mm) recorded from January 2018 to December 2020 in Velké Bílovice.

Both experimental vineyards are grassed in every other intermediate row. In the cultivated inter-rows, the soil is kept weed-free by regular cultivation using cultivator shovels and harrow plates, as well as mulching in the grassed inter-rows. The soil in the area around the tree trunks remains weed-free by regular cultivation. During the experiments, no additional irrigation was used for either vineyard.

2.2. Experimental Methodology

The effect of the deep placement of compost on the improvement of soil properties and the yield and quality of the grapes was monitored at the experimental sites over the 2018–2020 period. The applied compost was made from biologically degradable garden waste. The main components were grass cuttings, vegetable and fruit waste, wood chips, and grain straw. The input raw materials were composted in strip bases with triangular profiles and base widths of 1.5 m. In terms of composition, the applied compost met the requirements of the CSN 46 5735–Composting standard [25]. In Table 1 are the average values of selected parameters of the compost applied in the vineyards during the monitored period.

Table 1. Selected physical and chemical parameters of the compost applied.

Composition	K (mg·kg^{-1})	Mg (mg·kg^{-1})	P (mg·kg^{-1})	Ca (mg·kg^{-1})	Dry Matter (%)	N_C (%)	C_{ox} (%)	pH_{KCL}
Compost	4256 ± 240	1190 ± 57	608 ± 64	7605 ± 282	67.85 ± 1.63	0.87 ± 0.08	4.01 ± 1.13	7.05 ± 0.07

The compost was applied to the cultivated in-rows using a specially designed prototype of a device for deep placement of compost into the area around tree trunks. The device was designed as a semi-trailer tractor machine placed on a single-axe chassis with suspension. A rear tipping body is attached to the chassis. Its bottom is made of a transverse chain conveyor with a hydraulic motor drive. There are ploughshares on both sides of the machine that create a furrow 0.25–0.30 cm deep, into which the applied compost is fed. The compost is further routed through a hopper into a ploughshare, and it falls on the bottom of the created furrow. The resulting incorporation of compost is ensured by two plates located behind each ploughshare.

The experiment was based on the following variants:

Variant I—control without compost

Variant II—compost (dose of 30 t·ha^{-1})

Variant III—compost (30 t·ha^{-1}) + Lignohumax 20 (0.4 L·ha^{-1})

Each variant was based on the method of random blocks of 100 m in length in 3 repetitions. The applied dose of compost was 30 t·ha^{-1}. Lignohumax 20 was added to Variant III. This is a concentrated water solution produced by the hydrolytic-oxidation degradation of technical lignosulphonates made up of a mixture of humic and fulvic acids, including their salts. The application of lignohumax contributes to the higher activity of the photosystem and chlorophyll formation. It increases the usage of nutrients contained in the soil, supports the development of the root system, and helps to increase yields and quality of the harvest. After adding it to the compost, microorganisms are activated, so the degradation of the organic mass and maturing of the compost is accelerated [26].

2.3. Soil Analysis Methodology

Intact soil samples were collected for the determination of selected physical properties according to Kopecký [27] at each site once a year at the beginning of the growing season (in May) from depths of 0–0.10 m, 0.10–0.20 m, and 0.20–0.30 m. In each 10 cm layer, 5 undisturbed soil cylinders (100 cm^3, 50 mm height & diameter) were collected. The collected samples included these specifications: bulk density, total porosity, current water and air content, maximum capillary water capacity, and minimum air capacity (methodology according to the CSN 46 5331 standard) [28].

Kopecky's [27] cylinders were used for the collection of intact soil samples. Five cylinders were taken from each depth, and they were analyzed independently. The resulting values were derived from the average partial results for each depth [29].

Collection of intact samples was carried out with respect to the soil conditions in the monitored locality in inter-rows of vineyards, always from the same spot.

2.4. Grape Yield Evaluation

The grape harvest, regarding the ripeness of the grapes, was mainly based on meteorological conditions of the given year. An overview of the harvest dates at the two experimental sites is shown in Table 2.

Table 2. Overview of harvest dates in each year.

Experimental Site	Harvest Date		
Lednice (Sauvignon Blanc)	29 September 2018	26 September 2019	5 October 2020
Velké Bílovice (Pinot Gris)	1 October 2018	20 September 2019	28 September 2020

The average number of bunches (pcs) was determined by a calculation based on the total number of grapes summed from 10 shrubs of each monitored variety and variant, according to the methodology stated by Pavloušek [30]. The average grape yield per shrub was determined by calculating the weight of the grapes obtained by harvesting 10 randomly selected bushes for each of the varieties and variants evaluated. Grapes were stored in harvest containers and transported to a lab, where they were weighed using a digital scale.

2.5. Evaluation of the Main Quality Parameters of the Must

From the analytical values, the sugar content, the content of all titratable acids, the pH, and the amount of yeast assimilable nitrogen were determined. A total of 40 berries were separated from different parts of the harvested grapes at random to make the result as objective as possible. The berries were chosen so as not to distort the results, and the result was 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 determined according to standardized laboratory methods. The sugar content was measured using a digital refractometer from PAL-1 (ATAGO Co., LTD, Tokyo, Japan). The content of titratable acids was specified using titration using an automatic titrator from TitroLine Easy (Schott Instruments GmbH, Germany) on NaOH. The pH value was determined based on the potential of a glass electrode depending on the activity of hydrogen cations relative to the reference calomel electrode. The potential was measured using a pH meter, PH 526 from WTW company, with a combined glass and silver chloride gel electrode using a calibrated buffer solution with a known pH. The amount of yeast assimilable nitrogen was determined using formaldehyde titration. Each measurement was performed in three repetitions.

2.6. Methods of Statistical Analysis

Results were reported as averages and standard deviations. Analysis of variance (ANOVA) and Tukey's honestly significant difference (HSD) tests were conducted to determine the differences among averages using the software package Statistica 12.0 (StatSoft Inc., Tulsa, OK, USA). ANOVA 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

Tables 3 and 4 show the resulting values of the selected physical properties of soil samples taken from a depth of 0.2 m, which corresponded to the evaluated depth of compost placement. The determinations include the bulk density, total porosity, current content of water and air, maximum capillary water capacity, and minimum water capacity. Values measured for individually evaluated variants were compared mutually and, at the same time, with the critical values for the given parameter [31].

Table 3. Basic physical parameters of soil, Lednice.

Experimental Year	Variant	Bulk Density ($g \cdot cm^{-1}$)	Total Porosity (%)	Current Content		Max. Capillary Capacity (% vol.)	Min. Air Capacity (% vol.)
				Water (% vol.)	Air (% vol.)		
2018	I	1.43 ± 0.07 a	45.05 ± 2.66 a	16.05 ± 9.35 a	29.01 ± 8.80 a	35.07 ± 2.00 a,b	9.98 ± 1.58 a
	II	1.42 ± 0.09 a	45.36 ± 3.39 a	18.39 ± 1.10 a	26.97 ± 3.36 a	38.35 ± 2.81 b	7.01 ± 0.87 b
	III	1.42 ± 0.12 a	45.30 ± 4.43 a	14.22 ± 0.72 a	31.08 ± 4.22 a	32.94 ± 3.15 a	12.36 ± 1.72 a
2019	I	1.37 ± 0.07 b	47.38 ± 2.59 b	20.51 ± 2.25 a	25.51 ± 4.13 a	36.88 ± 1.03 a	10.50 ± 2.33 a
	II	1.30 ± 0.13 a	50.03 ± 4.93 a	23.37 ± 3.24 a	26.66 ± 8.13 a	36.08 ± 2.77 a	13.96 ± 2.81 a
	III	1.24 ± 0.07 a	52.67 ± 2.02 a	22.76 ± 2.44 a	29.36 ± 4.94 a	37.11 ± 4.07 a	15.00 ± 2.16 a
2020	I	1.47 ± 0.08 b	43.31 ± 3.24 b	28.30 ± 3.61 a	16.07 ± 3.29 a	35.74 ± 2.04 a	7.57 ± 1.99 a
	II	1.37 ± 0.08 a	47.49 ± 3.05 a	25.39 ± 1.48 a	22.10 ± 4.27 a	38.79 ± 1.59 b	8.70 ± 2.20 a,b
	III	1.37 ± 0.02 a	47.37 ± 0.82 a	28.30 ± 3.61 a	19.07 ± 3.86 a	36.60 ± 1.65 a,b	10.77 ± 2.43 b

Legend: Mean values in one column followed by the same letter were not significantly different from each other according to Tukey's test at $p < 0.05$.

Table 4. Basic physical parameters of soil, Velké Bílovice.

Experimental Year	Variant	Bulk Density ($g \cdot cm^{-3}$)	Total Porosity (%)	Current Content		Max. Capillary Capacity (% vol.)	Min.Air Capacity (% vol.)
				Water (% vol.)	Air (% vol.)		
2018	I	1.25 ± 0.11 a	51.77 ± 4.39 a	23.10 ± 3.90 a	28.67 ± 8.21 a	40.81 ± 5.20 b	10.96 ± 1.46 a
	II	1.32 ± 0.08 a	49.40 ± 3.12 a	22.56 ± 1.78 a	26.84 ± 4.89 a	34.98 ± 0.74 a	14.42 ± 3.41 a
	III	1.28 ± 0.06 a	50.77 ± 2.29 a	22.09 ± 1.18 a	28.68 ± 3.42 a	36.05 ± 1.03 a,b	14.72 ± 2.32 a
2019	I	1.44 ± 0.03 b	44.51 ± 1.04 a	14.47 ± 1.26 b	31.37 ± 3.72 a	30.88 ± 1.30 a	14.96 ± 3.17 a
	II	1.29 ± 0.05 a,b	50.52 ± 2.08 a,b	23.37 ± 1.32 a	26.65 ± 5.04 a	36.07 ± 1.47 a	13.96 ± 3.61 a
	III	1.37 ± 0.15 a	47.14 ± 5.61 b	22.75 ± 3.01 a	29.36 ± 8.41 a	37.11 ± 1.44 a	15.00 ± 4.58 a
2020	I	1.49 ± 0.06 b	42.62 ± 2.20 a	26.55 ± 0.90 a,b	16.07 ± 2.42 a	35.74 ± 2.04 a	6.88 ± 1.16 b
	II	1.44 ± 0.04 a,b	44.75 ± 1.38 a,b	23.79 ± 1.38 a	20.96 ± 2.40 b	34.86 ± 0.41 a	9.89 ± 1.14 a
	III	1.38 ± 0.06 a	47.04 ± 2.13 b	27.39 ± 2.46 b	19.65 ± 2.02 a,b	36.64 ± 2.46 a	10.41 ± 0.64 a

Legend: Mean values in one column followed by the same letter were not significantly different from each other by Tukey's test at $p < 0.05$.

No statistically conclusive differences between variants were recorded in 2018. Values of the bulk density were determined under the critical level for these soil types ($1.45 \ kg \cdot m^{-3}$). This was also reflected in porosity values, which did not fall below the critical limit for any of the variants (45% vol.). The values of the current water and air content were at a good level, which was consistent with the site conditions on the collection date. Values of the maximum capillary water capacity exceeded the limit value of 36% (Variant II, Lednice; Variants I and III, Velké Bílovice). Thus, the structure of the soil was disrupted. The minimum air capacity of Variant II, Lednice, was less favourable, for it dropped below the critical level of 10% vol.

Results recorded in 2019 and 2020 suggest the deep placement of compost had a positive effect on the physical parameters of the soil at both sites. For fertilised Variants II and III, this was proven by better values of bulk density and associated porosity. Values of the maximum capillary water capacity exceeded the limit value of 36% (Variant II, Lednice; Variants I and III, Velké Bílovice). Thus, the structural ability of the soil was disrupted. Values of the minimum air capacity for Variant I and Variant II, Lednice, and for Variant II, Velké Bílovice, were less favourable, for they dropped below the critical level of 10% vol.

Several papers have focused on the problems with the evaluation of the physical parameters of soils in viticultural regions regarding compost application, including Jha et al., Logsdon and Malone, and Yazdanpanah et al. [32–34]. Similar to our results, these papers also described the positive effect of applying compost on lower values of bulk density and overall lower soil susceptibility to consolidation and higher content of water in soil [35].

A number of papers abroad have dealt with problems with the effect of applied compost on grape yield. For instance, papers from Pinamonti and Morlat [12,36] found negligible or even no effect of compost on grape yield. On the contrary, in the results of their multiyear work, Tangolar et al. [8] stated that the application of compost led to a significant increase in the grape yield from the second year onwards. White et al. [7] stated that optimisation of the soil environment by adding organic fertilisers is one of the main factors affecting the quantitative and qualitative parameters of grapes. Likewise, Gaiotti et al. and Mylavarapu and Zinati [15,37] claimed that the application of compost in vineyards may affect the growth of roots by affecting the content and availability of nutrients in the soil. It also positively affects the soil-moisture regime, its physical properties, and structural stability, with a positive effect on grape yield.

Part of the experiments was also to determine the dynamics of changes in the content of N_c and C_{ox} in the soil in both experimental vineyards. In general, it was found that the values of total nitrogen (N_c) increased in the variants with incorporated compost.

Higher values were always recorded in the upper depth of the soil profile (up to 0.10 m). Similarly, the total organic carbon (C_{ox}) content of the fertilized variants was also higher. A comparison of the values of the C_{ox} content at the beginning and end of the performed experiments shows that in the Lednice experimental site, the C_{ox} content was on average higher by 0.99% for var. I, 1.15% for var. II, and 1.30% for var. III. At the Velké Bílovice experimental site, the increase in Cox content averaged 1.49% for var. I, 1.74% for var. II, and 1.95% for var. III.

While for the Sauvignon Blanc variety at the Lednice site, the grape yield was proportionally equal in each year, for the Pinot Gris variety in 2019 and 2020, the overall grape yield was significantly lower than in 2018. The main reason was probably low temperatures and higher rainfall, which affected the phenomenon of flowering and the establishment of grapes. A characteristic physiological problem of the variety, especially for unselected material, is its high susceptibility to flower abortion and alternating fertility. Except for one year, the obtained data, shown in Tables 5 and 6, show a higher grape yield of Sauvignon Blanc for both fertilised variants (Variant II and Variant III) compared with the unfertilised reference variant. For the Sauvignon Blanc variety, this increase was 12–34%. For the Pinot Gris variety, the differences across years were recorded at a higher level: in 2018, the increase was 23.8%; in 2019, the increase was 94%; and in 2020, the increase was 33%. A very high difference in yields between the unfertilized and both fertilized variants in 2019 may have been strengthened by accidental influences (e.g., local damage to shrubs), a higher sum of precipitation in the phenophase of development, and ripening of grapes, according to the BBCH-scale (code 71–81), as stated by Lorenz et al. [38].

Table 5. Results of grape yield evaluation, Lednice (Sauvignon Blanc).

Experimental Year	Variant	Average Yield ($kg \cdot shrub^{-1}$)
2018	I	2.66 ± 0.93 a,b
	II	2.21 ± 0.55 a
	III	2.07 ± 0.40 a
2019	I	2.48 ± 0.45 a
	II	3.08 ± 0.45 a,b
	III	3.33 ± 0.35 b
2020	I	2.39 ± 0.15 a
	II	2.75 ± 0.05 c
	III	2.68 ± 0.09 b

Legend: Mean values in one column followed by the same letter were not significantly different from each other by Tukey's test at $p < 0.05$.

Table 6. Results of grape yield evaluation, Velké Bílovice (Pinot Gris).

Experimental Year	Variant	Average Yield ($kg \cdot shrub^{-1}$)
2018	I	4.19 ± 1.21 a
	II	4.21 ± 0.08 a
	III	5.19 ± 1.46 b
2019	I	1.54 ± 0.69 a
	II	2.17 ± 0.45 a,b
	III	3.00 ± 0.27 b

Table 6. *Cont.*

Experimental Year	Variant	Average Yield (kg·shrub^{-1})
2020	I	1.58 ± 0.19 a
	II	2.00 ± 0.15 ab
	III	2.11 ± 0.07 b

Legend: Mean values in one column followed by the same letter were not significantly different from each other by Tukey's test at $p < 0.05$.

The resulting average values of selected analytical parameters of grapes, from which the sugar content, the content of titratable acids, pH, and amount of yeast assimilable nitrogen (YAN) were evaluated, are stated in Tables 7 and 8.

Table 7. Results of evaluation of grape′s qualitative parameters, Lednice (Sauvignon Blanc).

Experimental Year	Variant	Sugar Content (°NM)	pH (-)	Titratable Acids (g·L^{-1})	YAN (mg·L^{-1})
2018	I	17.32 ± 0.01 a	3.31 ± 0.01 a	6.22 ± 0.01 b	256.50 ± 3.54 a
	II	16.75 ± 0.07 b	3.31 ± 0.01 a	6.81 ± 0.01 c	454.50 ± 3.54 c
	III	17.32 ± 0.01 a	3.41 ± 0.01 b	6.12 ± 0.01 a	330.10 ± 0.02 b
2019	I	23.91 ± 0.01 c	3.21 ± 0.01 b	8.90 ± 0.01 b	285.00 ± 2.83 a
	II	22.01 ± 0.01 a	3.31 ± 0.01 a	9.31 ± 0.02 c	285.50 ± 2.12 a
	III	22.31 ± 0.01 b	3.30 ± 0.00 a	8.69 ± 0.03 a	250.00 ± 1.41 b
2020	I	23.81 ± 0.01 b	3.10 ± 0.01 a	11.21 ± 0.02 b	261.50 ± 2.12 b
	II	23.91 ± 0.01 c	3.11 ± 0.00 a	10.51 ± 0.02 a	291.5 ± 0.71 a
	III	23.32 ± 0.01 a	3.21 ± 0.01 b	10.51 ± 0.01 a	288.5 ± 4.95 a

Legend: Mean values in one column followed by the same letter were not significantly different from each other by Tukey's test at $p < 0.05$.

Table 8. Results of evaluation of grape′s qualitative parameters, Velké Bílovice (Pinot Gris).

Experimental Year	Variant	Sugar Content (°NM)	pH (-)	Titratable Acids (g·L^{-1})	YAN (mg·L^{-1})
2018	I	21.31 ± 0.01 a	3.91 ± 0.01 b	5.30 ± 0.03 a	167.50 ± 3.54 a
	II	23.92 ± 0.01 b	3.61 ± 0.01 a	6.61 ± 0.02 c	291.00 ± 1.41 c
	III	24.21 ± 0.01 c	3.60 ± 0.00 a	6.51 ± 0.01 b	272.50 ± 3.54 b
2019	I	22.41 ± 0.01 a	3.21 ± 0.01 a	7.71 ± 0.02 b	301.50 ± 2.12 c
	II	22.31 ± 0.01 b	3.21 ± 0.01 a	8.01 ± 0.02 c	276.00 ± 1.41 b
	III	22.41 ± 0.01 a	3.31 ± 0.01 b	7.51 ± 0.02 a	229.5 ± 2.12 a
2020	I	18.61 ± 0.01 a	3.31 ± 0.01 a	11.30 ± 0.02 a	214.50 ± 2.12 a
	II	19.21 ± 0.01 b	3.20 ± 0.00 b	11.11 ± 0.02 b	413.00 ± 2.83 b
	III	19.41 ± 0.01 c	3.31 ± 0.01 a	11.39 ± 0.04 a	426.00 ± 1.41 c

Legend: Mean values in one column followed by the same letter were not significantly different from each other by Tukey's test at $p < 0.05$.

In the Czech Republic, the sugar content is stated in degrees of the normalized must-meter (°NM). Degrees of the normalised must-meter indicate the measure of 1 kg of sugar in 100 litres of must. Thus, the sugar content is a value that states the number of fermentable sugars in must expressed in degrees of normalised must-meter (Act No 321/2004 Coll.). Results recorded from the experiments were not unambiguous at either site. For the Sauvignon Blanc variety at the Lednice site, the sugar content of must ranged from 17.32°NM to 23.91°NM. In 2018 and 2019, the value of the sugar content was identical or higher for the unfertilised Variant I. In 2020, it was lower for the unfertilised Variant I than for Variant II, although the difference was 0.4%. For the Pinot Gris variety at the Velké Bílovice site, the values of sugar content were different. Values of the sugar content ranged between 19.21°NM and 24.21°NM throughout the monitored period. Except in 2019, sugar content values of must were lower for the unfertilised Variant 1 compared with the fertilized Variant II and Variant III.

Bravdo et al. [39] reported a decrease in the production quality of grapes with excessive vegetative growth of shrubs. Gaiotti et al. [15] evaluated the effect of compost on soil fertility, vine growth, yield, and quality of grapes of the Cabernet Sauvignon variety during a five-year period. During the experiment, the compost was applied to the inter-rows and the area around tree trunks. The decrease in grape quality was recorded for both methods of application as well. On the contrary, a nine-year experiment by Mugnai et al. [13] showed different results regarding vine growth and grape quality following compost application to V. vinifera during the monitored period. The application of compost conclusively affected the average weight of grapes, except during 2003, 2004, and 2005. The quality of grapes (expressed by pH and °Brix) was not affected by the compost application, except during 2006 when °Brix was higher than for the variant fertilised with compost. Morlat and Symoneaux [40] also found that the pH of must increases with the increasing dosage of compost.

The pH value is defined as a negative decadic logarithm of hydrogen cation activity in must or the resulting wine. Under modern viticulture conditions, it is one of the most important parameters of must and wine which affects biochemical processes in wine and the development of fermentation itself [41]. The results obtained show that the pH value of must ranged between 3.10 and 3.41 at the Lednice site and between 3.20 and 3.91 at the Velké Bílovice site. At the Lednice site, all annual pH values were higher for fertilized Variants II and III. At the Velké Bílovice site, the pH values were higher for the unfertilized reference Variant I in 2018. In other years, the pH value was comparable to the fertilized variants. Ruffner [42] states that pH value is affected mainly by the ratio of tartaric acid and malic acid. According to Pavloušek [30], the pH of musts should range between 3.0 and 3.3, which allows the production of quality wine. It is clear from the results that besides the fertilisation method, values can be affected by other factors, such as temperature, precipitation, etc.

Acids in musts and wines are evaluated by total acidity. They are also referred to as titratable acidity due to the measurement of the value of all titratable acids. It follows from the results obtained that the acid content in the must ranged between 6.12 and 11.21 $g \cdot L^{-1}$ at the Lednice site and between 5.30 and 11.39 $g \cdot L^{-1}$ at the Velké Bílovice site. At the Lednice site, the acid content was different among the evaluated variants, generally comparable or higher in the unfertilised Variant I (2020, Variant I) than in the fertilised variants. The situation was similar at Velké Bílovice, except in 2018 when the acid content was lower in the unfertilised Variant I. Organic acids are formed from sugars and are produced as by-products of metabolic transformation during breathing. A high content of acids in must leads to imbalanced and highly acidic wine. Low content of acids makes wine sweet and insufficiently stable, especially against oxidative processes, as stated Arias-Gil et al. [43]. Pavloušek [30] also states that acid content is influenced by many factors during the ripening period; its content changes dynamically and ranges from 6 to 9 $g \cdot L^{-1}$.

Total YAN is a source of nitrogen in must that yeasts are able to use for reproduction and their own activity [43]. YAN can be seen as a central and dominant factor in the aromatic structure and subsequent quality of the produced wine. For an ideal fermentation process, the minimum amount of YAN should be at least 190–200 $mg \cdot L^{-1}$ [44]. Therefore, the obtained results show that the determined values of YAN correspond, in most cases, to technological needs, except for the unfertilised Variant I from 2018 at the Velké Bílovice site. The nutrition of the vine is a factor that can affect the composition of grapes, including the content of YAN, the lack of which is the main cause of fermentation processes [43]. The results of 2018 and 2020 suggest in both experimental vineyards that the application of compost can be an interesting tool in nitrogen management, which contributes to increasing its content in grapes, and, therefore, in pressed must. This effect may have an overlap in winemaking processes, where it may reinforce the restriction of the addition of yeast supplementary feed in the form of mono-or diammonium phosphate, which is normally added to must during fermentation. Verdenal et al. [45] state that in order to support the optimal yield of grapes and their quality, sufficient availability of nitrogen content in the soil is necessary, with an overlap to its optimal moisture content.

4. Conclusions

Results of experiments carried out between 2018 and 2020 suggest the deep placement of compost in the area around tree trunks in vineyards had a positive effect on selected soil properties and the yield and quality of grapes. Results show the positive effect of incorporated compost and compost combined with the applied Lignohumax 20 by the improvement of bulk density of the soil and its porosity, which ultimately resulted in improved soil moisture ratios at experimental sites under Central European conditions. At the same time, the results also show the positive influence of the compost applied and the selected method of application on the yield and quality of the grapes. Experiments carried out by other authors point to the great importance of the application dose, origin, chemical composition, and method of compost incorporation for achieving the optimal effects. Assuming the application of compost is carried out in the described methods and at sites with comparable soil and climatic conditions, doses around 30 $t{\cdot}ha^{-1}$ can be considered satisfactory. In this context, the importance of compost as a substitute for insufficient manure or mineral fertilisers, which can be fully used in sustainable vineyard management, should not be overlooked.

It is in sustainable viticulture that great attention still needs to be paid to issues associated with ensuring soil fertility in relation to threats, such as periods of prolonged drought due to climate changes, degradation of soil structure due to insufficient supply of organic fertilizers, and excessive soil loading, etc. Growers should aim to gradually replace high doses of mineral fertilisers with local organic fertilisers, such as compost, which are available both in terms of quantity and cost. Results of the experiments carried out may be used as a practical base for realisation and further evaluation of compost application in viticulture in order to improve cultivation conditions for grapevines with an emphasis on the optimization of the yield and quality under Central European conditions.

Author Contributions: Conceptualization—B.B. and P.B.; methodology B.B. and P.B.; validation B.B. and M.V.; investigation B.B. and M.V.; writing—original draft preparation B.B., P.B. and V.M.; writing—review and editing P.B. and V.M.; visualization—M.V., J.J. and J.P.; supervision B.B., M.V. and P.B.; funding acquisition B.B., P.B., A.Č. and K.K. All authors have read and agreed to the published version of the manuscript.

Funding: This work was funded by the Technology Agency of the Czech Republic (TACR), project no.: TH02030467, programme Epsilon, under the title "The development and verification of apparatus for deep incorporation of organic matter into the soil in vineyards and orchards" and no. RO1721, financed by the Ministry of Agriculture of the Czech Republic and by Operational Programme Research, Development and Education—Research Infrastructure for Young Scientists, project number CZ.02.1.01/0.0/0.0/16_017/0002334.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data sharing not applicable.

Acknowledgments: In this section, you can acknowledge any support given which is not covered by the author contribution or funding sections. This may include administrative and technical support, or donations in kind (e.g., materials used for experiments).

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Costantini, E.A.C.; Dazzi, C. *The Soils of Italy*; Springer: New York, NY, USA, 2013; p. 354.
2. Krauss, M.; Berner, A.; Perrochet, F.; Frei, R.; Niggli, U.; Mäder, P. Enhanced soil quality with reduced tillage and solid manures in organic farming—A synthesis of 15 years. *Sci. Rep.* **2020**, *10*, 4403. [CrossRef]
3. Pinamonti, F.; Sicher, L. Compost Utilization in Fruit Production Systems. In *Compost Utilization in Horticultural Cropping Systems*; Stoffella, P.J., Kahn, B.A., Eds.; Lewis Publishers: New York, NY, USA, 2001; pp. 177–200.
4. Borselli, L.; Pellegrini, S.; Torri, D.; Bazzoffi, P. Tillage erosion and land levelling: Evidences in Tuscany (Italy). In *Man and Soil at the Third Millennium, Proceedings of the International Congress of the European Society for Soil Conservation, Valencia, Spain, 28 March–1 April 2000*; CSIC, University of Valencia: Valencia, Spain, 2000.
5. Diacono, M.; Montemurro, F. Compost da residui organici per l'agricoltura biologica. *Agrifoglio* **2006**, *16*, 18–19.
6. Tippl, M.; Janeček, M.; Bohuslávek, J.; Kadlec, V. Organic soil fertilization and its influence on surface runoff and erosion. *Agritech Sci.* **2009**, *2*, 1–5. Available online: http://www.agritech.cz/clanky/2009-2-8.pdf (accessed on 1 April 2022). (In Czech).
7. White, R.L.; Balachandra, L.; Edis, R.; Chen, D. The soil component of terroir. *J. Int. Sci. Vigne* **2007**, *41*, 9–18. [CrossRef]
8. Tangolar, S.; Alkan Torun, A.; Ada, M.; Göçmez, S. Influence of supplementation of vineyard soil with organic substances on nutritional status, yield and quality of 'Black Magic' grape (*Vitis vinifera* L.) and soil microbiological and characteristics. *OENO One* **2020**, *54*, 1143–1157. [CrossRef]
9. Partanen, P.; Hultman, J.; Paulin, L.; Auvinen, P.; Romantschuk, M. Bacterial diversity at different stages of the composting-process. *BMC Microbiol.* **2010**, *10*, 94. [CrossRef]
10. Manios, T. The Composting Potential of Different Organic Solid Wastes: Experience from the Island of Crete. *Environ. Int.* **2004**, *29*, 1079–1089. [CrossRef]
11. Goulding, K.W.L.; Jarvis, S.; Whitmore, A. Optimizing nutrient management for farm systems. *Philos. Trans. R. Soc. B Biol. Sci.* **2008**, *363*, 667–680. [CrossRef]
12. Pinamonti, F. Compost mulch effects on soil fertility, nutritional status and performance of grapevine. *Nutr. Cycl. Agroecosyst.* **1998**, *51*, 239–248. [CrossRef]
13. Mugnai, S.; Masi, E.; Azzarello, E.; Mancuso, S. Influence of long-term application of green waste compost on soil characteristics and growth, yield and quality of grape (*Vitis vinifera* L.). *Compost Sci. Util.* **2012**, *20*, 29–33. [CrossRef]
14. Korboulewsky, N.; Robles, C.; Garzino, S. Effects of Sewage Sludge Compost on Volatile Organic Compounds of Wine from *Vitis vinifera* cv. Red Grenache. *Am. J. Enol. Vitic.* **2004**, *55*, 412–416.
15. Gaiotti, F.; Marcuzzo, P.; Belfiore, N.; Lovat, L.; Fornasier, F.; Tomasi, D. Influence of compost addition on soilproperties, root growth and vine performances of *Vitis vinifera* cv Cabernet sauvignon. *Sci. Hortic.* **2017**, *225*, 88–95. [CrossRef]
16. Laliberté, E. Below-ground frontiers in trait-based plant ecology. *New Phytol.* **2017**, *213*, 1597–1603. [CrossRef]
17. Amendola, C.; Montagnoli, A.; Terzaghi, M.; Trupiano, D.; Oliva, F.; Baronti, S.; Miglietta, F.; Chiatante, D.; Scippa, G.S. Short-term effects of biochar on grapevine fine root dynamics and arbuscular mycorrhizae production. *Agric. Ecosyst. Environ.* **2017**, *239*, 236–245. [CrossRef]
18. Nardi, S.; Pizzeghello, D.; Muscolo, A.; Vianello, A. Physiological effects of humic substances on higher plants. *Soil Biol. Biochem.* **2002**, *34*, 1527–1536. [CrossRef]
19. Dougherty, W.J.; Chan, K.Y. Soil properties and nutrient export of a duplex hard-setting soil amended with compost. *Compost Sci. Util.* **2014**, *22*, 11–22. [CrossRef]
20. Cataldo, E.; Fucile, M.; Mattii, G.B. A Review: Soil Management, Sustainable Strategies and Approaches to Improve the Quality of Modern Viticulture. *Agronomy* **2021**, *11*, 2359. [CrossRef]
21. Burg, P.; Zemánek, P.; Badalíková, B.; Mašán, V.; Novotná, J. *Soil Compaction in Vineyards and Possibilities of Their Remedy*; Folia Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, Mendel University in Brno: Brno, Czech Republic, 2016. (In Czech)
22. Hassanein, M.K.; Abul-Soud, M. Effect of Different Compost Types and Application Methods on Growth and Yield of Three Maize Hybrids. *J. Appl. Sci. Res.* **2010**, *6*, 1387–1399.
23. Navel, A.; Martins, J.M. Effect of long term organic amendments and vegetation of vineyard soils on the microscale distribution and biogeochemistry of copper. *Sci. Total Environ.* **2014**, *466–467*, 681–689. [CrossRef]
24. Walg, O. *Viticulture Machinery Book*, 2nd ed.; Rohr–Druck: Kaiserslautern, Germany, 2007; p. 620. (In German)
25. Plíva, J.; Hejátková, K.; Křížová, O.; Humplík, M.; Jalovecký, J.; Krčálová, E.; Matějů, L.; Řebíčková, K. *CSN 46 5735*; Composting. Czech Agency for Standardization: Prague, Czech Republic, 2020; p. 24. (In Czech)
26. Agrostim Biotechnologieprodukte GmbH, Germany. Available online: https://www.agrostim.de/en/products/plant-additives-and-soil-conditioners/lignohumax-application-e (accessed on 14 July 2015).
27. Kopecký, J. *Soil Science. Agrophysical Part*, 1st ed.; Ministry of Agriculture: Prague, Czech Republic, 1928; p. 278. (In Czech)
28. *CSN 46 5331*; General Requirements for Sampling. Publishing House of the Office for Standardization and Measurement: Prague, Czech Republic, 1983. (In Czech)
29. Pospíšilová, L.; Vlček, V.; Hybler, V.; Hábová, M.; Jandák, J. *Standard Analytical Methods and Criteria for Evaluation of Physical, Agrochemical, Biological and Hygienic Parameters of Soils*, 1st ed.; Folia Universitatis Agriculturae at Silviculturae Mendelianae Brunensis, Mendel University in Brno: Brno, Czech Republic, 2016. (In Czech)
30. Pavloušek, P. *Vine Growing: Modern Viticulture*; Grada: Prague, Czech Republic, 2011.

31. Sáňka, M.; Vácha, R.; Poláková, Š.; Fiala, P. *Evaluation Criteria Production and Organic Soil Properties*, 1st ed.; Ministry of the Environment of the Czech Republic: Prague, Czech Republic, 2018; p. 98. (In Czech)
32. Jha, C.K.; Sinha, S.K.; Alam, M.; Pandey, S.S. Effect of bio-compost and zinc application on sugarcane (*Saccharum* species hybrid complex) productivity, quality and soil health. *Indian J. Agron.* **2015**, *60*, 450–456.
33. Logsdon, S.D.; Malone, R.W. Surface compost effect on hydrology: In-situ and soil cores. *Compost. Sci. Util.* **2015**, *23*, 30–36. [CrossRef]
34. Yazdanpanah, N.; Mahmoodabadi, M.; Cerdà, A. The impact of organic amendments on soil hydrology, structure and microbial respiration in semiarid lands. *Geoderma* **2016**, *266*, 58–65. [CrossRef]
35. Aranyos, J.T.; Tomócsik, A.; Makádi, M.; Mészáros, J.; Blaskó, L. Changes in physical properties of sandy soil after long-term compost treatment. *Int. Agrophys.* **2016**, *30*, 269–274. [CrossRef]
36. Morlat, R. Long-term additions of organic amendments in a Loire valley vineyard on a calcareous sandy soil. II. Effects on root system, growth, grape yield, and foliar nutrient status of a Cabernet franc vine. *Am. J. Enol. Vitic.* **2008**, *59*, 364–374.
37. Mylavarapu, R.S.; Zinati, G.M. Improvement of soil properties using compost for optimum parsley production in sandy soils. *Sci. Hortic.* **2009**, *120*, 426–430. [CrossRef]
38. Lorenz, D.; Eichhorn, K.W.; Blei-Holder, H.; Klose, R.; Meier, U.; Weber, R. Phänologische Entwicklungsstadien der Weinrebe (*Vitis vinifera* L. ssp. *vinifera*). Codierung und Beschreibung nach der erweiterten BBCH-Skala. *Vitic. Enol. Sci.* **1994**, *49*, 66–70. (In Germany)
39. Bravdo, B.; Hepner, Y.; Loinger, C.; Cohen, S.; Tabacman, H. Effect of Crop Level and Crop Load on Growth, Yield, Must and Wine Composition, and Quality of Cabernet Sauvignon. *Am. J. Enol. Vitic.* **1985**, *36*, 125–131.
40. Morlat, R.; Symoneaux, R. Long-term additions of organic amendments in a Loire valley vineyard on a calcareous sandy soil. III. Effects on fruit composition and chemical and sensory characteristics of a Cabernet franc wine. *Am. J. Enol. Vitic.* **2008**, *59*, 375–386.
41. Balík, J.; Stávek, J. *Wine Technology*; National Wine Center: Valtice, Czech Republic, 2017; p. 463. (In Czech)
42. Ruffner, H.P. Metabolism of tartaric and malic acids in Vitis: A review—Part A. *Vitis* **1982**, *21*, 247–259.
43. Arias-Gil, M.; Garde-Cerdán, T.; Ancín-Azpilicueta, C. Influence of addition of ammonium and different amino acid concentrations on nitrogen metabolism in spontaneous must fermentation. *Food Chem.* **2007**, *103*, 1312–1318. [CrossRef]
44. Bell, S.J.; Henschke, P.A. Implications of nitrogen nutrition for grapes, fermentation and wine. *Aust. J. Grape Wine Res.* **2005**, *11*, 242–295. [CrossRef]
45. Verdenal, T.; Dienes-Nagy, Á.; Spangenberg, J.; Zufferey, V.; Spring, J.; Viret, O.; Marin-Carbonne, J.; van Leeuwen, C. Understanding and managing nitrogen nutrition in grapevine: A review. *OENO One* **2021**, *55*, 1–43. [CrossRef]