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Can Comparable Vine and Grape Quality Be Achieved between Organic and Integrated Management in a Warm-Temperate Area?

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Abstract: The growing demand for wine in Europe has increased the impact of viticulture on the environment. In line with European objectives, more sustainable agronomic practices have spread as an alternative to traditional management. This study aimed to compare, in a vineyard of Pinot blanc and Rhine Riesling in northeast Italy, the integrated agronomic practices (INT) with two types of organic management (ORG1—cattle manure and ORG2—green manure), in terms of production, grape quality, pest susceptibility, and soil nutrient availability. The results, after the fifth, sixth, and seventh year of testing, showed that organic management obtained a yield and vegetative features comparable to INT. Grape quality also did not show considerable overall differences between the theses in the must properties, despite the higher total sugar content and lower yeast available in ORG1. In the three-year period, the management of downy mildew, powdery mildew, and rot, as well as the soil fertilization, with the products available in organic farming proved to be comparable to the INT method. The application of cattle manure contributed by enriching the soil in K and P, while a balanced green manure mix has proven to be the best agronomic practice in terms of the release of mineral N during the phenological stages of greatest need of the vine. Organic management appears as an agronomic strategy able quantitatively and qualitatively support the vineyard system.

Keywords: viticulture; organic management; green manure; cattle manure; nutrients; mineral nitrogen dynamic; yield; must quality; grapevine diseases

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1. Introduction

Grapevines are one of the most common perennial crops [1] and in 2020, an estimated 7.3 million hectares of the world's surface area was under vines [2]. The high demand for wine in Europe led to a great exploitation of farmland, with an intensification in the use of synthetic pesticides and fertilizers and intensive agronomic practices. Consequently, the impact of viticulture on the environment has grown [3], causing soil and water pollution, pauperization of soil quality and fertility, reduction of biodiversity, and poses risks for human and fauna health [4–7]. For these reasons, in line with the European targets to be achieved in the coming decades [8], more sustainable agronomic practices have appeared as an alternative to minimize these negative effects. In recent years, organic viticulture in Europe has been expanding widely, reaching a total area of 396,022 ha in 2019 [9], corresponding to about 12% of world viticulture [2], and increasing by 105% since 2010 [9]. Organic practices aim to preserve the natural equilibrium of agroecosystems, promoting soil conservation and fertility, contributing to carbon sequestration and reducing greenhouse gas emissions [10,11]. The concern of winegrowers in converting to organic farming is linked to the yield decrease [11,12]. However, the yield reduction is essential in the production of high-quality wine because of its positive effect on quality parameters such as acidity and phenol and anthocyanin concentrations [11,13,14]. The use of organic amendments and cover crops in organic viticulture produce multiple benefits. Organic amendments, such as mature manure, also improve soil health by supplying organic matter [15] and nutrients [16] for crops and supporting microbial activities and biodiversity [17,18]. Green manure improves soil structure, reduces erosion [10,19], and increases or regulates the amount of nitrogen and organic matter [20], depending on the composition of the cover crops. Pisciotta et al. [21] demonstrated that the use of leguminous cover crops and pruning residue in vineyards ensured nitrate availability in soil, thus reducing nitrogen external inputs. Furthermore, cover crops contribute to pest control thanks to an enrichment in biodiversity and provision of ecological niches for the competitors/predators of pests [22]. Most research investigating the effects of sustainable agronomic practices and conversion to organic viticulture studies single agronomic aspects, such as soil quality [23,24], nitrogen nutrition/availability [21], and grape quality [25]. Only recently, a few studies [26,27] have performed a multifactorial analysis, which simultaneously takes into account soil quality, nutrient availability, plant, and grape quality.

This work aimed to compare the traditional agronomic practices with two types of organic management in terms of production, grape quality, pest susceptibility, and soil nutrient availability in a vineyard of a warm-temperate area (*Cfb* according to *Köppen-Geiger* climate classification) in northeastern Italy. The hypotheses, over five to seven years of testing, were: (1) to obtain comparable production and quality between different agronomic management; (2) to evaluate the incidence of the most common fungal diseases on vines; (3) to understand the capacity of different organic practices to supply available nutrients, in particular soil nitrogen; (4) to understand the link between different agronomic management and must quality in terms of the main quality parameters.

2. Materials and Methods

2.1. Site Description and Experimental Design

The study was carried out in a vineyard of Pinot blanc and Rhine Riesling located in the Adige Valley (Trentino Region—46°11′44″ N, 11°08′12″ E, 236 m a.s.l.), in northeastern Italy. The meteorological data for the study period (2016–2018) are depicted in Figure S1. The grapevines were planted in 2009 on a SO4 rootstock and trained in "simple pergola trentina trellis system" (2.80 m × 0.5 m). The soil was loam, extremely calcareous, subalkaline, and supplied with a good amount of organic matter and total N (Table 1).

Table 1. Soil characterization of the vineyard in the 3-year investigation (mean values ± SD) per cultivar in the layers 0–40 cm (n = 24). SOM and CEC represent soil organic matter and cation exchange capacity, respectively.

Soil Physical and Chemical Parameters	Pinot Blanc	Rhine Riesling
Sand (g kg^{-1} d.w.)	440 ± 43	463 ± 18
Silt (g kg^{-1} d.w.)	456 ± 32	438 ± 26
Clay (g kg^{-1} d.w.)	104 ± 19	99 ± 12
pH	7.9 ± 0.1	7.8 ± 0.1
Total carbonates (g $CaCO_3$ kg^{-1} d.w.)	408 ± 49	545 ± 1
Active carbonates (g $CaCO_3$ kg^{-1} d.w.)	11 ± 2	11 ± 1
SOM (g kg^{-1} d.w.)	32 ± 5	38 ± 6
Total N (g kg^{-1} d.w.)	1.4 ± 0.2	1.7 ± 0.3
C/N	13 ± 1	13 ± 1
CEC ($cmol_+$ kg^{-1} d.w.)	13 ± 2	14 ± 2

The trial has been operating since 2011. The vineyard was organized in randomized blocks, managed with three different protocols, corresponding to three theses: an integrated management according to "Disciplinare produzione integrata Provincia Autonoma di Trento": fertilized with synthetic products (INT), vine organic management with cattle manure fertilization (ORG1), and organic management fertilized with green manure (ORG2). All organic practices were performed according to Reg. UE 834/2007. The

INT thesis was fertilized yearly in spring with 300 kg of mineral fertilizer NPK 12-12-17, supplying 36 kg ha^{-1} of N, 36 kg of P, and 51 kg of K in the row. The pruning residues were shredded and left between rows. ORG1 thesis was amended in the rows during spring with 8.6 t ha^{-1} of cattle manure (organic C: 27% d.w., total N: 1.6% d.w., P: 0.26%, and K: 1.8%) every two years, providing 1.2 t ha^{-1} of total C, 72 kg ha^{-1} of total N, 12 kg ha^{-1} of P, and 80 kg ha^{-1} of K. The pruning residues of both organic managements were added and matured within the manure heap. The inter-row of INT and ORG1 was covered by permanent grass, and regularly mowed during spring-summer. The green manure of ORG2 consisted of a mix of *Poaceae* (47%), *Fabaceae* (40%), and *Brassicaceae* (13%), seeded every autumn (180 kg ha^{-1}) on alternate inter-rows in October, once bunches were collected. Additionally, in ORG2 management, 100 g ha^{-1} of horn manure (biodynamic preparation 500 consisted of cow manure fermented underground in a cow horn) were applied between rows after harvest and 4 g ha^{-1} of horn silicate (biodynamic preparation 501 consisted of a mix of silicates stored underground in a cow horn) were sprayed on leaves twice during the growing season. Every June, the green manure was chopped and left on the soil. The green manure produced on average a biomass of 0.74 kg m^{-2} d.w., containing 326 g m^{-2} of C and 15.5 g m^{-2} of N, whereas the biomass of permanent grass of all theses was on average 0.27 kg m^{-2} d.w., containing 113 g m^{-2} of C and 5.6 g m^{-2} of N. For pest control, protocols of the integrated pest management (IPM) according to "Disciplinare produzione integrata Provincia Autonoma di Trento" and organic regulations (Reg. UE 834/2007) were used respectively for INT and ORG theses. The drip irrigation system (pitch: 40 cm, flow rate: 2 L h^{-1}) was activated in emergency throughout the vineyard. Table 2 illustrates the management protocols and agronomic practices applied during the 3-year study.

Table 2. Agronomic practices adopted in the theses INT (integrated management), ORG1 (organic management with cattle manure), and ORG2 (organic management with green manure).

Agronomic Practices	INT	ORG1	ORG2
Chemical weed control (row)	x		
Mechanical weed control (row)		x	x
Mechanical weed control (inter-row)	x	x	x
Mineral fertilization (NPK 12:12:17)	x		
Organic manure (every two years)		x	
Green manure (alternate inter-row)			x
Biodynamic preparations (500 and 501)			x
Synthetic pesticides	x		
Pesticides allowed in organic farming	x	x	x
Pneumatic leaf removing at flowering	x	x	
Manual sprouts removal			x
Mechanical topping	x		
Shoot rolling		x	x
Chemical bunch thinning	x		
Mating disruption technique (*Lobesia botrana* + *Eupoecilia ambiguella*)	x	x	x

2.2. Nutrient Concentrations and Organic Matter in Soil

The assessments of soil organic matter (SOM) and nutrient concentrations (N, P, K, Mg, Fe, Mn, and Zn) were performed on the air-dried fine earth fraction (<2 mm). The soil samples were collected in the layer 0–40 cm every autumn from 2016 to 2018, in two replications per cultivar and thesis. The SOM was calculated using the organic carbon (conversion factor: 1.724), which was obtained from the difference between the total carbon, measured by Dumas combustion of powdered soil and TCD detection (ISO 10694:1995), and the total carbonates were determined using the volumetric method (ISO 10693:1995). The total N was measured simultaneously with the total carbon (ISO 13878:1998), using a CN elemental analyzer (Vario Macro Cube, MKK, DE). The exchangeable fraction of Mg and K was extracted in ammonium acetate (pH 7.00) and detected using an ICP-OES

(Optima8300, PerkinElmer®, MA, USA). The available fraction of Fe, Mn, and Zn was extracted in a DTPA/$CaCl_2$/triethanolamine solution and detected using ICP-OES. The assay of assimilable P was carried out using the Olsen method, providing solubilization of P in a $NaHCO_3$ solution and determination using spectrophotometry with the ascorbic acid method.

2.3. Extractable Nitrate in Soil

The analysis of extractable nitrate was carried out on bulk soil samples collected in the Rhine Riesling plot. Every year of the trial (2016–2018), the samples were gathered six times during the annual cycle, in correspondence with specific phenological stages (Table 3) from the layer 0–40 cm, in five replications per thesis. After sampling, fresh soil was sieved at 2 mm and stored at −20 °C. Ten grams of defrosted soil were added to 100 mL of distilled water and shaken for 60 min. After centrifugation, 20 mL of supernatant was added with 1 mL of 0.1 M HCl and diluted 1:2.5 with distilled water. The extracts were filtered at 0.45 µm and the nitrate concentration was measured by UV-spectrometry at a wavelength of 220 nm. The interference of organic matter on nitrate quantification was eliminated by subtracting the value acquired at 275 nm from the result. Concentration values were expressed as mg $N\text{-}NO_3^-$ kg^{-1} d.w. using a calibration curve and finally converted to kg $N\text{-}NO_3^-$ ha^{-1}.

Table 3. Phenological development of grapevines using the BBCH-scale (readapted from Lorenz et al. [28]).

Timing	Month	BBCH Scale		
		2016	2017	2018
T1	May	16–17 6–7 leaves unfolded	53 Inflorescences clearly visible	16–17 6–7 leaves unfolded
T2	June	69 End of flowering	72 Fruit set: young fruits begin to swell	73 Berries groat-sized, bunches begin to hang
T3	July	77 Berries beginning to touch	79 Majority of berries touching	79 Majority of berries touching
T4	August	83 Berries developing color	83 Berries developing color	83 Berries developing color
T5	September	89 Berries ripe for harvest	89 Berries ripe for harvest	89 Berries ripe for harvest
T6	October	93 Beginning of leaf-fall	93 Beginning of leaf-fall	95 50% of leaves fallen

2.4. Nutrients in Vine Leaves

The analysis of the nutrients in the leaves was carried out on Pinot blanc and Rhine Riesling varieties through two replications per thesis every year. Each replication consisted of thirty leaves sampled on an entire row at veraison. The samples were dried at 70 °C and grinded. Leaves were acid-digested with nitric acid and then analyzed with ICP-OES for the quantification of total P, K, Ca, Mg, S, Fe, Mn, B, Cu, and Zn. Total N was quantified by dry combustion with elemental analyzer.

2.5. Vegetative and Yield Parameters

The vegetative and yield parameters were measured at technological grape ripeness from 2016 to 2018, in ten replications per cultivar and thesis. In each replication, six vines were individually sampled for the quantification of shoots and cluster numbers and vine yield (kg/vine). Average bunch weight (ABW, g/bunch) was calculated from vine yield/number of clusters. For monitoring vine growth due to vineyard management practices, pruning weight (VPW, kg/vine) from each sampled vine was measured after pruning. The Ravaz index (RI) was calculated from vine yield/pruning weight.

2.6. Must Quality

The analyses of musts were carried out on grapes sampled in ten replications per cultivar. The quality control parameters of grape must—total soluble solids (TSS), pH, titratable acidity (Tit_acidity), tartaric acid, malic acid, potassium (K), and yeast assimilable nitrogen (YAN)—were assessed with a WineScanTM FT 120 Type 77310 (Foss Electric A/S Hillerød, Denmark) calibrated with the official methods [29].

2.7. Disease Surveys

The infections of *Erysiphe necator* (powdery mildew), *Plasmopara viticola* (downy mildew), and *Botrytis cinerea* plus acid rot (rot) were quantified on the clusters. The investigation was carried out on six replications per thesis every year. Powdery and downy mildew were assessed at the end of seasonal applications of protection products (June–July), whereas rot was evaluated at harvest. Incidence and severity percentages were obtained from 100 observations (clusters) per replication. The severity was calculated using a rating scale of eight classes (0, 2–5, 6–10, 11–25, 26–50, 51–75, 76–99, and 100% of infected cluster).

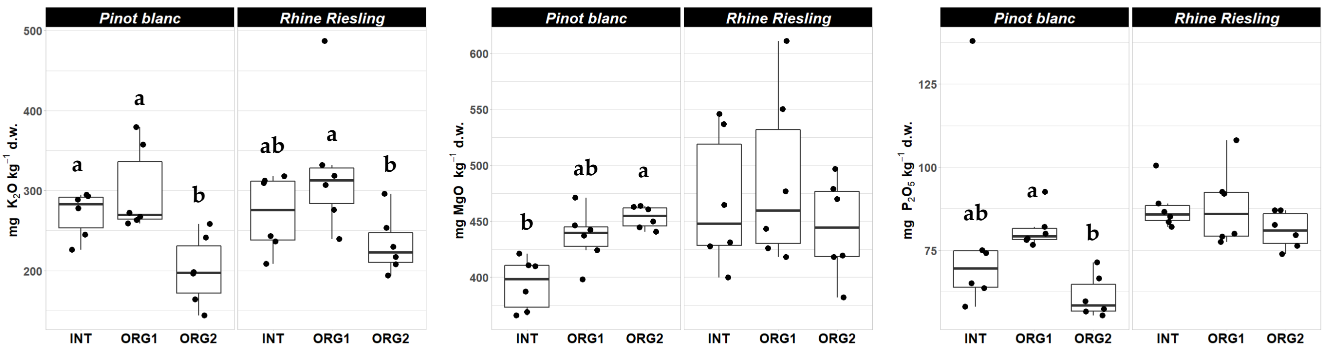
2.8. Statistical Analysis

The statistical analysis was performed by TIBCO Statistica® Software version 13.3 (2017) on the raw data. The differences among theses and sampling times for disease investigation were evaluated by Kruskal-Wallis non-parametric test (α = 0.05). The degree of relations between mineral N and YAN was appreciated by the non-parametric Spearman correlation test ($p \leq 0.05$; $\rho_S = |0.5|$). Factor analysis of mixed data (FAMD) of quantitative (grapevine parameters) and qualitative variables (cultivar, thesis and temporal factor) and the graphical elaborations were performed by RStudio software version 3.6.1.

3. Results and Discussion

3.1. Soil Organic Matter and Nutrient Availabity

The Rhine Riesling and Pinot blanc vineyards had a good level of SOM [30], with a higher range in Rhine Riesling (3.2–5.7%) than in Pinot blanc (2.4–3.9%). Fertilization practices and management systems showed no differences in SOM and total N for the whole three-year dataset (Table S1), exhibiting similar values between the three managements in both vineyards. The results displayed that the Pinot blanc soil was moderately/well-endowed with total N (1.0–1.7 g kg^{-1}) and the Rhine Riesling soil was well-endowed/rich in this nutrient (1.3–2.7 g kg^{-1}) [30]. The available concentrations of Mn (Pinot blanc: 6.1–11.0 ppm; Rhine Riesling: 6.1–9.4 ppm) and Fe (Pinot blanc: 14.9–21.0 ppm, Rhine Riesling: 10.5–21.6 ppm) showed normal values in the soils of both vineyards, as reported by Giandon and Bortolami [30]. The available concentrations of Zn (Pinot blanc: 5.1–21.1 ppm; Rhine Riesling: 9.2–18.8 ppm) found that the soils are within the range of non-acidic Italian viticulture soils [31]. The three mentioned micronutrients showed no differences between agronomic practices (Table S1). Regarding the macronutrients P, K, and Mg (Figure 1), the investigated soils were overall well-endowed/rich/highly rich in their available concentrations [30]. Differences between agronomic practices were found depending on the cultivar. In the Rhine Riesling vineyard, the concentration of exchangeable K (Figure 1a) differed between the theses, showing a higher concentration in ORG1 than in ORG2, while INT appeared in an intermediate condition. For Pinot blanc, all three macronutrients differed according to management. The exchangeable Mg (Figure 1b) exhibited higher values in ORG2 than in the thesis with mineral fertilizers (INT), although the soil of the whole vineyard seemed to have a good level of available fraction of Mg [30]. Assimilable P (Figure 1c) was lower in ORG2 than in ORG1 and exchangeable K (Figure 1a) was higher in INT and ORG1 than in ORG2. These results highlighted the effectiveness of manure in providing macronutrients [32], with a clear effect on the whole vineyard area, despite being applied in the row. Management solely with green manure, on the contrary, did not provide K, Mg, and P, and the significant removal of K and P by the vines [33] could have contributed to the decrease of these elements in the soil. By contrast, a lower removal of Mg by the vines [33] in green manure management could not have affected its availability in the soil. However, the gradual reduction of available K in ORG2 caused an increase in Mg/K ratio (4.4 for Rhine Riesling and 5.3 for Pinot blanc) (Table S2), approaching or exceeding the maximum value of the equilibrium range (2–5 [34]). The lower amount of Mg available in INT did not influence the Mg/K ratio (3.8 for Rhine Riesling and 3.3 for Pinot blanc) due to the annual mineral input of K (51 kg ha^{-1} K).



(**a**) (**b**) (**c**)

Figure 1. Soil concentrations of (**a**) exchangeable K as mg kg^{-1} of K_2O, (**b**) Mg as mg kg^{-1} of MgO and (**c**) assimilable P as mg kg^{-1} of P_2O_5 in Pinot blanc and Rhine Riesling vineyards submitted to INT, ORG1, and ORG2 management treatments in 2016–2018 (n = 6). Different letters (a,b) indicate significant differences between theses ($p \leq 0.05$).

3.2. Dynamics of Mineral Nitrogen in Soil

Overall, in the three-year period 2016–2018, the mineral N (extractable NO_3^-) dynamics (Figure 2) of ORG2 differed significantly from the dynamics of the other two theses (INT and ORG1). Examined separately by year, no differences were found between the theses in 2016 and 2017, while in 2018 ORG2 differed from ORG1, showing higher values of mineral N overall. In 2016, all theses showed an almost constant seasonal trend. In 2017, the NO_3^- dynamics of the two organic theses tended to show higher values in August (T4), at veraison. This trend towards higher concentrations in August was more pronounced in 2018 for all systems. At T2 (BBCH 69-73) of each year, mineral N values in ORG2 were always higher than in INT and in 2018 they were also higher than in ORG1. In INT and ORG1, mineral fertilizer and cattle manure applied in the row showed a slower and lower effect on the inter-row mineral N dynamics and the permanent grass reduced the N content in the soil, which was immobilized in its biomass [24,35]. The release of mineral N increased with increasing temperatures, which probably contributed to accelerating mineralization processes [36,37]. Higher values of mineral N in the green manure soil should be related to the atmospheric N fixation capacity of legumes [24,38]. In addition, the application of a balanced green manure of *Poaceae* and *Fabaceae* could compensate for the N sequestered in the biomass of *Poaceae* due to N fixation by *Fabaceae*, without reducing the availability for the profit crop [39]. In this study, the maximum effect of green manure on soil N availability was found at the end of flowering (T2) and at ripening (T4). These phenological stages correspond to the periods of highest N requirements by vines [40–42]. Similar results were found by Zapata et al. [43], who observed that, from the beginning of flowering to the berries' pea-sized stage, N uptake by roots was adequate to support the biomass of growing vines. The availability of N also depends on the SOM and its quality. Previous work carried out on the same experimental plot in a seven-year trial [44] showed that in ORG2 there was a 37% increase in the labile fraction of organic matter, i.e., the fraction from which mineral N is naturally released.

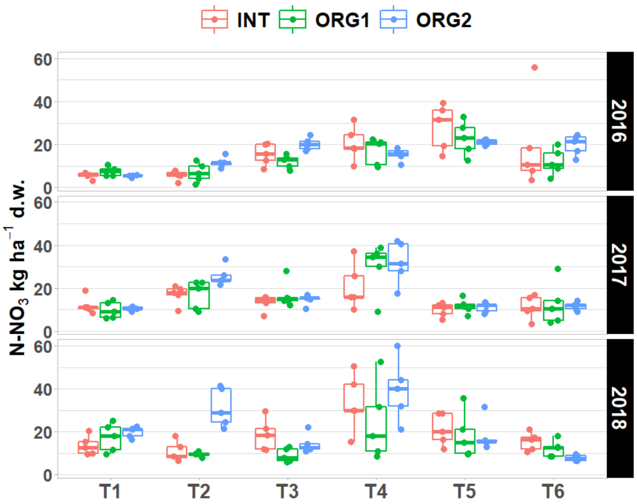


Figure 2. Soil mineral N dynamics (extractable N-NO_3^-) in Rhine Riesling vineyards submitted to INT, ORG1, and ORG2 management treatments in 2016–2018 (n = 5).

3.3. Nutrients in Leaves

No differences were observed among the management methods in the concentration of micro- and macronutrients in the leaves of Pinot blanc, although the available fractions of K, Mg, and P in the soil differed depending on the management method (Table 4). In Rhine Riesling, foliar P was found higher in ORG1 than in ORG2 and Mg showed higher values in INT than in ORG1, although no differences were found between theses on the soil availability of these nutrients for Rhine Riesling. Variability in the amount of K observed in the soil was not detected in the leaves of both cultivars studied. However, all foliar concentrations of micro- and macronutrients detected at veraison showed values within the normal ranges for vines grown in northern Italy [45]. Similar results were found by Meissner et al. [26] in a study comparing integrated, organic, and biodynamic management, where no deficiency in foliar nutrient concentrations was detected.

Table 4. Foliar macro- and micronutrient concentrations (d.w.) per cultivar and thesis in the three-year period (median, minimum, maximum, first (Q_1) and third (Q_3) quartile, n = 6). Non-significant differences among theses are marked with "*n.s.*". Different letters (a,b) indicate significant differences between theses ($p \leq 0.05$).

Cultivar	Variable	Thesis	Median	Min–Max	Q_1–Q_3	Significance
Pinot blanc	N (%)	INT	2.36	2.15–2.58	2.29–2.45	*n.s.*
		ORG1	2.24	2.08–2.56	2.22–2.27	
		ORG2	2.21	2.13–2.45	2.14–2.29	
	P (%)	INT	0.21	0.17–0.23	0.19–0.23	*n.s.*
		ORG1	0.20	0.16–0.26	0.17–0.24	
		ORG2	0.18	0.17–0.18	0.17–0.18	
	K (%)	INT	1.25	0.92–1.54	1.00–1.33	*n.s.*
		ORG1	1.02	0.83–1.29	0.93–1.09	
		ORG2	1.00	0.72–1.19	0.75–1.01	
	Ca (%)	INT	3.17	2.63–3.87	2.93–3.48	*n.s.*
		ORG1	3.19	2.86–3.86	3.07–3.77	
		ORG2	3.3	2.92–4.07	2.92–3.72	
	Mg (%)	INT	0.35	0.28–0.40	0.32–0.38	*n.s.*
		ORG1	0.35	0.30–0.41	0.33–0.40	
		ORG2	0.35	0.29–0.44	0.32–0.38	
	B (mg kg^{-1})	INT	28	25–33	25–30	*n.s.*
		ORG1	30	25–36	26–33	
		ORG2	30	26–36	28–33	
	Fe (mg kg^{-1})	INT	71	63–81	64–77	*n.s.*
		ORG1	69	63–75	64–72	
		ORG2	77	68–78	72–78	

Table 4. *Cont.*

Cultivar	Variable	Thesis	Median	Min–Max	Q_1–Q_3	Significance
	Mn (mg kg^{-1})	INT	73	52–110	53–107	
		ORG1	74	41–84	60–81	*n.s.*
		ORG2	58	41–68	52–68	
	Zn (mg kg^{-1})	INT	16	13–20	13–17	
		ORG1	17	15–22	16–18	*n.s.*
		ORG2	15	12–21	13–19	
Rhine Riesling	N (%)	INT	2.14	2.09–2.30	2.13–2.17	
		ORG1	2.06	1.92–2.19	1.97–2.11	*n.s.*
		ORG2	2.12	2.01–2.23	2.03–2.20	
	P (%)	INT	0.17	0.14–0.18	0.15–0.18	ab
		ORG1	0.18	0.16–0.19	0.16–0.18	a
		ORG2	0.15	0.13–0.15	0.14–0.15	b
	K (%)	INT	1.28	0.95–1.47	0.97–1.37	
		ORG1	1.08	0.97–1.42	1.00–1.23	*n.s.*
		ORG2	0.95	0.83–1.22	0.86–1.13	
	Ca (%)	INT	2.78	2.41–3.33	2.57–3.32	
		ORG1	2.76	2.56–3.35	2.63–3.18	*n.s.*
		ORG2	2.97	2.49–3.75	2.66–3.73	
	Mg (%)	INT	0.41	0.31–0.48	0.37–0.47	a
		ORG1	0.31	0.28–0.37	0.30–0.34	b
		ORG2	0.36	0.28–0.40	0.32–0.38	ab
	B (mg kg^{-1})	INT	34	27–39	29–38	
		ORG1	36	34–39	34–38	*n.s.*
		ORG2	34	31–36	32–34	
	Fe (mg kg^{-1})	INT	69	61–73	62–72	
		ORG1	63	59–71	61–65	*n.s.*
		ORG2	66	61–77	64–67	
	Mn (mg kg^{-1})	INT	102	71–126	92–116	
		ORG1	100	67–116	85–101	*n.s.*
		ORG2	106	78–115	81–112	
	Zn (mg kg^{-1})	INT	20	19–26	19–23	
		ORG1	21	16–25	18–25	*n.s.*
		ORG2	23	20–30	20–28	

3.4. Vegetative and Yield Variables

Table 5 shows the vegetative and production parameters. During the three-year period, the number of shoots was always higher in INT than in ORG2, while ORG1 was similar to the other two management methods for both Pinot blanc and Rhine Riesling. This result derives from the different canopy management in the organic plots. This agronomic practice focuses on improving microclimatic conditions (aeration and light), optimizing the volume of the canopy through the early removal of shoots. No significant differences were observed in the other vegetative and yield variables (cluster number, vine yield, ABW, VPW, and RI) between the theses. Otherwise, Döring et al. [46] found, in a systematic quantitative review of the comparison between agronomic management in viticulture, that organic and biodynamic practices showed a 21% and 18% decrease in pruning weight and yield, respectively, compared to conventional management. Tendentially lower values of ABW for both cultivars were found in INT due to chemical thinning (gibberellic acid—GA_3) and pneumatic leaf removal, and in ORG1 due to pneumatic leaf removal (Table 2). The effectiveness of chemical thinning also depends on the meteo-climatic conditions during flowering [47]. During the trial, the meteo-climatic optimum for chemical thinning was not concurrent during flowering (Figure S1), thus reducing its effectiveness. However, the indistinguishable crop yield between the management methods made it possible to exclude this factor from the comparison analysis of must quality and disease incidence. Furthermore, according to Smart [48], the RI (vine yield/VPW), which is the main factor explaining vine balance, fell within the optimal range (5–10) for all cultivars and management methods.

Table 5. Vegetative and yield parameters per cultivar and thesis in the three-year period (median, minimum, maximum, first (Q_1) and third (Q_3) quartile, n = 180). ABW, VPW and RI represent average bunch weight, vine pruning weight, and Ravaz index, respectively. Non-significant differences between theses are marked with "*n.s.*". Different letters (a,b) indicate significant differences between theses ($p \leq 0.05$).

Cultivar	Variable	Thesis	Median	Min–Max	Q_1–Q_3	Significance
Pinot blanc	n_shoots	INT	13	6–31	11–16	a
		ORG1	12	6–21	10–15	ab
		ORG2	11	5–21	9–13	b
	n_clusters	INT	15	4–31	12–19	*n.s.*
		ORG1	14	5–32	12–18	
		ORG2	14	4–31	11–18	
	ABW (g)	INT	153	89–263	134–175	*n.s.*
		ORG1	167	66–288	138–194	
		ORG2	170	30–357	146–197	
	Vine_yield (kg)	INT	2.28	0.55–5.66	1.72–2.95	*n.s.*
		ORG1	2.47	0.64–5.40	1.75–3.01	
		ORG2	2.39	0.24–5.63	1.82–3.01	
	VPW (kg)	INT	0.32	0.05–1.03	0.18–0.48	*n.s.*
		ORG1	0.39	0.09–1.50	0.28–0.53	
		ORG2	0.33	0.09–1.15	0.23–0.46	
	RI	INT	7.6	0.9–24.5	4.2–12.0	*n.s.*
		ORG1	6.5	1.1–18.6	4.4–8.4	
		ORG2	7.1	0.8–22.3	5.1–9.8	
Rhine Riesling	n_shoots	INT	12	5–20	10–14	a
		ORG1	11	4–18	9–13	ab
		ORG2	10	6–15	8–12	b
	n_clusters	INT	21	8–42	17–25	*n.s.*
		ORG1	22	5–40	18–26	
		ORG2	21	9–37	16–24	
	ABW (g)	INT	102	52–193	85–119	*n.s.*
		ORG1	104	56–215	86–126	
		ORG2	112	61–219	97–129	
	Vine_yield (kg)	INT	2.06	0.67–4.10	1.70–2.51	*n.s.*
		ORG1	2.16	0.49–4.43	1.67–2.95	
		ORG2	2.24	0.96–4.20	1.80–2.76	
	VPW (kg)	INT	0.39	0.10–1.08	0.28–0.51	*n.s.*
		ORG1	0.39	0.12–1.48	0.30–0.49	
		ORG2	0.39	0.08–0.85	0.30–0.52	
	RI	INT	6.2	0.9–18.4	3.9–8.0	*n.s.*
		ORG1	6.0	1.6–15.9	4.7–7.4	
		ORG2	5.8	2.3–18.8	4.4–7.6	

3.5. Must Quality

Among the grape must parameters studied for assessing grape maturity, only YAN, pH and TSS were affected by the management of Rhine Riesling during the overall period of study (Figure 3). For this cultivar, ORG1 showed the lower YAN and pH and the higher TSS, reflecting the lower mineral N values found in the soil of this thesis (Figure 2). In detail, the YAN measured in the musts of the ORG1 thesis differed from that found in INT and ORG2, while the pH and TSS of ORG1 differed from those of INT. The interpretation of the results seems to indicate that ORG1 management sped up the maturity of Rhine Riesling grapes, increasing the sugar content and decreasing pH, the latter an expression of the real acidity of musts. Both are the result of the physiological and biochemical changes that occur in grapes after veraison during ripening [48]. Additionally, during these phenological phases, the soil mineral N in T3 and T4 was significantly correlated with YAN (Table S4), when for all the theses, mineral N in the soil increased. However, YAN results are more difficult to understand. From one side, it is widely reported that the nitrogen supplementation affects vine physiology and influences the nitrogen content and composition of grape berries [49–51]. From the other, the ripening status can alter the concentration of the compounds forming part of this index [52], but also the mechanical features of grape berries as a consequence of the cell wall degradation of the different berry tissues and thus the extractability of these compounds [53].

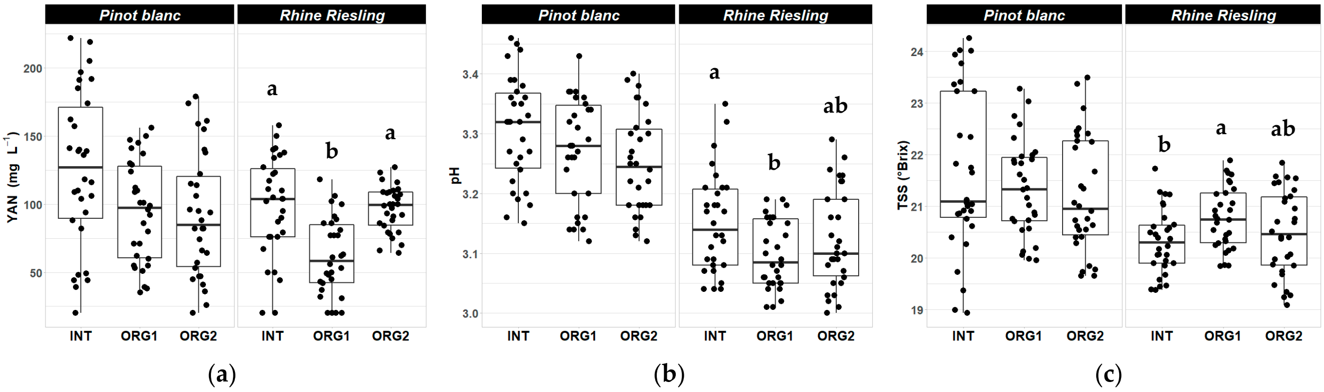


Figure 3. (**a**) YAN, (**b**) pH, and (**c**) TSS in musts of Pinot blanc and Rhine Riesling for INT, ORG1, and ORG2 theses (n = 30) in the three-year period of study. YAN and TSS represent the yeast assimilable nitrogen and total soluble solids, respectively. Different letters (a,b) indicate significant differences between theses ($p \leq 0.05$).

3.6. Multivariate Analysis of Vine and Grape Parameters

FAMD (Figure 4) was performed on the vegetative and yield variables and must quality parameters, considering the cultivar, the agronomical management, and the year as qualitative factors. The multivariate analysis explained 45.7% of the overall variance and highlighted a clear separation between cultivars (total contribution: 8.6%). K, TSS, and pH represented the vine variables with the highest significant contribution to separate groups. No separation was observed between theses (total contribution: 0.28%) during the three years for either cultivar. The factor "year" contributed significatively to the separation between individual groups within each cultivar (total contribution: 11.7%). For Pinot blanc, the first (2016) and the last year (2018) of study were completely separated and 2017 was in an intermediate condition. Rhine Riesling responded differently to the year factor, showing a clear separation between the first two years (2016 and 2017), whereas 2018 was similar to 2016 and 2017. These results underline the different response of cultivars to the seasonal weather trends [54,55].

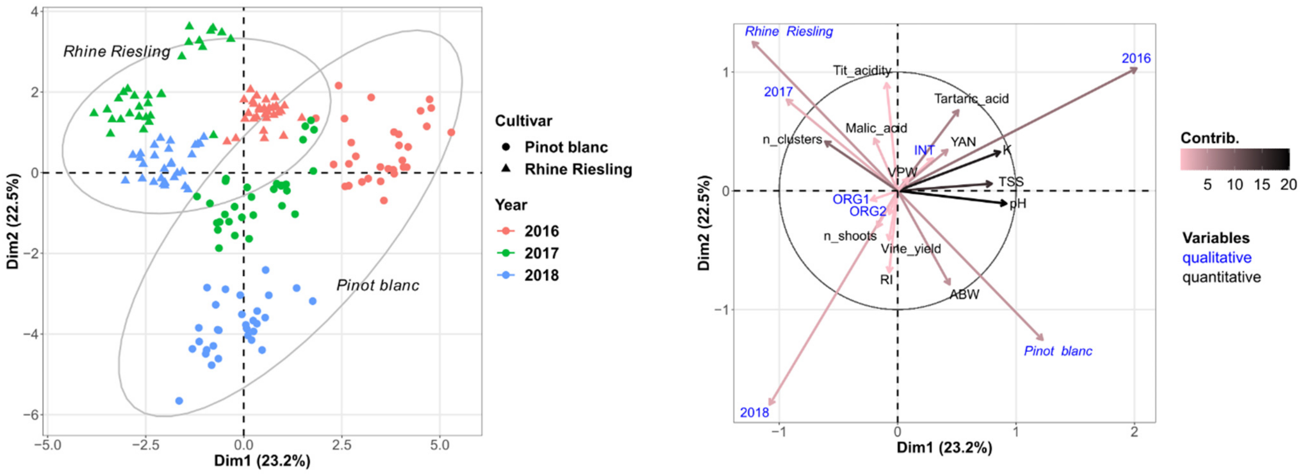


Figure 4. FAMD of vegetative and yield parameters and must quality for Pinot blanc and Rhine Riesling in the three-year period.

3.7. Disease Surveys

Overall, over the three-year period, the incidence and severity of infections for the main grapevine pathogens studied (powdery mildew, downy mildew, and rot) were similar between the managements and cultivars (Figure 5). *P. viticola* and rot infections were influenced by different weather conditions (Figure S1) in the three study years. Heavy rainfall in July–August 2017–2018 was the most predisposing condition to the development of grape rot. Significant differences in rot infection were found in 2018. ORG2 showed a higher incidence and severity of rot than ORG1 in Pinot blanc and ORG1 and INT in Rhine Riesling. In predisposing years, greater bunch compactness could lead to a higher incidence of rot [26], as was the case in 2018 for Pinot blanc, where ABW values tended to be higher in ORG2 (214 g ± 40 g) than in ORG1 (191 g ± 40 g) and INT (181 g ± 30 g). Higher rainfall in May 2016 favored the development of downy mildew compared to 2017 and 2018. This led to increased severity for Pinot blanc vines in ORG2 compared to those in ORG1, where pneumatic leaf removal facilitated the interception of copper treatments on the surface of the bunches. The protection strategy used in the organic management against *E. necator* (sulfur) gave the same results as the integrated strategy (sulfur plus synthetic fungicide), probably due to canopy management.

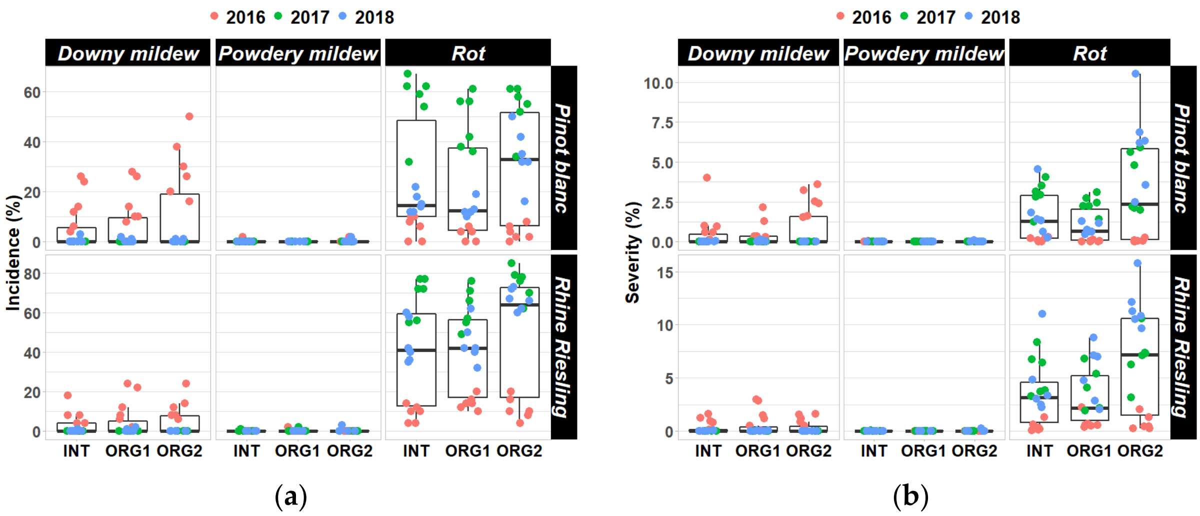


Figure 5. (**a**) Incidence (%) and (**b**) severity (%) of investigated diseases (powdery mildew, downy mildew, and rot) on grapes of Pinot blanc and Rhine Riesling for INT, ORG1, and ORG2 theses from 2016 to 2018 (n = 6).

4. Conclusions

This study, conducted in a Pinot and Riesling vineyard managed since 2011 with three different agronomic protocols, has shown that organic management can be effective in obtaining the same vegetative and yield results as integrated management. No reduction in vegetative growth, crop load, and grape yield was highlighted in the organic theses compared to the integrated ones. The grape quality showed a slight worsening in ORG1 only for Riesling, with an increase in total sugars and a reduction in YAN, which usually occurs in organically managed grapes. Pinot, on the other hand, showed a similar quality of grapes in integrated and organic management. Pathogen infection was associated with the different meteorological trends of the year. The summer rains and less management of the canopy and bunches in ORG2 sometimes contributed to making the grapes more susceptible to rot and downy mildew, but overall, in the three-year period, the management of downy mildew, powdery mildew, and rot with the products available in organic farming, in this context, proved to be comparable to the integrated method. The supply of nutrients to the soil by organic fertilizers such as cattle manure and green manure can match mineral fertilization. The application of cattle manure has contributed to enrich the soil in K and P, while a balanced green manure mix has proven to be the best agronomic practice in terms of release of mineral nitrogen in the phenological stages of greatest need for the vine. The nutrients in the leaves did not always reflect the nutrient levels in the soil and no nutrient deficiency was found in the leaves of the studied theses. Overall, organic management, particularly with the use of green manure, appears to be an agronomic strategy capable of quantitatively and qualitatively supporting the vineyard system.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/agronomy12081789/s1, Table S1: SOM, total N, and micronutrient concentrations in soil per cultivar and thesis in the three-year period (median, minimum, maximum, first and third quartile, $n = 6$); Table S2: Median concentrations of exchangeable K and Mg as meq/100 g of element and Mg/K ratio in soil of the three theses per cultivar; Table S3: K, malic acid, tartaric acid, and titratable acidity in must per cultivar and thesis in the three-year period (median, minimum, maximum, first and third quartile, $n = 30$); Table S4: Spearman correlation coefficients (ρ_S) between mineral N concentrations measured during vegetative cycle before harvest and YAN. Red values represent the significant correlations ($p \leq 0.05$); Figure S1: Meteorological data in three-year 2016–2018, acquired by Fondazione Mach weather station located in San Michele all'Adige (203 m a.l.s.).

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