Biodynamic preparations improve the soil structure

Horn manure and horn pebbles have a significant effect in vineyard soils

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"The results support the hypothesis that that the microbial community plays a role in the effects of horn manure and honing silica preparations."

The soil and the climate play a role in winemaking a key role for the terroir and can influence the quality of the wine. Soil structure problems have negative effects on grape quality and yields in viticulture.
One of the main goals of organic farming is to increase biological interactions in the soil to improve its physical, chemical and biological properties. The soil and in particular the microbial soil community have been identified as an important component of the terroir and contribute significantly to the quality of the wine and its uniqueness.

10% of the world's organic wine-growing area is currently farmed biodynamically. One of the characteristics of biodynamic farming systems is the use of special preparations as additives to compost and for spraying the fields. The two most important preparations are horn manure and horn pebbles, which are applied to the field. The application quantities are low. 100 g/ha of fermented horn manure and 4 g/ha of ground quartz powder are used per treatment. The preparations are stirred in water for one hour before use. Similar effects to auxin on plants were found in studies with horn manure by Radha and Rao (2014) and Giannattasio et al. (2013) found. The use and effectiveness of these preparations are a controversial topic, as Faust et al. (2017) and Jukneviÿienÿ et al. (2019) discuss.

In a long-term trial in Geisenheim, Germany, the parameters of growth, plant health and yield were integrated into the three cultivation methods and examined biologically and biodynamically in viticulture (Meissner et al. 2019). In this study, the biodynamic and biological treatments only differed in the use of the biodynamic preparations. Using the image-creating methods, the grape juice samples from the integrated, organic and biodynamic cultivation methods could be differentiated and classified over the five growing years examined (Fritz et al. 2017, 2021a). Kokornaczyk et al. (2014) were able to produce organic and biodynamic wines the method of droplet evaporation. According to Guz-zon et al. (2016), biodynamic viticulture had a positive influence on the development of the microbiota in grapes in years with difficult climatic conditions compared to conventional production systems. In Patrignani et al. (2017), the yeast microbiota did not differ between organically and biodynamically produced Sangiovese red wines. The bacterial diversity and composition of the soil in the vineyard were found by Burns et al. (2016) differ between biodynamic and biological systems.

In studies of the chemical properties of wine, Parpinello et al. (2015), Laghi et al. (2014) and Picone et al. (2016) Differentiate wine from organic and biodynamic cultivation in terms of chemical substances. In the sensory evaluation of wine, Ross et al. (2009) also distinguish between organic and biodynamic wine, while Meissner (2015) was only able to partially distinguish between wines from the different systems and Parpinello et al. (2015) stated that the wines could not be distinguished.

Since it is more difficult to apply a randomized arrangement in steep vineyards than on flat surfaces (Reeve et al. 2005), "on-farm" methods are often used in viticulture. In the present study, an on-farm approach was used for hillside vineyards to investigate the effects of the application of the biodynamic preparations horn manure and horn pebbles on soil structure under organic farming. In this study, a visual assessment of soil structure (VESS) was carried out using the spade diagnostic method.

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Table 1: Information on the three study locations

	A: Vinzelles	B: Bray	C: Bouzeron	
Height above sea level (m)	257	265	299	*In July 2016 the*
Slope inclination (%)	11	11	11 - 19	*Soil samples were*
Alignment slope	East	West	East-southeast	*collected from the BD+*
Precipitation (mm)	773	786	805	*and BD- treatments, at*
Annual temperature (°C)	10.7	10.6	10.4	*5.1 m intervals between*
Volume (%)	34	34	24	*each treatment pair.*
Silt (%)	52	52	52	
Sand (%)	14	14	24	*The sampling points*
rock	Limestone and marl	Limestone and marl	Limestone and marl	*were evenly distributed*
Soil type (FAO-WRB)	Cambic Leptosol	Cambic Leptosol	Calcaric Leptosol	*across the slope of the vineyards.*
vineyard since	A1: 1976 A2: 1951	2013	C1: 1977 C2: 1999	
grape variety	Chardonnay	Chardonnay	Aligoté doré	*At the five locations*
BD preparations since	2001	2013	2015	*became six each*
BD preparations/year	2×500P+501	2 × 500P + 3 - 5 × 501	2×500P+501	*Pairs of soil samples*
BD application/year	40 l / ha	30 - 35 l / ha	35 l / ha	*(0 - 10 cm depth) were taken*
Additional preparations/year	Equisetum arvense L.	No	Valeriana officinalis L.	*For more information see Fritz et al. 2021b*
Tillage in row/year	1 × chopping	Chop	2 × kerning	
	4 × slice cutting			
Plant cover between d. rows	Underseed > 70%	<10%	<10%	

Annual average precipitation and temperature. Horn manure prepared with biodynamic compost preparations was used (method according to A. Podolinsky.n) = 500P

Over the last two decades, important fundamental work has been undertaken to develop a standardizable visual assessment of soil structure using spade diagnosis (Beste 2003; Ball et al. 2017). Since VESS is a qualitative or semi-quantitative method, aggregate stability was also assessed by wet sieving as an additional test and the stability index for the mean weight diameter (MWD) was calculated according to Angers et al (2006). Due to the high stone content of the soil, it was not possible, as originally planned, to take undisturbed soil samples to measure water retention capacity, hydraulic conductivity and air conductivity. The same soil samples used in the present study were additionally examined for their microbial biomass and various indices of microbial activity, according to Fritz et al. (2020). The results suggested that the biodynamic preparations have significant effects on the soil microbial community, as in Fritz et al. (2021b).

The hypothesis underlying the present experiments was that the use of horn pebbles and horn manure improves the soil structure in the vineyards and increases the stability of the aggregates.

Study locations and sampling

The soil samples were taken from five vineyards at three locations in Burgundy between the Mâcon (Saône et Loire) and Beaune (Côte d'Or) regions. Each of the five plots was divided into two halves and one half of each vineyard plot was treated annually with the biodynamic preparations horn manure and horn pebbles (BD+ = 500P and 501; BioDynamie Services sarl Pierre et Vincent Masson, France), while the other half was treated annually received no BD preparations (=BD-) during the respective periods.

The vineyards A1 and A2 belong to a vineyard in the town of Vinzelles. Vineyard B is located near the Bray region. The vineyards C1, C2 are located near Bouzeron on limestone. Further information about the vineyards can be found in Fritz et al. (2021b) and presented in Table 1. All locations were managed according to organic farming guidelines.

In July 2016, soil samples were collected from the BD+ and BD-treatments, at 5.1 m intervals between each treatment pair. The sampling points were evenly distributed across the slopes of the vineyards. Six pairs of soil samples (0 -10 cm depth) were taken at each of the five locations (for more information see Fritz et al. 2021b).

Table 2: Results of the visual soil assessment

Was standing-places	Color change Upper-to subfloor in cm depth	Macro and Biopores in rating Values 1 – 5	Case study Topsoil in rating Values 1 – 5	Case study subfloor in rating Values 1 – 5	Color Topsoil in rating Values 1 – 5	Color subfloor in rating Values 1 – 5
A1						
BD	13.33	3.78	1.00	3.33	3.00	3.00
BD+	18.00	2.89	1.00	2.50	1.50	3.00
A2						
BD	11.00	3.12	1.00	2.67	3.00	3.67
BD+	12.67	2.45	1.17	2.33	1.83	3.00
b						
BD	20.00	2.89	1.67	2.00	2.50	3.00
BD+	20.67	3.11	1.00	1.33	1.83	3.00
C2						
BD	10.00	3.34	1.50	2.50	2.83	3.00
BD+	12.33	3.34	1.17	1.83	2.00	3.00
Medium-values						
BD	13.58*	3.28	1.29	2.62**	2.83***	3.17
BD+	15.92*	2.95	1.08	2.00**	1.79***	3.00

- *Application of biodynamic preparations: with (BD+) and without (BD-)*
- *Categories: 1 (best…) to 5 (worst structures)*
- *Investigation locations: A1, A2, B, C2*
- *For a description of the parameters see Fritz et al. (2021b)*

Asterisks indicate a significant difference with BD+ treatment (*: $P < 0.05$; **: $P < 0.01$; ***: $P < 0.001$).

Results

Wet sieving revealed significantly lower aggregate stability for locations A1, A2 and B compared to locations C1 and C2. There was no difference in the measurement of aggregate stability between the BD- and BD+ variants.

When visually assessing the soil structure, the color change between topsoil and subsoil was significantly 2.34 cm deeper in the soil at BD+ than at BD- when considering the values for all locations (Table 2). There were no significant differences between BD- and BD+ in macropores/biopores, upper horizon soil drop test, or subsoil color. However, for the drop sample (dropping height of 1 m of the spade sample) from the lower horizon and for the color of the upper soil layer, the values for BD+ were lower at all locations (a low value indicates better soil structure) than for BD-, and for the average values of all Locations for these parameters the differences were highly significant (Table 5 and Figure 1).

At three of four locations, root penetration was better (lower scores) with the BD+ treatment than with the BD- treatment (Figure 2). When all locations were evaluated, the difference between treatments was significant. The structure of the surface, topsoil and subsoil was better with the BD+ treatment at all locations with lower values than with BD-. When the four locations were evaluated for these parameters, the differences were significant to highly significant (Figures 2 to 5).

Discussion – Biodynamic preparations

The use of the biodynamic preparations horn manure (500P) and horn silica (501) did not lead to significant differences in aggregate stability. However, when visually assessing the soil, there were significant improvements in the soil structure in 7 out of 10 parameters through the use of BD preparations (BD+) compared to without preparations (BD-). In the statistical analysis, the differences between BD+ and BD- were most noticeable in the soil color of the upper horizon and in the structure of the topsoil and subsoil (Table 2, Figures

The drop test results for the topsoil and subsoil showed similar trends to the results for the structure of the topsoil and subsoil in the study (Table 2, Figures 3 and 4). Guimarães et al. (2011) compared the normal assessment of soil structure with the assessment after breaking the clod through drop tests and reported that the normal assessment of soil structure or assessment of the soil after the fall also gave the same result. In the study reported here, normal assessment of soil structure resulted in a statistically clearer distinction between the BD- and BD+ treatments.

Other parameters were also examined using the same soil samples as in the present study. The results were published by Fritz et al. (2020) reported. These results showed that for the parameters bulk density, carbonate, proportion

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of soil organic carbon (SOC), total N, soil C/N, microbial carbon (MBC), microbial nitrogen (MBN), ergosterol and CO_2 C (basal respiration rate) no significant differences between BD and BD+ gave. However, significant differences were found between the BD+ and BD- treatments in soil pH, microbial carbon to microbial nitrogen ratio (MB-C/N), microbial carbon to soil organic carbon ratio (MBC/SOC) and found in 16 of 18 substrates in the "Multi Substrate induced Respiration" study (the soil is offered 18 different substrates and the respective CO_2 respiration is measured). These are parameters that are indicators of sensitive and variable microbiological soil processes.

Based on the data presented by Fritz et al. (2020) results, the hypothesis was developed that the use of biodynamic preparations has significant effects on the microbial community of the soil.

A long-term experiment in Darmstadt showed that biodynamic cultivation led to more efficient use of organic carbon in the soil by microbes compared to organic cultivation (the only difference was the use of biodynamic preparations) (Sradnick et al. 2013). In the long-term DOK experiment in Switzerland, a biodynamic farming system (compared to a non-biodynamic system, ie a system comparison in which the differences between the systems were not just in the use of biodynamic preparations) led to a better use of coal material through the microbial biomass, to higher biological activity, higher values of more stable organic matter and higher values of organic carbon in the soil and microbial carbon (Mäder et al. 2002; Fließbach et al. 2007; Birkhofer et al. 2008). In the same DOK experiment in Switzerland it was also shown that the biodynamic system has an influence on the microbial community in the soil (Hartmann et al. 2015). Higher biological activity in soil in response to the application of horn manure and horn silica was also reported by Jukneviÿienÿ et al. (2019) and Vaitkeviÿienÿ et al. (2019) reported in three-year trials with pumpkins and potatoes. Burns et al. (2016) also reported that the bacterial diversity and composition in the soil of vineyards was different when comparing biodynamic and biological systems (also in a system comparison experiment).

Studies have shown that the use of biodynamic preparations had a balancing effect in unfavorable growth conditions (Raupp and König 1996), influenced the activity of microorganisms in the soil (Fritz et al. 2020), and influenced the yield (Spiess 1978; Vaitkeviÿienÿ et al. 2019; Jukneviÿienÿ et al. 2019), the content of secondary plant substances (Jukneviÿienÿ et al. 2021) and the germination of the seeds in the following generation (Fritz and Köpke 2005). These effects are indications of better self-regulation of plants in the form of increased resilience (Schneider and Ullrich 1994; Döring et al. 2015b).

Fig. 1: Visible differences between the variants

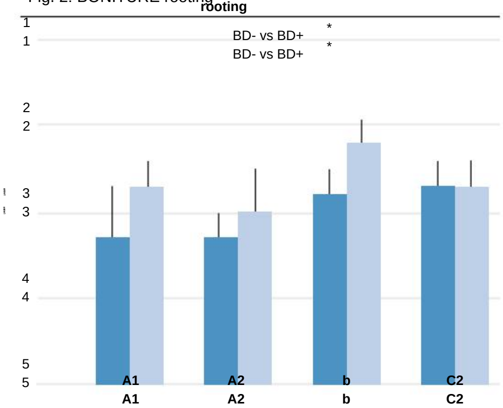

Fig. 2: BONITURE rooting

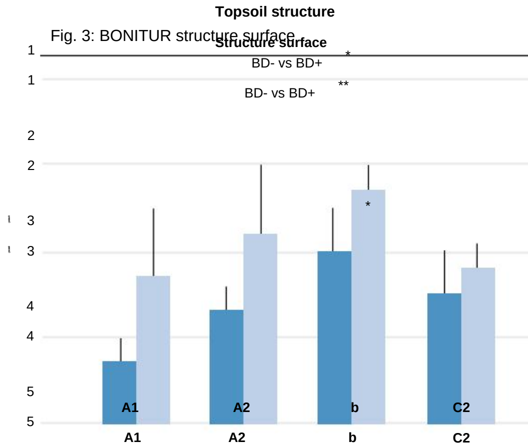

Fig. 3: BONITUR structure surface

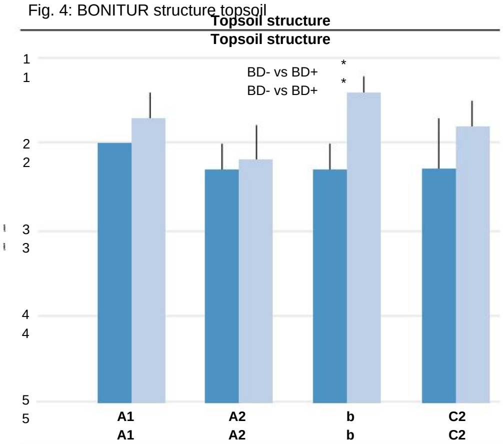

Fig. 4: BONITUR structure topsoil

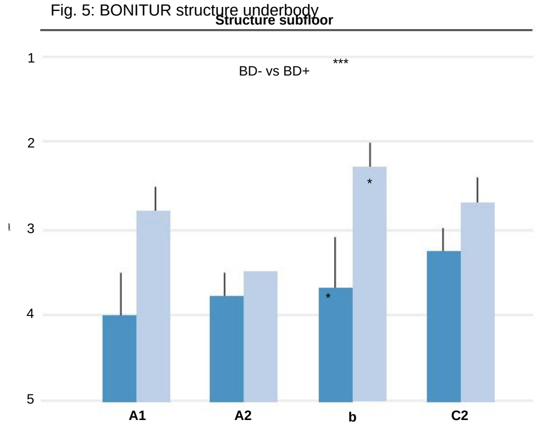

Fig. 5: BONITUR structure underbody

structure at four wine-growing locations (A1;A2;B;C2) without (BD-) and with the use of biodynamic preparations (BD+).

The statistical evaluation between the mean of the four locations is in the Figures labeled BD- vs. BD+ (t-test).

Stars indicate significant differences BD+ treatments (: P < 0.05; **: P < 0.01; ***: P < 0.001).*

Rating values from 1 to 5 (1 = best structure; 5 = worst structure)

The lines on the bars show the standard deviation.

Hypothesis on how it works biodynamic preparations

The application quantities of the biodynamic preparations are very low (100 g/ha of fermented cow dung and 4 g/ha of quartz powder per treatment for horn manure or horn pebbles). A nutrient effect as the cause of the effect on the soil structure observed in this study can therefore be excluded. There are various models to explain the effect of biodynamic preparations. One explanatory model is that the preparations influence the microbial communities in the soil and have a regulating effect. For example, bacteria can detect and respond to extremely low concentrations of signaling molecules such as carbohydrates and peptides. These can arise from micro-robially mediated slow maturation under oxygen deficiency conditions during the production of the preparations (Spac-cini et al. 2012). This could lead to increased microbial contamination

Activity in the rhizosphere (Reeve et al. 2010; Giannattasio et al. 2013) or lead to the stimulation of natural defenses (Schneider and Ullrich 1994; Botelho et al. 2015).

Ortiz-Álvarez et al. (2020) found that fungal networks in soils from biodynamically managed vineyards worked together more closely (clustering), formed fewer autonomous groups in collaboration (modularity) and had a lower proportion of mutually negative interaction (co-exclusion), compared to soils from organic and conventional vineyards. These characteristics of biodynamic soils were considered to be beneficial for a high suppressive effect of the soil against pathogens and for a high resilience potential of the soil. From Ortiz-Álvarez et al. (2020) this was summarized as follows: "Based on this, we can hypothesize that fungal communities that form in small-scale and collaborative networks, as they are managed in biodynamic

Soils that are found in well-developed soils are more resilient to the constantly changing environmental conditions caused by climate change and land use.

Another complementary explanatory model for bacterial regulation is that the biodynamic preparations work via hormonal effects. For example, in horn manure preparations

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Bacterial strains have been detected that produce indoleacetic acid (Radha and Rao 2014), and this preparation has also been reported to contain undegraded lignin residues that have similar activity to indoleacetic acid (Spaccini et al. 2012). Giannatta-sio et al. (2013) found strong auxin-like effects in horn manure and Fritz (2000) reported gibberellic acid-like effects in horn silica. Significant differences between the BD+ and BD- treatments in the results of the "Multi Substrate induced respiration" method (see text above; Fritz et al. 2020) supported the hypothesis that the microbial community plays a role in the effects of horn manure and horn silica preparations. Changes in microbial community activity may have been the cause of changes in soil structure in the BD+ treatment compared to the BD- treatment.•

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