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INFLUENCE OF ORGANIC FERTILIZATION WITH VITIVINICULTURAL BY-PRODUCTS ON VINE GROWTH AND FRUIT BEARING IN THE CODRU WINE-GROWING REGION

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Abstract

This study investigates the influence of organic fertilization using vitivinicultural by-products on vine growth and fruit bearing in the Codru wine-growing region. The research was conducted in the locality of Cricova, Republic of Moldova, using the wine grape variety Pinot Noir. The experimental design included three treatment variants: an unfertilized control, application of dried grape seeds, and organic fertilization with compost obtained from grape pomace mixed with cattle manure at a 1:1 ratio. Throughout the vegetation period, vine growth and fruiting parameters, overall plant condition, and cluster development were systematically monitored in relation to soil characteristics and agroclimatic conditions. The results revealed noticeable differences among the tested variants, indicating that the use of vitivinicultural by-products as organic fertilizers may support vine growth dynamics without negatively affecting vine productivitycan positively influence vine growth dynamics. The study highlights the potential of valorizing these by-products in sustainable viticulture and supports the implementation of circular economy principles within wine-growing systems.

Key words*: fruit bearing, organic fertilization, Pinot Noir, sustainable viticulture, vitivinicultural by-products.*

INTRODUCTION

Global wine production generates millions of tons of winery by-products annually, highlighting a significant waste management challenge (OIV, 2023). Within this context, the European Green Deal promotes resource efficiency and waste reduction across agricultural systems (European Commission, 2019). Vitivinicultural by-products, particularly grape pomace, are increasingly recognized as valuable resources within circular economy models (Beres et al., 2017; Provenzano et al., 2024). Composting has been identified as an effective approach for recycling these residues and improving soil fertility (Carmona et al., 2022). Grape pomace is rich in organic carbon, nutrients, and bioactive compounds such as phenolics, while winery residues also contain structural components including cellulose and hemicelluloses (Buchmann et al., 2025; Rockenbach et al., 2011; Spigno et al., 2008). Grape pomace is increasingly recognized as a sustainable source of bioactive compounds with potential applications in agriculture and other value-added sectors (Karastergiou et al., 2025). Its application enhances soil organic matter, microbial activity, and nutrient availability (Teixeira et al., 2014; Galantini et al., 2021; Bhatta et al., 2021). Consequently, organic fertilization supports sustainable viticulture and may improve vine growth and productivity (Pascual et al., 2022; Riva et al., 2023; Ferrara et al., 2020; Santos et al., 2020) , with similar approaches also reported under local vineyard conditions (Visanu, 2022).

MATERIALS AND METHODS

Study area and experimental design

The study was carried out during the 2025 vegetation period in the Codru wine-growing region of the Republic of Moldova.

The experimental vineyard was planted with Pinot Noir under local production conditions. The site was located at an altitude of approximately 160-195 m (Figure 1), with a slope of 3-6° and north-east/east exposure. The soil was classified as typical clay-loam chernozem, with pH 8.4, 38-40% physical clay, mobile phosphorus 2.5 mg 100 g^{-1} soil, and mobile potassium 15.4 mg 100 g^{-1} soil. The planting scheme was 2.5 × 1.2 m (about 3333 vines ha^{-1}).

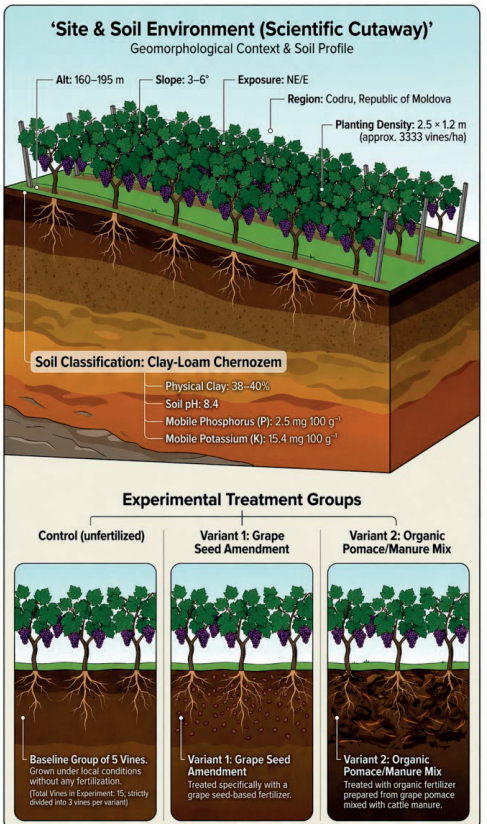

Figure 1. Experimental design and site characteristics of the Pinot Noir vineyard, including soil profile and treatment structure in the Codru wine-growing region (Republic of Moldova)



Figure 2. Application of organic fertilizer derived from grape pomace at a depth of 25-30 cm in the experimental vineyard

The experiment included 75 vines, distributed into three treatments with 25 vines per variant:
Control (unfertilized) - without fertilization;
Variant 1 - fertilization with grape seed-based fertilizer;
Variant 2 - fertilization with organic fertilizer prepared from grape pomace mixed with cattle manure.

Agroclimatic conditions

The agroclimatic conditions during the 2025 vegetation period were characteristic of the temperate continental climate of the Codru wine-growing region. Meteorological data were obtained from the vineyard weather monitoring system used for disease-climate monitoring.

Air temperature gradually increased from early spring, with mean values rising from approximately 10-12°C in April to peak summer temperatures exceeding 25-30°C during July and August. From September onward, temperatures progressively declined, reaching approximately 8-12°C by the end of October.

Relative air humidity showed notable fluctuations throughout the vegetation period, frequently exceeding 70-80%, particularly during late spring and early summer. Several precipitation events occurred mainly between May and September, contributing to moderate soil moisture conditions during the main stages of vine development.

Soil temperature followed a seasonal pattern similar to that of air temperature, increasing from approximately 8°C in early spring to about 24-26°C during midsummer before gradually decreasing in autumn. These climatic conditions provided a suitable thermal regime for vine vegetative growth and reproductive development during the study period.

Preparation of organic fertilizer

The organic fertilizer used in Variant 2 was prepared from grape pomace obtained from Mireşti Mici winery, originating from the cultivars Rara Neagră, Fetească Neagră, and Merlot. A 100 g reference sample showed the following composition: 65.43 g skins, 23.3 g seeds, and 8.82 g stems.

Before composting, preliminary tests were carried out to evaluate the extractability of soluble and phenolic compounds. Distilled water was used to observe the release of water-soluble components and to adjust the material moisture. A second test was performed using Histanol 100 (an ethanol-based solution), which produced a dark red extract, indicating a stronger dissolution of phenolic compounds.

The material was also heated to approximately 68°C to facilitate the release of active components.

After this preliminary stage, the pomace was mixed with cattle manure at an approximate 1:1 ratio and composted under natural outdoor conditions during the early vegetation period. During this period, the heap was manually turned about four times, and water was added twice. Due to the relatively short composting period, the resulting material was considered a partially stabilized organic fertilizer.

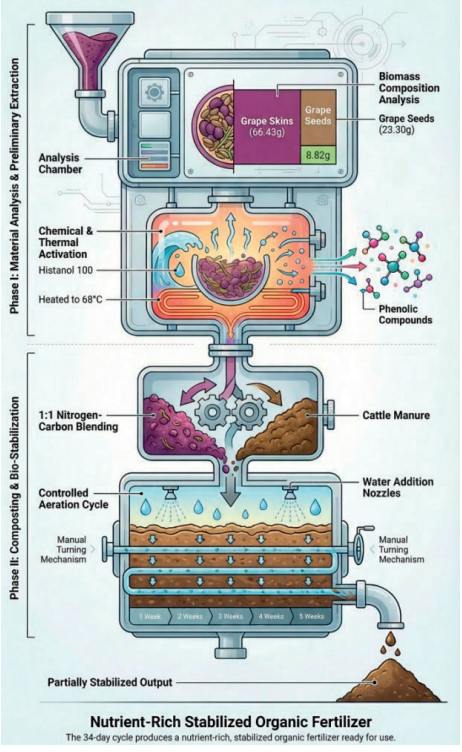

Figure 3. Processing pathway for the transformation of grape pomace into organic fertilizer, including preliminary extraction, thermal activation, and composting stages

Fertilizer application and measured indicators

The treatments were applied manually during the vegetation period at an approximate depth of 25-30 cm (Figure 2), then covered with soil. The application dose was about 3-4 kg vine^{-1}, corresponding to approximately 10-13 t ha^{-1}.

To evaluate the effect of the treatments, a set of vegetative and reproductive parameters was recorded during the vegetation period. These included structural indicators related to vine load (number of spurs, number of canes, number of buds per spur, and number of buds per cane), vegetative development indicators (number of buds that started growth and number of shoots from dormant buds), and reproductive indicators (number of fertile shoots and inflorescences from winter buds and dormant buds).

At harvest, grape yield was also recorded and expressed as kg vine^{-1}. The mean yield values were 1.71 kg vine^{-1} for the control, 1.59 kg vine^{-1} for Variant 1, and 1.73 kg vine^{-1} for Variant 2.

The processing steps of grape pomace transformation into organic fertilizer are illustrated in Figure 3.

Statistical analysis

The data were processed using descriptive statistics and one-way ANOVA. For each indicator, the mean, standard deviation, F value, and p value were calculated. Differences were considered significant at $p < 0.05$.

RESULTS AND DISCUSSIONS

The vegetative and reproductive indicators of Pinot Noir under different fertilization treatments are presented in Table 1, while fertility coefficients, fertility indices, and yield data are summarized in Table 2 and illustrated in Figure 4.

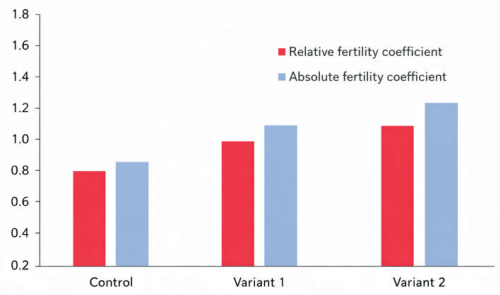

Figure 4. Relative and absolute fertility coefficients of Pinot Noir under different fertilization treatments in the Codru wine-growing region

In general, the structural parameters of the vines, including the number of spurs, number of canes, number of buds per spur, and number of buds per cane, showed only moderate variation among treatments. No statistically significant

differences were observed ($p > 0.05$), indicating that the tested fertilization strategies did not disturb the vine structural balance during the first year after application.

A similar pattern was recorded for the number of buds that started growth and the number of shoots from dormant buds, which remained relatively stable across treatments.

Slight differences were observed in the reproductive indicators among treatments. The number of fertile shoots from winter buds increased from 11.60 in the control to 16.00 in Variant 1 and 18.25 in Variant 2. The number of inflorescences on shoots from winter buds followed the same tendency, rising from 14.20 in the control to 23.60 in Variant 1 and 30.25 in Variant 2. Although these differences were not statistically significant ($p > 0.05$), Variant 2 consistently showed the highest reproductive values. A similar tendency was observed for the indicators associated with dormant buds, where Variant 2 recorded higher values for both fertile shoots and inflorescences. The fertility coefficients and indices further supported this tendency. As shown in Figure 4, the relative fertility coefficient increased from 0.798 in the control to 1.372 in Variant 1 and 1.476 in Variant 2, while the absolute fertility coefficient increased from 1.224 to 1.475 and 1.658, respectively. The fertilized treatments generally showed higher fertility indices compared with the control, indicating a favorable tendency in reproductive potential.

Table 1. Effect of fertilization treatments on vegetative and fruit-bearing indicators of Pinot Noir in the Codru wine-growing region

Indicator	Control (Mean ± SD)	Variant 1 (Mean ± SD)	Variant 2 (Mean ± SD)	F value	P value
Number of spurs:	4.40 ± 2.07	3.80 ± 1.30	4.00 ± 1.63	0.175	0.842
Number of canes:	4.00 ± 1.22	2.60 ± 0.55	3.50 ± 1.29	2.476	0.126
Number of buds per spur:	8.80 ± 4.97	8.80 ± 3.90	9.00 ± 4.24	0.004	0.996
Number of buds per cane:	19.40 ± 5.03	13.60 ± 3.36	18.25 ± 7.93	1.690	0.226
Number of buds that started growth:	17.80 ± 6.76	17.20 ± 6.87	20.50 ± 9.40	0.294	0.750
Number of fertile shoots from winter buds:	11.60 ± 10.41	16.00 ± 7.11	18.25 ± 7.54	0.857	0.449
Number of inflorescences on shoots from winter buds:	14.20 ± 11.43	23.60 ± 12.50	30.25 ± 15.92	2.058	0.170
Number of shoots from dormant buds:	6.40 ± 3.05	6.20 ± 2.28	6.50 ± 3.51	0.015	0.985
Number of fertile shoots from dormant buds:	3.20 ± 3.27	3.40 ± 2.07	6.25 ± 6.40	0.964	0.409
Number of inflorescences on fertile shoots from dormant buds:	4.20 ± 4.38	3.80 ± 3.49	4.50 ± 3.42	0.046	0.955

Overall, the fertilized treatments demonstrated a more favorable reproductive tendency than the control, particularly the treatment based on composted grape pomace mixed with cattle manure.

Yield data supported this interpretation. The mean yield per vine was 1.71 kg in the control, 1.59 kg in Variant 1, and 1.73 kg in Variant 2. Thus, the highest productivity was recorded in Variant 2, which corresponded with the highest fertility coefficients and indices. Although yield differences were relatively small, the pomace-based treatment showed a slightly improved fruit-bearing potential compared with the control.

Table 2. Fertility coefficients, fertility indices, and yield of Pinot Noir under different fertilization treatments

Parameter	Control	Variant 1	Variant 2
Relative fertility coefficient	0.80	1.37	1.48
Absolute fertility coefficient	1.22	1.48	1.66
Relative fertility index	97.26	155.00	152.12
Absolute fertility index	149.24	166.63	170.88
Mean yield (kg vine^{-1})	1.71	1.59	1.73

These results may be related to the expected effects of organic amendments on soil fertility. Grapevines annually remove significant quantities of nutrients from the soil through biomass production and fruit development from the soil, including nitrogen, phosphorus, and potassium (Visanu, 2022). Previous studies have shown that grape pomace-based materials can improve soil organic matter, stimulate microbial activity, and enhance the availability of essential nutrients, which may indirectly support vine vigor and reproductive performance. In the present study, the pomace-based fertilizer did not negatively affect vine growth and showed the most favorable tendency in reproductive indicators and yield.

However, the compost applied in this experiment was only partially stabilized, as it was produced under natural outdoor conditions and composted for 34 days. Therefore, strong short-term responses were not necessarily expected. In addition, although the number of

vines per treatment was limited, the experiment still provided useful preliminary observations on the effect of organic fertilization, which may have limited the statistical power of the analysis. Nevertheless, the absence of negative effects and the favorable tendency observed in Variant 2 suggest that grape pomace mixed with cattle manure can represent a feasible organic fertilization strategy for vineyards in the Codru wine-growing region.

CONCLUSIONS

This study evaluated the influence of organic fertilization using vitivinicultural by-products on the vegetative growth and fruit-bearing performance of Pinot Noir cultivated in the Codru wine-growing region of the Republic of Moldova.

The results showed that the applied fertilization treatments did not significantly affect the structural vegetative parameters of the vines during the first year after application. Indicators such as the number of spurs, canes, and buds per spur and cane remained relatively stable across treatments, suggesting that the applied organic fertilizers did not disrupt the vegetative balance of the vines.

However, some reproductive indicators showed a favorable tendency in the fertilized variants. In particular, the treatment based on composted grape pomace mixed with cattle manure (Variant 2) recorded higher values for the number of fertile shoots and inflorescences compared with the control treatment.

Yield data followed a similar trend, with Variant 2 presenting the highest mean yield per vine (1.73 kg vine^{-1}). Although the differences among treatments were not statistically significant, the results indicate that the application of grape pomace-based organic fertilizer did not negatively affect vine productivity and may contribute to improved fruit-bearing potential.

Overall, the findings suggest that composted grape pomace mixed with cattle manure can represent a viable organic fertilization strategy for vineyards in the Codru wine-growing region. Further research conducted over multiple growing seasons and larger experimental plots is necessary to better understand the long-term effects of these fertilization practices on soil fertility, vine physiology, and grape yield.

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