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IMPROVING SOME STEPS OF GRAPEVINE GROWING TECHNOLOGIES TO REDUCE PRODUCTION COSTS

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Abstract

Grapevine growing technologies require continuous adjustments to both climate instabilities and, in particular, current viticulture issues such as a sharp increase in prices for the vast majority of inputs and an increasing difficulty in finding labour at reasonable prices. The research focuses on a varietal assortment of five cultivars, as well as the main technological sequences of grapevine growing that require a significant amount of manual labour or inputs, such as soil management and summer pruning and activities. The influence of the experimental variants both on grape production and especially on the economic indicators was monitored. For each technological sequence, several experimental variants with different complexity were tried, adaptable to each vineyard with various technological and financial possibilities. In these circumstances, Romanian vineyards must align their organization, management, and growing technologies in order to compete with products from other countries for quality and price. To achieve this goal, in addition to ongoing organization and documentation, it is necessary to select technological options that allow for high-tech mechanization which is critical for lowering costs while still maintaining grape quality and lowering carbon emissions.

Key words*: grapevine, grapes, wines, quality, profit.*

INTRODUCTION

Grapevine growing technologies changed and improved continuously over time, especially as they became more intensive (Delrot et al., 2020). Today, grapevine growing technologies must be updated to reflect the current issues facing humanity in general and viticulture in particular, such as the difficulty to find qualified manual labour, the excessive increase in the price of most inputs due to the energy crisis, the urgent need to reduce soil and environmental pollution, and to decrease carbon emissions (Campbell, 2019). Last but not least, winemakers must contend with the extraordinary competition on the wine market, which sometimes exceeds legal boundaries (Wilson & Winchester, 2019). Soil management is a major component of production costs, with significant implications for grape production, soil quality, and environment sustainability (Lazcano et al., 2020). It is impossible to develop a technology framework with broad application due to the large climate variability, soil, and technological diversity in which grapevine is grown (Biasi et al., 2019). Growing technologies must be applied differently in accordance with the climate and economic realities, as well as the challenges in finding qualified labour (Chedea et al., 2021; Cichi et al., 2021). Furthermore, recently were recorded unprecedented price increases for the large majority of inputs, particularly fuels, fertilizers, and fungicides (Cataldo et al., 2021). All of these factors have determined major changes in both Romanian and global viticulture technology (Rahoveanu, 2021). The new technologies emphasis mechanization to counterbalance as much as possible for the shortage of manual labour and higher costs, a reasonable, balanced use of pesticides and fertilizers, carbon emissions mitigation by reducing soil and environmental pollution, correlated with high quality, healthy, and pesticide-free grapevine by-products obtained at a lower cost to be more competitive on the challenging international wine market (Clemens et al., 2018; Sun et al., 2022). In addition to the previously mentioned barriers, there is also the challenge of joining and, more

importantly, surviving on a competitive wine market that has experienced powerful competition from both new world of wine as well as from European countries with tradition in viticulture, which offer high-quality wine by-products, sometimes at unbelievably low prices (Durmaz et al., 2019).

MATERIALS AND METHODS

The research was carried on in a young vineyard at the beginning of the full maturation in the Buziaș-Silagiu Viticultural Center from western Romania, during the growing season 2021 (typically favourable year for grapevine growing). In order to identify the most feasible solution in the existing environment which is characterized by the necessity to decrease carbon emissions, the overstated price increases for most inputs, and the increasing difficulty in finding labour, the improvement of the main technological sequences in grapevine growing technology was studied. The vineyard where the research was carried out is situated on a southern-exposed plot with a slope of 5-7%; planting distances were 2.2 m between rows and 1 m between vines per row, with a density of 4545 plants per hectare. The vines were trained as simple Guyot, with one or two one-year-old canes. The experimental variants for vineyard soil management were: S1 - complex variant (autumn and spring ploughing, 3 mechanical harrows per row, 3 mechanical harrows between rows); S2 - medium complexity (autumn ploughing, 2 mechanical harrows on row, 2 mechanical harrows inter-rows; S3 (Control) - lower complexity (autumn ploughing, rotary tillage and weeding); S4 - minimum complexity (two mowings of the cover crop and one ploughing every 2 years). The experimental variants for the improvement of pruning and training during the growing season were: P1 - complex (shoot thinning, tying, desuckering, and shoot trimming); P2 (Control) - medium complexity (shoot thinning, desuckering, and shoot trimming); P3 - reduced complexity (two mechanical trimming); and P4 - minimal complexity (one mechanical trimming). Five wine grape varieties - Cabernet Sauvignon, Feteasca neagra, Merlot, Feteasca regala, and Italian Riesling - with diverse biological characteristics and growth rates were the subjects of the research. The production obtained and the key economic indicators were observed and determined in experimental variants (production expenses, expenses for the experimental variant, cost price, grape production value and profit). Each experimental variant had four rows of vines. The samples for observations and analyses were collected from the rows in the middle of the experimental block. The vine row was approximately 250 meters long and divided into three plots, each with 20 vines (three replicates). The control variant in both experiments was chosen as the standard technological variant used in the plantation. It was analyzed how yields, costs, and economic indicators changed during the growing season 2021. All data on variable costs and expenses for cultivation operations were collected. Statistical analyses were used to clarify the research results and also to determine the correlations and regressions for economic indicators. A factorial analysis of variance and the Tukey test were used with Microsoft Excel, version 16.18, (180903) 2019, to compare the factor levels at significance $p < 0.05$. Averages per treatment were calculated for all parameters measured and used in statistical analyses. To summarize the main features of data distribution, descriptive statistics were computed for the variables under study.

RESULTS AND DISCUSSIONS

The soil maintenance system is an important technological step that has a significant impact on production, quality, carbon emissions, and last but not least, the major economic indicators. The need to decrease costs without compromising the quantitative and qualitative production parameters, the physical and chemical characteristics of the soil, or reducing carbon emissions to the minimum level has forced soil management to undergo continuous change. An important technological sequence, with major influence on production, quality, and carbon emissions and last but not least on the main economic indicators, is represented by the soil maintenance system. In last decades, soil management is in a continuous change and search, for the optimal option, imposed by the current needs to reduce costs, without affecting

the quantitative and qualitative parameters of grape production, the physical-chemical properties of the soil, and to decrease to the minimum possible the carbon emissions.

Table 1. Soil management influence on grape production during 2021 growing season

Indicator	Variety	Experimental variants			
		S1 (± SD)	S2 (± SD)	S3 (Control) (± SD)	S4 (± SD)
Grape production (kg/ha)	Cabernet Sauvignon	10775±441	10345±506	9745±426	9220±411
	Feteasca neagra	9987±412	9526±415	8941±321	8383±305
	Merlot	9534±409	9105±398	8618±304	7815±296
	Feteasca regala	12575±582	12324±572	11765±527	10912±421
	Italian Riesling	11961±534	11683±514	10984±452	10268±398
Difference from control (kg/ha)	Cabernet Sauvignon	1030±93**	600±41*	-	-525±35*
	Feteasca neagra	1046±81**	585±37*	-	-558±33*
	Merlot	916±73**	487±29	-	-803±62**
	Feteasca regala	810±61*	559±38ns	-	-853±69*
	Italian Riesling	977±76**	699±49*	-	-716±51*

(ns, not significant; *, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$)

In order to save fuel and minimize greenhouse gas emissions, many vineyards have reduced soil tillage with agricultural machinery.

The reduction of soil loosening works to a minimum in the fourth variant also resulted in the lowest productions, with differences depending on the variety, ranging from 853 kg per hectare for the Feteasca regala variety to 525 kg per hectare for the Cabernet Sauvignon variety (Table1). The S1 with the most soil tillage works produced the highest yields; differences from the control fluctuated depending on the variety, ranging from 810 kg per hectare for the Feteasca regala variety to 1046 kg per hectare for the Feteasca neagra variety. All varieties reacted by reducing their output in direct correlation with the reduction of soil works (most of the differences were statistically significant).

In all varieties, the control variant produced reasonable grape yields by applying a minimum number of soil tillage; therefore it was a balance option between carbon emissions as low as possible and an acceptable production of grapes.

Table 2. Influence of vineyard soil management on economic indicators during 2021 growing season

Economic indicator	**Variety**	**Variants of vineyard soil management**			
		S1	**S2**	**S3 (Control)**	**S4**
Total production cost (euro/ha)	Cabernet Sauvignon	2720	2638	2494	2440
	Feteasca neagra	2835	2753	2609	2555
	Merlot	2560	2478	2334	2280
	Feteasca regala	2680	2598	2454	2400
	Italian Riesling	2590	2508	2364	2310
Costs with soil management variants (euro/ha)	Cabernet Sauvignon	462	380	236	182
	Feteasca neagra	462	380	236	182
	Merlot	462	380	236	182
	Feteasca regala	462	380	236	182
	Italian Riesling	462	380	236	182
Grape production value (euro/ha)	Cabernet Sauvignon	6530	6270	5906	5588
	Feteasca neagra	6053	5773	5419	5081
	Merlot	5778	5518	5223	4736
	Feteasca regala	5588	5447	5229	4850
	Italian Riesling	5316	5192	4882	4576
Cost price (euro/ton)	Cabernet Sauvignon	252	255	256	265
	Feteasca neagra	284	289	292	305
	Merlot	268	272	271	292
	Feteasca regala	213	211	208	220
	Italian Riesling	216	215	215	225

Gross profit (euro/ha)	Cabernet Sauvignon	3810	3632	3412	3148
	Feteasca neagra	3218	3020	2810	2526
	Merlot	3218	3040	2889	2456
	Feteasca regala	2908	2849	2775	2450
	Italian Riesling	2726	2684	2518	2266

However, the minimally invasive technologies cannot compete with the intensive variants regarding the level of grape production.

Different subsidies are imposed to compensate farmers for lower grape production in order to practise less polluting viticulture, because the higher price for organic products is not easily accepted by consumers on the Romanian market.

The analysis of the influence of soil maintenance variants on economic indicators (Table 2) produced distinct findings for each indicator. Obviously, less tillage decreased production costs. Therefore, the variant with the least tillage (S4) in all varieties resulted in a 300-euro-per-hectare decrease in grape production costs. The control variant also had a reasonable level of production costs for soil works, which were decreased by more than 200 Euros per hectare when compared to the most complex S1 variant. For soil management, the expenses with the experimental variant ranged from 462 Euros per hectare for the S1 to 182 Euros per hectare for the S4.

As the number of soil works decreased, the cost per tonne of grapes increased proportionally. The difference in grape production influenced the cost price to decrease, not the total cost of grape production. Although there were significant differences in grape production between the complex variant S1 and the less intensive variants S2 and S3, Feteasca Regala was the only variety where less tillage resulted in lower costs. The profit was correlated with the complexity of the soil works, and the level of production achieved in the intensive variants had an impact on the profit.

According to similar studies, Akdemir (2022) found that the experimental variants where soil tillage was done by machines recorded the highest values of profit per hectare. Also, Borca et al. (2020) found that less vineyard floor management resulted in lower production costs for six wine grape varieties in the Silagiu vineyards. Nan et al. (2021) validated the evidence, that complex soil works generate a higher profit, by showing that soil management through tillage and herbicides yielded a higher income than bare soil, in two wine grape varieties, Chardonnay and Fetească neagră, respectively.

Summer canopy management is another technological sequence that has significantly changed in recent years, due mainly to the manual labour availability (Bucur, 2021); depending on the technological option chosen, this sequence has a significant impact on grape production. Although the P1 - the variant with many summer canopy management interventions, some of them entirely manual - provided the highest grape production for all varieties, it is now used less frequently in vineyards because it is nearly impossible to ensure the necessary workforce, particularly in large vineyards (Table 3).

Tabel 3. Canopy management influence on grape production during 2021 growing season

Variable	Variety	Experimental variant			
		P1 (±SD)	P2 (Control) (±SD)	P3 (±SD)	P4 (±SD)
Grape production (kg/ha)	Cabernet Sauvignon	11256±527	10930±438	10456±399	9625±436
	Feteasca neagra	10653±452	10124±412	9211±418	8850±316
	Merlot	9783±411	9308±403	8724±335	8115±299
	Feteasca regala	12743±563	12491±579	11935±527	11317±504
	Italian Riesling	11992±519	11691±513	10815±449	10393±438
Difference from the control (kg/ha)	Cabernet Sauvignon	326±18^{ns}	-	-474±28^{ns}	-1305±91***
	Feteasca neagra	529±37*	-	-913±71**	-1274±97***
	Merlot	479±28*	-	-580±40*	-1189±83**
	Feteasca regala	252±11^{ns}	-	-556±31^{ns}	-1174±76**
	Italian Riesling	301±14^{ns}	-	-876±59*	-1298±81**

(ns, not significant; *, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$)

The P2 (control variant) is ideal for small vineyards that cannot afford to invest in mechanical canopy management equipment. Summer canopy management was reduced by half in P2 compared to P1; grape production was satisfactory even though it was declining, with differences between 251 kg on hectare for the Feteasca regala variety and 529 kg on hectare for the Feteasca neagra variety. The lowest productions for all varieties were found in the P3, with two mechanical trimming, and P4 with one mechanical trimming for canopy management.

The P3 variant, however, can be a viable alternative to most varieties, with production differences of several hundred kilograms recorded, compared to the control. In the Cabernet Sauvignon, Fetească Regală, and Italian Riesling varieties, summer canopy management interventions (P1) did not result in significant increases in production to justify their costs. However, mechanized pruning had a significant negative impact on grape production for the majority of varieties.

During summer canopy management, the variants were classified similarly to those for soil management in order to evaluate economic indicators (Table 4). The mechanical canopy management reduces expenses significantly for the P3 and especially for the P4. In Feteasca neagra, for instance, expenses for canopy management, decreased from 325 Euros on hectare in the P1 to 160 Euros in the P3, and 80 Euros in the P4. In the summer canopy management, the level of production had a higher impact on the cost price and profit than did the level of expenses. Because the quality of mechanized works is still lower than that of manual ones, it is necessary to continually improve the machines used to optimize these activities (Wang et al., 2019; Gil et al., 2022). Scheduling the canopy management over an extended period of time (May-September), an interval that overlaps with holidays as well as the summer heat, makes it impossible to provide enough manual labour, especially in the current economic and social context (Somkuwar et al., 2019). For these reasons, the majority of vineyards are forced to carry out mechanized canopy trimming, which requires the purchase of special machines and equipment whose prices have recently increased significantly (Kurtural et al., 2021).

Table 4. Influence of canopy management on economic indicators during 2021 growing season

Economic indicators	Variant	Variants for canopy management			
		P1	P2 (Control)	P3	P4
Total production cost (euro/ha)	Cabernet Sauvignon	2643	2603	2483	2403
	Feteasca neagra	2763	2718	2598	2518
	Merlot	2478	2438	2323	2243
	Feteasca regala	2593	2553	2443	2363
	Italian Riesling	2508	2468	2353	2273
Costs with canopy management variants (euro/ha)	Cabernet Sauvignon	320	280	160	80
	Feteasca neagra	325	280	160	80
	Merlot	315	275	160	80
	Feteasca regala	310	270	160	80
	Italian Riesling	315	275	160	80
Grape production value (euro/ha)	Cabernet Sauvignon	6822	6624	6337	5833
	Feteasca neagra	6456	6136	5582	5364
	Merlot	5929	5641	5287	4918
	Feteasca regala	5663	5552	5304	5030
	Italian Riesling	5330	5196	4805	4619
Cost price (euro/ton)	Cabernet Sauvignon	235	238	237	249
	Feteasca neagra	259	268	282	284
	Merlot	251	262	266	276
	Feteasca regala	203	204	205	209
	Italian Riesling	209	211	217	219
Gross profit (euro/ha)	Cabernet Sauvignon	4179	4021	3854	3430
	Feteasca neagra	3693	3418	2984	2846
	Merlot	3451	3203	2964	2675
	Feteasca regala	3070	2999	2861	2667
	Italian Riesling	2822	2728	2452	2346

Schütte et al. (2020) investigated the cost distribution in grape production and discovered that labour accounts around half of the winery budget, followed by machinery costs and closely followed by chemicals, and this can be attributed to higher quality grapes that involve more pruning and canopy management.
Figure 1 shows the different grape production of the five varieties based on tillage and canopy management. Overall, the Feteasca regala yielded the most grapes, followed by Italian Riesling. Regardless of soil or canopy management, the Merlot variety produced the fewest grapes, while the Feteasca neagra variety produced slightly more. Of the four varietals, Cabernet Sauvignon had the most balanced grape production.

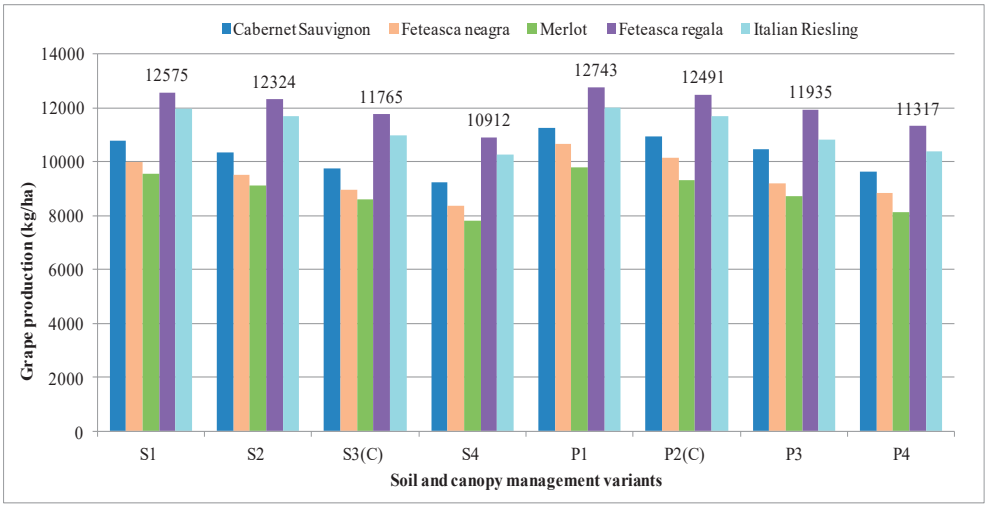

Figure 1. Soil and canopy management influence on grape production during 2021 growing season

Compared to the other soil and canopy management variants, the variant with two mowings of the cover crop and one ploughing every two years (S4), and one mechanical trimming (P4) had the lowest grape production. The highest grape yields were obtained when the soil was ploughed in the autumn and spring, supplemented with three mechanical harrows per row and three mechanical harrows between rows, correlated with canopy management through shoot thinning, tying, desuckering, and shoot trimming. Zumkeller et al. (2022) investigated the effect of reduced tillage and cover crops and discovered that, contrary to the presented results, the productive response of the vine and the grape production remains unclear.

CONCLUSIONS

For all grape varieties investigated, grape yield was higher in experimental variants with intensive soil tillage compared to minimal invasive soil management. Minimally invasive soil management options would undoubtedly require reimbursements to compensate for the difference in profit and to encourage winegrowers to choose friendlier, less invasive technologies despite the obvious decline in grape production. Among the investigated varieties, Feteasca regala proved to be the least sensitive to soil maintenance options. Within this variety, the complex variant of soil maintenance is not justified, because the production difference between it and the control variant S3 is small. The S2 option, with a favourable expense-to-production ratio, is the most commonly recommended option within this range.
In the Cabernet Sauvignon and Feteasca neagra varieties, the variant with minimal tillage (S4) had the smallest differences from the control (S3). This option remains a viable alternative, applicable only if the vineyard doesn't have the financial resources to pursue a more expensive option. The economic indicators were affected

differently by the soil maintenance options. S2 and S3 for the Riesling Italian variety were the only more affordable variants that recorded a lower price.

Profit is the most important economic indicator, and it has grown exponentially as soil maintenance options in all varieties have become more complex. Feteasca Regala and Riesling Italian varieties adapted best to lower-cost soil maintenance, with smaller profit differences between the complex variant (S1) and the other variants.

The summer canopy management represent another technological sequence that requires an upgrade, imposed by the difficulty in finding available manual labour during the growing season and less due to the invasive aspect. Therefore, the only currently viable option for the canopy management, particularly in large vineyards, is mechanization. But, even though the level of production expenses is significantly reduced by mechanization, all of the researched varieties experience a decline in profit as a result of the grape production decline.

Only the Feteasca neagra and Merlot varieties justify the complex variant (P1) for canopy management. In the Feteasca regala variety, the P3 variant, which consisted of two mechanized interventions on the canopy, was a cost-effective and viable option. With the exception of canopy management costs, a single mechanized intervention (P4) proved to be inefficient for all economic indicators studied, in all varieties.

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