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The anthropogenic influence of soil management on grape yield and economic parameters in grapevine growing

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Abstract The research was carried out during 2017, in a vineyard at the beginning of the full maturity located in the Buzias-Silagiu area. The wine grape varieties involved in the research were: Merlot, Cabernet Sauvignon, Feteasca neagra and Feteasca regala to which were added the table grape varieties Victoria and Muscat Hamburg. The experimental variants consisted in the differentiated maintenance of the soil, from complex and expensive variants to the variant with a minimal tillage. The influence of the experimental plots treatments on the grape yield and quality was investigated. The economic efficiency indicators (total production costs, costs per experimental plot, rate of costs per plot from total costs, grape production value, and profit) were analyzed to find out if the expenditures are justified by the grape production increase, the cost price or by the profit. In the favorable growing season for grapevine 2017, none of the less expensive options could surpass the control plot for the grape production.
Experimental plots (three and four) with less conventional tillage, registered significant negative differences compared to the control. The best grape quality was found in plots V_1 but differences between variants were not significant. Production costs and those for the control plot decreased accordingly with less vineyard floor management. The cost per kilogram and ton of grapes was the highest in the experimental plots V_2 and V_3.

Key words

grapes, soil maintenance systems, production, quality, economic efficiency, grapevine

Soil is a dynamic, heterogeneous system, with a major role in biomass production, nutrient storage and recycling, carbon sequestration (crucial for GHG reduction and soil fertility), water retention, biodiversity conservation [1,2]. Vineyard floor management is an important and complex technological sequence, for achieving appropriate production parameters, for the most accurate management of water resources of an area, and for conservation the soil physical parameters [3]. Also, soil maintenance system is an important component in the annual costs of vineyard management [4]. The soil maintenance is important for the achievement of a high level of production, considering the pollution and carbon emissions mitigation, in the context of an economic efficiency exploitation of the vineyard [5]. Vineyard floor management involves two areas: the rows of vines and the inter-rows [6;7] and the management strategies should consider weed control, which reduce grapevine development and grape production, help to facilitate irrigation and pest control, improve the physical and biological condition of the soil, eliminate harmful pest habitats and provide good habitat for beneficial insects, etc. [8;9]. With complete tillage both on the vine row and the rows middle, a lot of equipment, like spring-hoe weeder or French plow in late winter or early spring on vine row and standard disks and harrows on row middles are used to control weeds [10;11]. In complete non-tillage system, weeds are control with herbicides both in the vineyards with wine grapes and in those for table grapes but not in those for raisins [12;13]. The tremendous diversification of the inputs and the large variety of machines for soil maintenance facilitate complex systems of soil maintenance, offering to the viticulturist the possibility to choose the most suitable variant according to the soil type, land, climate during the year and not lastly, according to the cultivated variety and the grape production destination [9]. In order to accomplish all these factors, is essential an optimal coordination for a maximum economic effect, minimal soil damage and pollution [12].

Material and Method

The research was carried out during 2017 year, characterized by high heliothermal resources and moderate water resources, considered very favorable for grapevine growing. The vineyard for research is located on Silagiu Hills, within the Buzias-Silagiu Vineyards and is spread on land with a moderate slope, with loam-clay soil and with favorable eastern and

south-eastern sun exposure. The vineyard is at the beginning of the full maturity stage, and is planting at 2.2 m between rows and 1 m between vines on row; the vines were Guyot head-trained type. The experimental variants were: V1 (C) - complex variant with autumn plowing, spring plowing, 3 mechanical plows per row, 3 mechanical plows between rows; V2- variant of medium complexity, with autumn plowing, 2 mechanical plows per row, 2 mechanical plows between rows; V3- variant of reduced complexity, with autumn plowing, weeding and herbicide application; V4-minimum variant, with two weeds chopping and a plowing at 2 years. These variants were applied to varieties with different agro-technical characteristics and biological particularities; 4 wine varieties (Merlot, Cabernet Sauvignon, Feteasca neagra and Feteasca regala) and two table grape varieties (Victoria and Muscat Hamburg). The influence of these experimental variants was analyzed for the grape yield and production, for the must content in sugar and acidity.
The maturation index was calculated, which shows the must degree of equilibrium and the indicators of economic efficiency (total costs of production, experimental costs, rate of costs per plot from total costs, production value, cost price and profit). For the statistical analysis, ANOVA and Dunett's comparative test were used in GraphPad Prism 7 (GraphPad Software Inc., USA) [14]. Statistical tests were applied at levels of significance $p < 0.05$, $p < 0.01$ and $p < 0.001$.

Results and Discussions

The grape productions were obviously influenced by the experimental variants for vineyard floor management. The most complex and expensive option of soil maintenance (V1) registered by far the largest grape yields. Grape production has decreased with the less soil maintenance options. The V4 variant with minimal soil tillage led to the lowest yields and the differences from the control ranging between 1681 and 2773 kg per hectare, depending on the grape variety.

Table 1

The influence of vineyard floor management on grape yield and production in 2017

Variant	Variety	Production			Difference to control	Significance
		kg / vine	kg/ ha	%		
V_1(C)	Merlot	2.49	11317	100	-	
	Cabernet Sauvignon	2.25	10226	100	-	
	Feteasca neagra	2.30	10454	100	-	
	Feteasca regala	2.92	13271	100	-	
	Victoria	3.13	14226	100	-	
	Muscat Hamburg	2.68	12181	100	-	
V_2	Merlot	2.39	10863	95.9	-454	-
	Cabernet Sauvignon	2.18	9908	96.8	-318	-
	Feteasca neagra	2.21	10044	96.1	-410	-
	Feteasca regala	2.84	12908	97.2	-363	-
	Victoria	2.97	13499	94.8	-727	-
	Muscat Hamburg	2.53	11499	94.4	-682	-
V_3	Merlot	2.19	9953	87.9	-1364	00
	Cabernet Sauvignon	2.02	9181	89.7	-1045	0
	Feteasca neagra	2.03	9226	88.2	-1228	00
	Feteasca regala	2.61	11862	89.4	-1409	0
	Victoria	2.69	12226	85.9	-2000	00
	Muscat Hamburg	2.28	10363	85.1	-1818	00
V_4	Merlot	2.08	9454	83.5	-1853	00
	Cabernet Sauvignon	1.88	8545	83.6	-1681	00
	Feteasca neagra	1.87	8499	81.3	-1955	000
	Feteasca regala	2.49	11317	85.3	-1954	00
	Victoria	2.52	11453	80.5	-2773	000
	Muscat Hamburg	2.19	9953	81.7	-2228	000

Merlot	DF 5%	775.3	DF 1%	1211.1	DF 0.1%	1964.2
Cabernet Sauvignon	DF 5%	693.1	DF 1%	1117.6	DF 0.1%	1793.4
Feteasca neagra	DF 5%	711.3	DF 1%	1194.2	DF 0.1%	1820.8
Feteasca regala	DF 5%	896.2	DF 1%	1371.3	DF 0.1%	2217.9
Victoria	DF 5%	927.2	DF 1%	1498.3	DF 0.1%	2315.6
Muscat de Hamburg	DF 5%	823.4	DF 1%	1291.2	DF 0.1%	2163.1

The grape varieties that proved to be the most sensitive to less soil maintenance were the Victoria and Muscat Hamburg table grape varieties. Among the wine varieties, the Cabernet Sauvignon and Feteasca regala were more constant accordingly with the complexity of the soil maintenance, while the Feteasca neagra and Merlot varieties which were more dependent on the complexity of soil maintenance. Variants V3 and especially V4, which involved a single loosening of the soil, registered significantly lower yields in the V2 variants and especially in the control variant V1, during which several soil loosening were carried out. Between the complex soil maintenance variant V1 (C) and the medium complexity variant V2, the differences registered in all varieties were less significant.

Considering the soil different treatments – intercrop or bare soil – influence on grape yield, Ripoche et al. (2010) [15], mentioned that in bare soil treatment registered grape yield was the lowest but also the highest, while in the intercrop treatment grape yield was intermediate. On contrary, Gattullo et al. (2020) [16] found in a table grape vineyard from Puglia region that conventional tillage and cover crops does not influenced the yield per vine or the mean cluster weight, but were significantly affected by the climate during the growing season and by the interaction year x soil treatment.

Table 2

The influence of vineyard floor management on grape quality in 2017

Variant	Variety	Sugar (g/l)	Total acidity (g/l H_2SO_4)	The maturation index	Difference to control (C) Sugar (g/l)	Significance
V_1(C)	Merlot	233	4.1	56.8	-	
	Cabernet Sauvignon	247	4.0	61.7	-	
	Feteasca neagra	249	4.1	60.7	-	
	Feteasca regala	223	4.3	51.8	-	
	Victoria	171	3.2	53.4	-	
	Muscat Hamburg	183	3.9	46.9	-	
V_2	Merlot	232	4.1	56.5	-1	-
	Cabernet Sauvignon	245	4.1	59.7	-2	-
	Feteasca neagra	246	4.2	58.7	-3	-
	Feteasca regala	222	4.3	51.6	-1	-
	Victoria	168	3.3	50.9	-3	-
	Muscat Hamburg	180	4.0	45	-3	-
V_3	Merlot	229	4.3	53.2	-4	-
	Cabernet Sauvignon	241	4.3	56	-6	-
	Feteasca neagra	241	4.4	54.7	-8	-
	Feteasca regala	219	4.5	48.6	-4	
	Victoria	161	3.5	46	-10	0
	Muscat Hamburg	175	4.1	42.6	-8	-
V_4	Merlot	227	4.4	51.5	-5	-
	Cabernet Sauvignon	238	4.4	54	-9	-
	Feteasca neagra	236	4.5	52.4	-13	0
	Feteasca regala	218	4.6	47.3	-5	-
	Victoria	156	3.7	42.1	-15	00
	Muscat Hamburg	169	4.2	40.2	-14	0

Merlot	DF 5%	10.93	DF 1%	18.75	DF 0.1%	30.11
Cabernet Sauvignon	DF 5%	11.02	DF 1%	20.32	DF 0.1%	31.32
Feteasca neagra	DF 5%	12.27	DF 1%	21.18	DF 0.1%	32.71
Feteasca regala	DF 5%	9.94	DF 1%	17.16	DF 0.1%	28.21
Victoria	DF 5%	7.23	DF 1%	13.71	DF 0.1%	23.39
Muscat Hamburg	DF 5%	9.01	DF 1%	16.11	DF 0.1%	27.31

In table 2 are presented the results regarding the influence of the experimental variants on the estimated production quality based on the sugar content, acidity, and maturity index. The favorable grapevine growing season from 2017, contributed to high quality grapes, with high sugar content in all varieties and experimental variants. The quality of grape production proved to be less influenced by the soil maintenance system, with less significant differences; only in several variants differences were statistically

significant. The grape quality was the highest in the variant V1, followed by variants V2, V3 and V4. The variants that involved soil tillage have reached a higher sugar content compared to the variants with herbicide and mowing maintenance. The varieties with significant differences compared to the control, were Victoria for variants V3 and V4, Muscat Hamburg and Feteasca neagra for variant V4. In all variants and in all varieties, the values of the maturity index show a balanced grape production for sugar and acidity content.

Studying the influence of different soil management systems (bear soil, cover crops, permanent intercropping) in a vineyard located near Montpellier, Ripoche et al. (2010) [15] did not observed significant differences for sugar content between soil treatments.

Production costs (table 3) are an important economic indicator because in grapevine growing is necessary relatively high financial expenditure per hectare, which suppose large differences between the variants. Obviously, the highest expenses per hectare were reached within the control variant of 10,800 lei per hectare in wine varieties, respectively 12,800 lei per hectare in table grape varieties. Regarding the experimental variants, the most expensive was the variant V1 with 2600 lei per hectare, followed by V2 - 1450 lei per hectare, V3 - 1250 lei per hectare and V4 - 575 lei per hectare. The higher the number of soil works, the higher the production costs. In variant V1, the soil maintenance expenses represented 24.1% of the total expenses in wine varieties, respectively 20.3% in table grape varieties. In variant V2, less soil loosening works led to the decrease of the production expenses by 1150 lei per hectare. In this case, the expenses with soil maintenance represented 15% of the total expenses in wine varieties and 12.4% in table grape varieties.

Soil maintenance by plowing and two herbicides application decreased the expenses per hectare by 1350 lei, and therefore soil maintenance costs decreased to 14.2% of the total in wine varieties, respectively 12.4% of the total in table grape varieties. The cheapest option for soil maintenance was in the V4 variant (a 2-year plowing and chopping of vegetation), with expenses decreased to 2025 lei per hectare compared to the control. In this variant, the soil maintenance expenses represented 6.5% of the total in wine varieties and 5.3% of the total in table grape varieties.

Table 3

The influence of vineyard floor management on expenses for grapevine production in 2017

Variant	Variety	Production costs (lei/ha)	Costs with the control plot lei/ha	Costs with the control plot % from total expenditure	Difference to the control
V_1(MT)	Merlot	10800	2600	24.1	-
	Cabernet Sauvignon	10800	2600	24.1	-
	Feteasca neagra	10800	2600	24.1	-
	Feteasca regala	10800	2600	24.1	-
	Victoria	12800	2600	20.3	-
	Muscat Hamburg	12800	2600	20.3	-
V_2	Merlot	9650	1450	15	-1150
	Cabernet Sauvignon	9650	1450	15	-1150
	Feteasca neagra	9650	1450	15	-1150
	Feteasca regala	9650	1450	15	-1150
	Victoria	11650	1450	12.4	-1150
	Muscat Hamburg	11650	1450	12.4	-1150
V_3	Merlot	9450	1250	14.2	-1350
	Cabernet Sauvignon	9450	1250	14.2	-1350
	Feteasca neagra	9450	1250	14.2	-1350
	Feteasca regala	9450	1250	14.2	-1350
	Victoria	11450	1250	12.4	-1350
	Muscat Hamburg	11450	1250	12.4	-1350
V_4	Merlot	8775	575	6.5	-2025
	Cabernet Sauvignon	8775	575	6.5	-2025
	Feteasca neagra	8775	575	6.5	-2025
	Feteasca regala	8775	575	6.5	-2025
	Victoria	10775	575	5.3	-2025
	Muscat Hamburg	10775	575	5.3	-2025

In table 4 are presented data for the cost price per kilogram of grapes, respectively per ton of grapes. The most expensive soil maintenance variant, variant V1, registered the highest cost price, with values between 810 lei per ton of grapes for the Feteasca regala variety, respectively 1050 lei per ton of grapes for the Cabernet Sauvignon and Muscat Hamburg varieties. The V2 variant with an average soil maintenance complexity

also registered the lowest cost prices between 740 lei per ton of grapes for the Feteasca regala variety, respectively 1031 lei per ton of grapes for the Muscat Hamburg variety. The continuous decrease of soil maintenance costs in variants V3 and V4, did not show an obvious decrease in the cost price, which increased slightly, and in table grape varieties the cost price is even higher than in the control plot.

Table 4

The influence of vineyard floor management on cost price for grapevine production in 2017

Variant	Variety	Costs for production (lei/ha)	Production (kg/ha)	Cost price (lei/kg grapes)	Cost price (lei/ton grapes)	Difference to the control (lei/ha)
V_1(MT)	Merlot	10800	11317	0.95	950	-
	Cabernet Sauvignon	10800	10226	1.05	1050	-
	Feteasca neagra	10800	10454	1.03	1030	-
	Feteasca regala	10800	13271	0.81	810	-
	Victoria	12800	14226	0.89	890	-
	Muscat Hamburg	12800	12181	1.05	1050	-
V_2	Merlot	9650	10863	0.88	880	-70
	Cabernet Sauvignon	9650	9908	0.97	970	-80
	Feteasca neagra	9650	10044	0.96	960	-70
	Feteasca regala	9650	12908	0.74	740	-70
	Victoria	11650	13499	0.86	860	-30
	Muscat Hamburg	11650	11499	1.01	1031	-19
V_3	Merlot	9450	9953	0.94	940	-10
	Cabernet Sauvignon	9450	9181	1.02	1020	-30
	Feteasca neagra	9450	9226	1.02	1020	-10
	Feteasca regala	9450	11862	0.79	790	-20
	Victoria	11450	12226	0.93	930	+40
	Muscat Hamburg	11450	10363	1.1	1100	+50
V_4	Merlot	8775	9454	0.92	920	-30
	Cabernet Sauvignon	8775	8545	1.02	1020	-30
	Feteasca neagra	8775	8499	1.03	1030	-
	Feteasca regala	8775	11317	0.76	760	-50
	Victoria	10775	11453	0.94	940	+50
	Muscat Hamburg	10775	9953	1.08	1080	+30

The profit (table 5) is finally the most important indicator, and from this point of view, the highest values were recorded in the control plot. Depending on the variety, the profit ranks between 15,742 lei per hectare for the Feteasca regala variety and 44140 lei per hectare for the Victoria variety. In the other variants, the decrease of the costs per hectare did not lead to the increase of the profit compared to the control plot; on the contrary, costs decreased accordingly with the fewer number and complexity of soil maintenance works. The only exception was in the Feteasca regala variety in variant V2, when less number of soil tillage led to the decrease of the soil maintenance costs, but also to the increase of the profit compared to the control by 424 lei per hectare. Less soil maintenance in V3 but especially V4 variants, led to a significant decrease in maintenance costs, but also to a high decrease of profit compared to the control plot. The most significant decrease in profit by less soil maintenance works was in the Victoria and Muscat Hamburg table grapes varieties.

The total production cost is driven by the each year increases of fertilizers, pesticides, insecticides, fuel, herbicides or electricity prices as Rabie and Marcus (2019) reported for vineyards from South Africa; from 2009 until 2018, total production cost increased from 26.580 RSD (1100,41 Ron) to 48.423 RSD (2004,71 lei/ha).

According to the report analyses for the production costs in two vineyards, with the same age of vines, density of planting, with double Guyot pruning and mechanical harvesting, but with different management technique (one without deleaf and the other mechanically deleaf), Hall A. (2019) [18], reported total production cost of €3,862 per hectare and €4,156 per hectare respectively.

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Table 5

The influence of vineyard floor management on the profit for grapevine in 2017

Variant	Variety	Costs for production (lei/ha)	Production values (lei/ha)	Profit (lei/ha)	Difference to the control
V_1(MT)	Merlot	10800	33951	23151	-
	Cabernet Sauvignon	10800	30678	19878	-
	Feteasca neagra	10800	31362	20562	-
	Feteasca regala	10800	26542	15742	-
	Victoria	12800	56940	44140	-
	Muscat Hamburg	12800	42633	29833	-
V_2	Merlot	9650	32589	22939	-212
	Cabernet Sauvignon	9650	29724	20074	-196
	Feteasca neagra	9650	30132	20482	-80
	Feteasca regala	9650	25816	16166	+424
	Victoria	11650	53996	42346	-1794
	Muscat Hamburg	11650	40246	28596	-1237
V_3	Merlot	9450	29859	20409	-2742
	Cabernet Sauvignon	9450	27543	18093	-1785
	Feteasca neagra	9450	27678	18228	-2334
	Feteasca regala	9450	23724	14274	-1468
	Victoria	11450	48904	37454	-6686
	Muscat Hamburg	11450	36270	24820	-5013
V_4	Merlot	8775	28362	19587	-3564
	Cabernet Sauvignon	8775	25635	16860	-3018
	Feteasca neagra	8775	25497	16722	-3840
	Feteasca regala	8775	22634	13859	-1883
	Victoria	10775	45812	35037	-9103
	Muscat Hamburg	10775	34835	24060	-5765

Compared with the profit registered in Silagiu Hills vineyards in different wine or table grapes varieties, data collected by Retallack (2012) [19] during different growing seasons, from Murray Valley wine growing region, show an average gross income of $7,526/ha AUD (23,423.17 lei/ha) in 2006/07 growing season and then due to the decline of vines yields and grapes price, $5,203/ha AUD (16,193.30 lei/ha) in 2008/09 and 2010/2011 seasons

Conclusions

Soil maintenance is a basic technological sequence in grapevine growing, with a major influence on both grape production and economic indicators. The variants of soil maintenance must be very well established according to the type of soil, the topography of the land surface, the rainfall related with the area/year and last but not least the cultivated variety. The level of production is in direct correlation with the complexity of the soil maintenance; the variants with the best soil maintenance, recorded the highest productions. Less soil maintenance works in V2, but especially in V3 and V4 variants, have led to a significant decrease in grape production. Soil maintenance is also an expensive technological sequence; the percentage of soil maintenance costs from the total annual costs is variable depending on the complexity of the vineyard soil maintenance. In V1 variant, the complex soil maintenance had a share of about 24% of the total annual costs. Less soil loosening works and the replacement with herbicide or vegetation chopping, led both to the decrease of the total costs and to the decrease of the number of the soil maintenance costs up to 6.5% for the wine varieties, respectively 5.3% for the for the table varieties in V4 variant. The variants of soil maintenance have decisively influenced another important economic indicator, namely the cost price, which in the end is decisive in establishing the selling price of the product. Therefore, the complex maintenance of the soil shows the highest cost price of the grapes. Exceptions were the table grape varieties Muscat Hamburg and Victoria, with the cheapest soil maintenance options also recorded the highest cost price. Soil maintenance options have decisively influenced the profit. The most expensive option of soil maintenance led to the highest values of profit, excepting for the Feteasca regala variety in V2 variant. Less soil maintenance costs led to a considerable decrease in profit, especially in V3 and V4 variants in which the replacement of soil loosening with vegetation chopping and herbicide proved to be inferior comparing to profit from the control plot.

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