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THE INFLUENCE OF THE DIFFERENT DISEASES AND PESTS CONTROL TREATMENTS ON THE PHYSIOLOGICAL, TECHNOLOGICAL AND ECONOMIC INDICATORS IN GRAPEVINE

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Abstract

Disease and pest control is a very important and costly technological phase that significantly influences the success of grape yield. The research was carried out in a vineyard from Buzias-Silagiu area, focusing on both table and wine grape varieties. The experimental trial was organized in plots with three different complex treatments and analysed their influence on the total and one-year-old wood growth, photosynthetic yield, grape yield quality and quantity, and economic indicators. The growing seasons, during which observations were made varied climatically, resulting in conclusive and informative findings. The experimental plots significantly influenced all the monitored indicators, with the impacts varying depending on the climate conditions during each year. In years with favourable conditions for grapevine growing, vineyard management with a smaller number of treatments proved to be efficient. In contrast, during years with less favourable climate conditions, the reliable experimental strategy that achieved satisfactory results was the complex treatments applied for disease and pest control.

• Introduction

- Pests and diseases affect grape production both in terms of quantity and quality and can also threaten the longevity of vineyards. Managing these issues in a chclimate can be challenging. Depending on grape varieties' resistance or susceptibility to diseases, significant production costs and economic losses may occur [11,12]. Modern integrated pest and disease management involves selecting effective management systems, utilizing complex monitoring tools, applying early warning technologies, and using plant protection products (PPP) in precise quantities and at optimal timings. These combined strategies can help protect vineyards effectively while minimizing environmental impact. Implementing this integrated approach requires advanced technology and substantial investments, which may not be accessible to all winegrowers. However, the wine sector is one of the most advanced in agriculture regarding integrated disease and pest management, primarily due to the higher revenues that enable such investments [7]. Nevertheless, every vineyard must address diseases with a major impact on grape production and quality.
- Grapevine downy mildew *(Plasmopara viticola)* can have severe impacts in climates with relatively hot and humid summers. It affects all European grape varieties to varying degrees and can lead to significant production losses. Common symptoms include stem or shoot necrosis, berry discoloration (including brown spots), and yellow-green leaf tips [5]. Similarly, all European grape varieties are susceptible to powdery mildew, caused by *Erysiphe necator*. This disease infects all green parts of the vine, including young leaves and berries, and can result in considerable yield losses. Its prevalence is favored by warmer, drier climates. Powdery mildew is easily recognizable by its dusty appearance on the upper surfaces of the leaves, although it can also infect the lower parts, as well as buds, flowers, berries, and young stems. This disease can lead to the deterioration of wine quality both directly and indirectly. In fact, any changes in the vineyard can affect the winemaking process. Even pesticides must be carefully selected and applied to avoid negatively impacting the wine production process [8, 9].
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Material and Method

The purpose of the research is to establish the most suitable scheme for combating diseases and pests as concerns complexity and the number of treatments for each variety in correlation with the climatic conditions of each year, to can achieve the most favourable ratio between the cost of treatments and their influence on the analyzed indicators. The research was carried out between 2017-2019 years, in a vineyard from Buzias-Silagiu Vineyard Centre, located in Timis County. The vineyard is located on a plot of land with a slight slope and southern or south-eastern exposure depending on the plot. Vineyard established in 2007-2008, was at the beginning of the period of full maturity during the research. Planting distance were 2.2 m between rows and 1 m between vines per row, resulting a density of 4545 vines per hectare. The research focused on table grape varieties ('Victoria' and 'Muscat de Hamburg') and grape varieties for superior wines ('Merlot', 'Cabernet Sauvignon', 'Feteasca Neagră', 'Feteasca regală'). The experimental plots for the influence of the anthropic activity and the diseases and pests control on grapevine growing, were: V1(MT) - the complex variant; V2 - variant of medium complexity; V3 - reduced complexity version. On each experimental plot, within each analyzed technological sequence, was observed the influence on the physiological indicators (total annual growth, annual matured wood, leaf area and photosynthetic yield), on the technological indicators (grape yield, grape production per hectare, the sugar accumulation in the must, must acidity, the maturity index) and on the economic indicators (production expenses, cost price and profit).

Table 3

The impact of anthropogenic interventions regarding pest and disease control on grape production, on average, during 2017-2019 growing seasons

Experimental plot	Variety	Grape production			Difference to control (%)	Significance
		kg / vine				
V_1(C)	Merlot	2.854	12971	100	-	-
	Cabernet Sauvignon	2.535	11523	100	-	-
	Feteasca neagră	2.586	11753	100	-	-
	Feteasca regală	3.343	15194	100	-	-
	Victoria	3.464	15745	100	-	-
	Muscat Hamburg	3.019	13720	100	-	-
V_2	Merlot	2.465	11205	86.4	-1766	000
	Cabernet Sauvignon	2.362	10735	93.2	-788	0
	Feteasca neagră	2.262	10279	87.5	-1474	00
	Feteasca regală	3.094	14064	92.6	-1130	00
	Victoria	2.983	13557	86.1	-2188	000
	Muscat Hamburg	2.48	11272	82.2	-2448	000
V_3	Merlot	2.095	9522	73.4	-3449	000
	Cabernet Sauvignon	2.214	10064	87.3	-1459	00
	Feteasca neagră	2.039	9265	78.8	-2488	00
	Feteasca regală	2.883	13103	86.2	-2091	00
	Victoria	2.757	12529	79.6	-3216	000
	Muscat Hamburg	2.078	9443	68.8	-4277	000

Table 4

The impact of anthropogenic interventions regarding pest and disease control on the quality of grape production, on average, during 2017-2019 growing seasons

Experimental plot	Variety	Sugar (g/l)	Acidity (g/l H_2SO_4)	Maturity index	Difference to control (%)	Significance
V_1(C)	Merlot	210	4.4	47.73	-	-
	Cabernet Sauvignon	222	4.1	54.15	-	-
	Feteasca neagră	222	4.3	51.63	-	-
	Feteasca regală	204	4.4	46.36	-	-
	Victoria	157	3.3	47.58	-	-
	Muscat Hamburg	175	4.2	41.67	-	-
V_2	Merlot	198	4.8	41.25	-12	0
	Cabernet Sauvignon	215	4.4	48.86	-7	-
	Feteasca neagră	214	4.5	47.56	-8	-
	Feteasca regală	196	4.6	42.61	-8	-
	Victoria	155	3.7	41.89	-2	-
	Muscat Hamburg	167	4.4	37.95	-8	-
V_3	Merlot	188	5.1	36.86	-22	0 0
	Cabernet Sauvignon	207	4.6	45	-15	0
	Feteasca neagră	201	4.7	42.77	-21	0 0
	Feteasca regală	190	5.1	37.25	-14	0
	Victoria	144	4.1	35.12	-13	0

• Results and discussions

Table 1

The impact of anthropogenic interventions regarding pest and disease control on annual shoots and canes, on average, during 2017-2019 growing seasons

Experimental plot	Variety	Annual growth			Difference to control (%)	Significance
		Total (m/vine)	Mature (m/vine)	Mature (% from total)		
V_1(C)	Merlot	13	10.1	77.69	-	-
	Cabernet Sauvignon	15.27	12.35	80.88	-	-
	Feteasca neagră	16.17	12.37	76.5	-	-
	Feteasca regală	11.7	9.37	80.09	-	-
	Victoria	14.03	10.97	78.19	-	-
	Muscat Hamburg	11.7	9.07	77.52	-	-
V_2	Merlot	11.03	8.43	76.43	-1.26	-
	Cabernet Sauvignon	12.7	9.67	76.14	-4.74	0
	Feteasca neagră	13.87	10.23	73.76	-2.74	-
	Feteasca regală	9.57	7.9	82.55	2.46	-
	Victoria	11.9	9.07	76.22	-1.97	-
	Muscat Hamburg	9.8	7.6	77.55	0.03	-
V_3	Merlot	10.23	7.47	73.02	-3.41	0
	Cabernet Sauvignon	11.93	8.93	74.85	-1.29	-
	Feteasca neagră	12.7	9.17	72.2	-1.56	-
	Feteasca regală	9.17	6.93	75.57	-6.98	0
	Victoria	10.87	8.4	77.28	1.06	-
	Muscat Hamburg	9.13	6.73	73.71	-3.84	0

Table 2

The impact of anthropogenic interventions regarding pest and disease control on leaf area and photosynthetic efficiency, on average, during 2017 -2019 growing seasons

Experimental plot	Variety	Leaf area			Difference to control (%)	Significance
		m^2/ vine	m^2/ kg grapes	m^2/ kg sugar		
V_1(C)	Merlot	5.5	1.94	13.2	-	-
	Cabernet Sauvignon	8	3.11	20.01	-	-
	Feteasca neagră	9.4	3.57	22.97	-	-
	Feteasca regală	7.1	2.11	14.78	-	-
	Victoria	8	2.29	20.84	-	-
	Muscat Hamburg	8.3	2.77	22.61	-	-
V_2	Merlot	5.1	2.08	15.01	1.81	-
	Cabernet Sauvignon	7.5	3.12	20.73	0.72	-
	Feteasca neagră	9	3.96	26.44	3.47	0
	Feteasca regală	6.5	2.09	15.23	0.45	-
	Victoria	7.5	2.51	23.13	2.29	0
	Muscat Hamburg	7.6	3.12	26.69	4.08	0
V_3	Merlot	4.7	2.28	17.33	4.13	0
	Cabernet Sauvignon	6.6	2.94	20.29	0.28	-
	Feteasca neagră	7.9	3.91	27.79	4.82	0
	Feteasca regală	6.1	2.08	15.64	0.86	-
	Victoria	6.7	2.38	23.61	2.77	0
	Muscat Hamburg	6.6	3.16	29.31	6.7	0 0

The average results per research cycle indicate that all experimental treatments across all varieties yield satisfactory total and matured growth, ensuring that winter hardiness and crop load are not significantly impacted. However, a difference exists between the treatments, with the best results naturally observed in the control group, which performed the most comprehensive disease and pest control management.

Both the absolute and relative values of annual and matured growth decreased across all varieties as the treatment protocol was simplified.

During the research, the use of a simplified treatment protocol presented challenges regarding total annual growth, particularly in 2019, a year considered less favourable for viticulture. In years with favourable or even moderately favourable climatic conditions, the application of simplified disease and pest control protocols does not suppose issues related to annual growth, wood maturation, winter hardiness, or crop load. According to these circumstances, implementing fewer treatments becomes viable option. (Table 1).

Effective control of diseases and pests is crucial for maintaining the canopy within appropriate quality parameters. By preventing disease and pest damage, the photosynthetic area remains at maximum, resulting in superior photosynthetic efficiency.

The average results from the research regarding leaf area and photosynthetic efficiency are evident, because climatic conditions during the study ranged from highly favourable to less favourable. On average, over the three years of research, applying a complex treatment management yielded the best results for all three analyzed indicators. Using a treatment protocol of moderate complexity led to a decrease in photosynthetic efficiency compared to the control group, though the differences were not substantial. Statistically significant decline was observed only in the 'Feteasca Neagra' and 'Muscat de Hamburg' varieties, which required large leaf area, over 26 m^2, to produce one kilogram of sugars (Table 2).

In the V3 plot, the lower numbers of treatments negatively influence the leaf area, resulting in the lowest values, ranging from 4.7 m^2 per vine in the Merlot variety to 7.9 m^2 per vine in the Feteasca Neagra variety. While this plot had the lowest sugar accumulations, the photosynthetic efficiency was also the most ineffective, for both one kilogram of grapes and accumulation of one kilogram of sugar. It can be concluded that the methods for diseases and pests control significantly influence both leaf area and photosynthetic efficiency for grape and sugar production. The less favourable the climatic conditions during growing season, the greater the leaf area needed with fewer treatments to produce one kilogram of grapes or sugar. In years with favourable conditions for grapevine growing and low precipitation, options with fewer treatments may offer viable alternatives both economically and for photosynthetic efficiency.

Grape yield is the technological indicator most significantly influenced by diseases and pests management. Maintaining a healthy canopy, without disease and pest damage, facilitates proper photosynthesis and high yields. Alongside pruning, disease and pest control represents the most impactful aspect of vine production. The average results during the research regarding the influence of disease and pest control on grape yield were reasonable and informative, given the climatic variability across the three years of study; this observations allowed the assessment of the experimental plots influence on production under conditions of precipitation deficit, considered favourable for viticulture in 2017, as well as under conditions of excessive precipitation, generally unfavourable for grapevine growing. On average, during research and for all varieties, the plot that yielded the highest production was the control, where the most treatments were applied. Reducing the number of treatments within a protocol of moderate complexity still resulted in high yields for all varieties, but lower than the control, ranging from 788 kg/hectare for the Cabernet Sauvignon variety to 2,448 kg/hectare for the 'Muscat Hamburg' variety. The application of a simplified disease and pest control protocol during the research achieved relatively satisfactory yields, but these were significantly lower compared to the control plot for all varieties. The largest differences were recorded in varieties more vulnerable to disease and pest damage, such as Muscat Hamburg, Victoria, and Merlot. In Muscat Hamburg variety, this experimental plot resulted in a significantly lower production, over 4,000 kg/hectare, compared to the control (Table 3). In conclusion, for all researched varieties, the production level is clearly influenced by the complexity of the disease and pest control protocol, with evident differences between the experimental plots. However, in years with favourable climatic conditions, both the V2 and V3 plots yielded higher grape production**S.**

The quality of the grape yield is critical for producing competitive wines in a dynamic market with increasing competition (3). From this perspective, the application of effective treatment protocols for diseases and pest control, which maintain the canopy healthy, is essential. Additionally, the rising prices of phyto-pharmaceutical products make this technological sequence one that must be carefully managed.

Table 5

The impact of anthropogenic interventions regarding pest and disease control, on production expenses in grapevine cultivation, during 2017-2019 growing seasons

Experimental plot	Variety	Production expenses (lei/ha)	Experimental variant expenses (lei/ha)	Experimental variant expenses as % of total	Difference to control
V_1(C)	Merlot	11329	3100	27.36	-
	Cabernet Sauvignon	11293	3100	27.45	-
	Feteasca neagră	11329	3100	27.36	-
	Feteasca regală	11293	3100	27.45	-
	Victoria	13360	3100	23.2	-
	Muscat Hamburg	13317	3100	23.28	-
V_2	Merlot	10256	2413	23.53	687
	Cabernet Sauvignon	10220	2413	23.61	687
	Feteasca neagră	10256	2413	23.53	687
	Feteasca regală	10220	2413	23.61	687
	Victoria	12287	2413	19.64	687
	Muscat Hamburg	12244	2413	19.71	687
V_3	Merlot	8906	2013	22.6	1087
	Cabernet Sauvignon	8870	2013	22.69	1087
	Feteasca neagră	8906	2013	22.6	1087
	Feteasca regală	8870	2013	22.69	1087
	Victoria	10937	2013	18.41	1087
	Muscat Hamburg	10894	2013	18.48	1087

The V3 plot had the lowest costs and the lowest rate of total expenses compared to the control, with savings of 1,087 lei/ha compared to the control and resulted in the lowest production costs (Table 5).

The average production cost during the three years of research was strongly influenced by the results from 2019 with excessive precipitation and consequently increased production costs. The lowest cost prices were recorded for the control plot. For more resilient varieties such as 'Cabernet Sauvignon', options with fewer treatments proved cost-effective, resulting in lower cost prices compared to more complex control plots. Sensitive varieties such as 'Merlot', 'Muscat Hamburg', and 'Victoria' experienced higher cost prices when fewer treatments were applied, especially in unfavourable climatic conditions. It can be concluded that the cost price is a highly sensitive indicator, influenced by production costs, production level, yearly climatic conditions, and variety sensitivity to diseases and pests.

Conclusions

In years with favourable or moderately favourable climatic conditions, applying simplified treatment protocol for disease and pest control does not create issues for annual growth, wood maturation, or winter resistance. It also does not jeopardize crop load, making the option of using fewer treatments viable. Disease and pest control options significantly impact both leaf area and photosynthetic grapes and sugar yield. When climatic conditions are less favourable, experimental plots with fewer treatments require higher leaf area to produce the same amount of grapes or sugar.

Using a simplified treatment protocol for disease and pest control during the research allowed for relatively satisfactory yields, although grape yield was much lower across all varieties compared to the control. Even in favourable climatic conditions, the positive impact of complex and moderate treatment protocol on grape production was evident. Complete treatment protocol produced statistically significant increases in yields in all varieties. In favourable years with reduced precipitation, simpler treatment protocol was still effective, achieving large sugar accumulations, albeit lower than complex protocol. Effective treatment protocol must consider the climatic conditions of each year, each variety's sensitivity to diseases and pests, and the qualitative potential of each wine-growing area. Cost price is a sensitive indicator influenced by production costs, production levels, climatic conditions, and the variety's sensitivity to diseases and pests. More resilient varieties yield lower cost prices with fewer treatments in years of high and medium favourability, only requiring numerous treatments in challenging climatic years. Analyzing the research results, it is clear that regardless of the climatic conditions of the year, all three diseases and pest control protocols were effective and allowed for profit. However, profit values varied according to the year's climatic conditions, being higher in favourable years compared to unfavourable ones. In years with challenging climatic conditions, experimental plots V2 and especially V3 showed much larger profit differences compared to the control, beyond the difference in expenses between plots. In such years, applying medium complexity disease and pest control treatments protocol is effective only for varieties relatively resistant to diseases and pests •