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RESEARCH ON THE INFLUENCE OF PRUNING ON WOOD MATURATION, PHOTOSYNTHETIC YIELD, QUANTITATIVE AND QUALITATIVE PRODUCTION, AND PROFIT IN GRAPEVINE GROWING

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Abstract

The research focused on winter pruning in grapevine, a very important and costly technological phase, that decisively influences both the physiological and biological balance of the vine, as well as grape yield, grape quality, and last but not least, the economic indicators for vineyard management. The experimental plots organized in the experimental trial were: V1 (Control): standard manual pruning; V2: light pruning; V3: mechanized hedge-type pruning. The research was carried out on four table grape varieties and two wine grape varieties in a vineyard at full maturity located in the Buzias-Silagiu area. Winter pruning is the most expensive technological phase due to the difficulty in finding qualified labour and the challenge of mechanizing winter pruning and establishing crop loading, without affecting the longevity of the vines, the quantity and especially the quality of the grape production. During research, conventional pruning (V1) provided the best results for all the indicators analyzed. Mechanized pruning remains an option that should only be applied under conditions of strict necessity, even though it offers the lowest costs.

Introduction

- Dormant pruning sets the crop load and influences subsequent vine bud development. The pruning impact various parameters related to productivity and bud growth, including the number and length of shoots, as well as the distribution of shoots and clusters [3]. The optimal management and pruning system for a vineyard should consider factors such as climate, location, investment, and profit projections based on expected yields, as well as the equipment used, which depends on row spacing. Simpler training, pruning, and maintenance systems tend to be more profitable due to lower costs and increased efficiency [6].
- Many vineyard tasks, including dormant pruning, canopy management, and harvesting, require significant labor and time investment. Rising labor costs and shortages have led growers to explore mechanization options for tasks like pruning, canopy management, and harvesting [15]. The adoption of mechanized equipment is driven by economic factors, as growers seek to reduce dependence on seasonal manual labour and gain efficiency through mechanization [12], [16].
- Preparation for vineyard mechanization begins before planting, considering factors such as soil type, slope, soil fertility and drainage, grape variety, row spacing, and irrigation systems [1]. Mechanized operations are most efficient in vineyards with long, straight rows that allow easy access for equipment. Longer rows enhance operational efficiency, while straight rows minimize damage to vines and support posts. Row spacing in mechanized vineyards should typically range from 2.75 to 3.35 meters for basic mechanization systems [13].

Material and method

- The aim of the research concerning this technological process is to optimize crop load pruning to strike a balance between the costs involved, performing cuts at the optimal time, and achieving favourable outcomes across all analyzed parameters. Concurrently, the selected experimental plots took into consideration the biological, agro-technical, and ecological requisites of the main grape varieties cultivated in the vineyard where the study was conducted. The research was carried out from 2017 to 2019, in a vineyard situated in the Buzias-Silagiu Vineyard Centre, located in Timis County. The vineyard is spread on land area with south or southeast exposure, varying depending on the plot. Established in 2007-2008, it was in its nascent phase of full maturity during the research. Planting distances were set at 2.2 meters between rows and 1 meter between vines within rows, resulting in a plantation density of 4545 vines per hectare.
- The study focused on two table grape varieties ('Victoria' and 'Muscat Hamburg') and four grape varieties for premium wines ('Merlot', 'Cabernet Sauvignon', 'Fetească Neagră', 'Fetească Regală'). As for the human interventions related to crop load pruning, the experimental plots included: V1(C) - conventional manual crop load pruning; V2 - superficial crop load pruning; V3 - mechanized hedge-type crop load pruning. Each experimental plot was scrutinized for its impact on total and matured annual growth, leaf area and photosynthetic output, grape yield, sugar and acidity content of the must, production expenses, cost price, and profit. The experiment was structured following the randomized block design.

Table 3
The impact of anthropogenic interventions regarding pruning on grape production, during 2017-2019 growing seasons

Experimental plot	Variety	Grape yield /production			Difference compared to control	Significance
		kg / vine	kg/ ha	%		
V1(C)	Merlot	1.95	8863	100	-	-
	Cabernet Sauvignon	1.79	8151	100	-	-
	Fetească neagră	1.83	8333	100	-	-
	Fetească regală	2.41	10969	100	-	-
	Victoria	2.51	11408	100	-	-
	Muscat Hamburg	2.16	9832	100	-	-
V2	Merlot	1.44	6545	73.85	-2318	000
	Cabernet Sauvignon	1.30	5893	72.30	-2258	000
	Fetească neagră	1.33	6045	72.55	-2288	000
	Fetească regală	1.89	8590	78.31	-2379	000
	Victoria	1.96	8893	77.95	-2515	000
	Muscat Hamburg	1.58	7196	73.19	-2636	000
V3	Merlot	0.93	4212	47.52	-4651	000
	Cabernet Sauvignon	0.82	3742	45.91	-4409	000
	Fetească neagră	0.83	3772	45.27	-4561	000
	Fetească regală	1.15	5242	47.79	-5727	000
	Victoria	1.16	5287	46.35	-6121	000
	Muscat Hamburg	0.95	4303	43.76	-5529	000

Table 4
The impact of anthropogenic interventions regarding pruning on the quality of grape production, during 2017 - 2019 growing seasons

Experimental plot	Variety	Sugar (g/l)	Titratable acidity (g/l H_2SO_4)	Maturity index	Difference compared to control	Significance
V1(C)	Merlot	226	4.3	52.56	-	-
	Cabernet Sauvignon	241	4.1	58.78	-	-
	Fetească neagră	244	4.2	58.10	-	-
	Fetească regală	215	4.5	47.78	-	-
	Victoria	166	3.3	50.30	-	-
	Muscat Hamburg	175	4.0	43.75	-	-
V2	Merlot	221	4.5	49.11	5	0
	Cabernet Sauvignon	237	4.4	53.86	4	0
	Fetească neagră	240	4.6	52.17	4	0
	Fetească regală	212	4.8	44.17	3	-
	Victoria	162	3.6	45.00	4	0
	Muscat Hamburg	171	4.2	40.71	4	0
V3	Merlot	206	4.8	42.92	20	000
	Cabernet Sauvignon	224	4.9	45.71	17	000
	Fetească neagră	226	5.1	44.31	18	000
	Fetească regală	200	5.3	37.74	15	000
	Victoria	149	4.0	37.25	17	000
	Muscat Hamburg	159	4.7	33.83	16	000

The quality of grape yield, although influenced by crop load pruning, is less affected compared to grape production. Favourable climatic conditions for qualitative accumulations throughout the vine's life resulted in balanced grape yield with high sugar content in all varieties and pruning experimental plots. However, the control plot consistently yielded the highest sugar accumulations, nearing the maximum value specific to each variety. Analyzing average results over the research, reveals that experimental pruning plots also significantly influenced quality, albeit to a lesser extent than quantity. Even in less favourable climatic years, these experimental plots notably impacted grape yield quality.

The most significant decrease in sugar concentration compared to the control was observed with mechanized hedge-type pruning, with all varieties showing maximum negative significance. This suggests that mechanized hedge-type pruning, with current technologies, is not a viable alternative, even for grape yield quality. The differences compared to conventional pruning are substantial, especially in less favourable climatic conditions. Mechanized pruning remains an emergency option, only to be used when no other alternative is available.

Conversely, superficial pruning resulted in slightly lower sugar accumulations than the control, but the difference was less significant, especially in years with favourable or moderately favourable conditions. Superficial pruning can be considered when necessary, provided it is not executed consecutively, and a corrective pruning is performed in the following year. While this option allows for satisfactory sugar levels in all varieties, there is a risk of bud desiccation and biological imbalance.

Economic indicators play a crucial role in vineyard management as they significantly impact the longevity of wine-growing operations. These indicators are influenced by various factors including the cultivated variety, climatic conditions, cultivation techniques, as well as prices and subsidies received. Crop load pruning represents a significant part of total expenses and is considered one of the most challenging tasks due to the need for skilled labour, execution difficulties, adverse weather conditions, and the inability to mechanize effectively.

Profit, as the primary objective of economic activity, depends on two main components: production expenses and production value. Fruiting pruning has a substantial impact on production and, consequently, on profit. Analyzing average results over the research, which spanned years with varying climatic conditions from highly favourable to unfavourable, provides valuable insights into the influence of pruning experimental plots on profit.

Conventional pruning emerged as the most profitable option for all varieties, yielding profits ranging from 10,645 lei/ ha for the 'Fetească regală' variety to 32,272 lei/ha for the Victoria variety. Superficial pruning (V2 plot) resulted in significant profit decreases compared to the control for all varieties, with differences ranging from 3,685 lei/ha for the Fetească regală variety to 8,987 lei/ha for the Victoria variety. Mechanized hedge-type pruning yielded thelowest profits

in all varieties, with reductions of up to 22,061 lei/ha for the Victoria variety compared to the control.

Results and discussions

Pruning represents a critical technological stage with significant impacts on the physiological and biological equilibrium of buds, as well as on production, quality, and the economic performance of the vineyard. It also stands out as the most labour-intensive process, resisting mechanization due to its intricate nature and potential consequences on the aforementioned indicators. The climatic variations observed over the three years of research provided a nuanced and comprehensive understanding of the differentiated effects of pruning methods on both total and matured annual growth across the studied grape varieties.

Among the pruning experimental plots, only the V1 variant, characterized by normal pruning, consistently delivered satisfactory results regardless of the climatic conditions of the year. This experimental plot ensured adequate values for both annual and matured growth, facilitating the subsequent crop load pruning. The V2 plot yielded acceptable outcomes in favourable growing seasons, where sufficient growth values were achieved to preserve the integrity of the crop load pruning. However, in less climatically favourable years, superficial pruning posed challenges in terms of annual wood maturation, impeding the execution of subsequent crop load pruning, particularly noticeable in varieties such as 'Muscat Hamburg', 'Victoria', and 'Fetească Regală'.

Mechanized hedge-type pruning yielded satisfactory results exclusively during favourable growing years, where despite lower total and matured annual growth compared to the control and V2 variant, conditions remained conducive for successful crop load pruning execution. Conversely, during less favourable or moderately favourable years, mechanized pruning failed to deliver efficient outcomes in terms of total and matured annual growth, resulting in diminished values across all studied varieties. Mechanized pruning, therefore, remains a temporary recourse, to be employed only in emergency situations when no alternative method is viable (Table 1).

Among other functions, crop load pruning play a crucial role in maintaining a relative balance within the leaf canopy to minimize self-shading and optimize leaf area for efficient photosynthetic activity. Despite an increased number of annual growths leading to a higher leaf count, it paradoxically results in decreased leaf area due to slower growth rates and reduced photosynthetic efficiency. The excessive precipitation experienced in 2019 also impacted the outcomes of the experimental variants. Leaf area measurements for the control plot exhibited lower values compared to 2017 but slightly higher than 2018, attributed to favourable water conditions that modestly promoted growth. The ranking order of varieties regarding analyzed indicators remained consistent across the years.

While leaf area values were not the lowest in the current year, all varieties demonstrated reduced photosynthetic yields compared to previous years. The highly variable climatic conditions over the research period significantly influenced the results, highlighting the impact of pruning experimental plots on photosynthetic indicators under varying levels of climatic favourability.

Average values during research indicated the superiority of conventional pruning over other experimental plots, with varieties exhibiting the highest leaf area values with this method. These values positively correlated with photosynthetic yields, as conventional pruning required the lowest leaf surface area to produce one kilogram of grapes or sugars.

Table 1
The impact of anthropogenic interventions regarding pruning on annual shoots and canes, on average, during 2017-2019 growing seasons

Experimental plot	Variety	One year old wood			Difference compared to control (%)	Significance
		Total (m/vine)	Matured (m/vine)	Matured (% from total)		
V1(C)	Merlot	12.07	9.23	76.52	-	-
	Cabernet Sauvignon	13.63	11.30	82.89	-	-
	Fetească neagră	15.37	11.57	75.27	-	-
	Fetească regală	9.97	8.00	80.27	-	-
	Victoria	13.17	9.80	74.43	-	-
	Muscat Hamburg	10.67	7.00	65.63	-	-
V2	Merlot	8.97	7.03	78.44	1.92	-
	Cabernet Sauvignon	11.10	9.20	82.88	-0.01	-
	Fetească neagră	12.50	9.50	76.00	0.73	-
	Fetească regală	6.83	5.83	85.37	5.1	-
	Victoria	9.57	7.57	79.09	4.66	-
	Muscat Hamburg	7.53	5.50	73.01	7.38	-
V3	Merlot	6.53	5.47	83.67	7.15	-
	Cabernet Sauvignon	8.33	7.63	91.60	8.71	-
	Fetească neagră	10.13	8.57	84.54	9.27	-
	Fetească regală	4.83	3.90	80.69	0.42	-
	Victoria	7.77	6.00	77.25	2.82	-
	Muscat Hamburg	5.50	3.77	68.48	2.85	-

Table 2
The impact of anthropogenic interventions on soil tillage on leaf area and photosynthetic efficiency, on average, during 2017-2019 growing seasons

Experimental plot	Variety	Leaf area			Difference compared to control	Significance
		m^2/ vine	m^2/ kg grapes	m^2/ kg sugar		
V1(C)	Merlot	5.2	2.76	8.60	-	-
	Cabernet Sauvignon	8.3	4.82	14.08	-	-
	Fetească neagră	10.0	5.72	16.54	-	-
	Fetească regală	7.5	3.26	10.69	-	-
	Victoria	8.1	3.38	14.42	-	-
	Muscat Hamburg	8.2	3.92	15.76	-	-
V2	Merlot	4.1	2.98	9.51	0.91	-
	Cabernet Sauvignon	7.1	5.81	17.34	3.26	000
	Fetească neagră	9.2	7.34	21.66	5.12	000
	Fetească regală	6.3	3.51	11.66	0.97	-
	Victoria	7.1	3.84	16.81	2.39	00
	Muscat Hamburg	6.9	4.60	19.14	3.38	000
V3	Merlot	3.2	4.14	14.32	5.72	000
	Cabernet Sauvignon	6.1	8.80	27.79	13.71	000
	Fetească neagră	8.1	11.59	36.35	19.81	000
	Fetească regală	5.5	5.73	20.32	9.63	000
	Victoria	5.9	5.99	28.74	14.32	000
	Muscat Hamburg	5.8	7.19	32.24	16.48	000

Unsurprisingly, the average production over the three-year research period was highest in the control experimental plot, representing conventional pruning. Production levels varied across experimental plot, ranging from 8151 kg/ha for Cabernet Sauvignon to 11408 kg/ha for Victoria. Superficial pruning (V2) resulted in significant decreases in average production compared to the control across all varieties. Production level ranged from 5893 kg/ha for 'Cabernet Sauvignon' to 8893 kg/ha for Victoria. The ranking of varieties based on production level with the V2 experimental plot mirrored that of the V1 plot, with all varieties exhibiting lower productions compared to the control, ranging from 2258 kg/ha for 'Cabernet Sauvignon' to 2636 kg/ha for 'Muscat Hamburg'. These differences were statistically significant compared to the control.

Over the three-year of research, the mechanized pruning experimental plot (V3) consistently yielded the lowest productions in all varieties. Production levels were relatively low, with significant differences compared to the control, ranging from 4409 kg/ha for 'Cabernet Sauvignon' to 6121 kg/ha for 'Victoria'. Mechanized pruning resulted in productions representing at most 40-45% of those achieved with normal pruning, irrespective of the climatic conditions. However, in favourable grapevine cultivation years, mechanized pruning could be considered as a necessary option only when normal or superficial pruning is unfeasible.

Table 5
The impact of anthropogenic interventions regarding pruning on the profit obtained in grapevine cultivation, during 2017 – 2019 growing seasons

Experimental plot	Variety	Production expenses (lei/ha)	Production value (lei/ha)	Profit (lei/ha)	Difference compared to control
V1(C)	Merlot	11329	26589	15260	-
	Cabernet Sauvignon	11293	24453	13160	-
	Fetească neagră	11329	24999	13670	-
	Fetească regală	11293	21938	10645	-
	Victoria	13360	45632	32272	-
	Muscat Hamburg	13317	34412	21095	-
V2	Merlot	10256	19635	9379	-5881
	Cabernet Sauvignon	10220	17679	7459	-5701
	Fetească neagră	10256	18135	7879	-5791
	Fetească regală	10220	17180	6960	-3685
	Victoria	12287	35572	23285	-8987
	Muscat Hamburg	12244	25186	12942	-8153
V3	Merlot	8906	12636	3730	-11530
	Cabernet Sauvignon	8870	11226	2356	-10804
	Fetească neagră	8906	11316	2410	-11260
	Fetească regală	8870	10484	1614	-9031
	Victoria	10937	21148	10211	-22061
	Muscat Hamburg	10894	15060.5	4166.5	-16928.5

Conclusions

The leaf area was evidently influenced by the pruning type throughout the three years of research in all varieties, with differences becoming more significant in less favourable climatic conditions. Variety rankings within each experimental plot based on this indicator remained consistent throughout the study period. Mechanized pruning, while serving as an emergency solution, is not advisable for consecutive years as it promotes bud thinning, necessitating manual correction if used repeatedly. Conventional pruning consistently yielded the best results in terms of leaf area, grape production and sugar accumulation. Conversely, mechanized pruning consistently resulted in the lowest production levels in all varieties, representing at most 40-45% of normal pruning production. Analyzing the average results over the research reveals that pruning type also significantly influenced quality, albeit less conspicuously than quantity. The experimental plots also notably affected profitability regardless of yearly climatic conditions. Manual pruning, although more traditional and costly, consistently generated the highest profits in all varieties, while superficial manual pruning, employed as a last resort, still yielded profit in all research years, irrespective of climatic conditions. Mechanized hedge-type pruning only proved profitable in very favourable climatic conditions, such as in 2018, and incurred losses during less favourable years. Consequently, mechanized pruning is a viable option strictly under dire circumstances and only in exceptionally favourable years for grapevine growing.

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