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Spur pruning and yield structure of the Syrah variety (clon 99)

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Abstract

The experiment was conducted during the period 2024-2025 with the red wine grape variety Syrah (clone 99) grown under non-irrigated conditions. Two spur pruning approaches with different bud loads were compared – 5 spurs with two buds each (a total of 10 buds) and 8 spurs with two buds each (a total of 16 buds). The main goal was to establish the influence of different bud loads on the grape yield structure. Indicators characterizing the actual fertility of the vines were: developed buds (%), fruiting shoots (%), coefficient of actual fertility (Cr). The estimated indicators characterizing grape yield were: average bunch number per vine, average mass per bunch (g), average mass of 100 berries (g), average yield per vine (kg), and average yield per hectare (kg). The load of 16 buds, resulted in higher yield, due to the larger bunch number, while pruning with 10 buds, showed a higher average cluster weight, average weight per 100 berries and a tendency towards increased average bunch length and berry size. The obtained results can be used for the optimization of cultivation practices, as well as a basis for comparison with other clones of the Syrah variety when assessing their bud load under similar climatic conditions.

Keywords: Syrah, bud loading, spur pruning, yield, grape quality

INTRODUCTION

Optimizing pruning is a tool for managing yield and quality in grapevine varieties planted in different soil and climatic conditions. The load, presented as the number of buds remaining after winter pruning, determines the balance between vegetative and generative growth of the vine and has a direct effect on yield, bunch size, sugar, and acid content (Popescu, 2012; Ene et al., 2025). Smart & Robinson, (1991) and Keller, (2020), found that the optimal load is a key of achieving a balance between vegetative growth and reproductive vine activity in Merlot, Syrah and Cabernet Sauvignon varieties. The load has a direct effect on the balance between vegetative growth and fruiting, affecting both total yield and structural parameters of the bunches - weight, size and density. Increasing the number of buds leads to an increase in yield, mainly due to the greater number of clusters per vine. However, it is often accompanied by a decrease in the average mass of the cluster and a lower accumulation of sugars (Keller, 2020). Intrigliolo & Castel (2010) found that with increasing load, the vine exhibits compensatory mechanisms, but limited assimilation capabilities lead to competition between clusters for photosynthetic products. A lower load improves grape ripening, accounting for a higher content of sugars and phenolic compounds, important for the quality of red wines (Kliewer & Dokoozlian, 2005). A higher loads often lead to the formation of small clusters, which can reduce grape quality (Al Saif et al., 2023; Poni et al., 2009). Guidoni et al. (2008) found that moderate stress favors accumulation of anthocyanins and phenolic compounds in grape skins. Quantitative indicators (number of bunches, yield) and quality parameters (sugars, acids, phenolics) are closely interrelated, and their balance depends on the optimal degree of vine loading (Kliewer & Dokoozlian, 2005; Guidoni et al., 2002;

Smart & Robinson, 1991). Clones 174 and 470 of the Syrah variety respond differently to load management, either by removing part of the bunches or by regulating the number of buds, which affects bunch size, sugar content, and acidity (Popova & Angelov, 2024). The application of different practices in the Syrah variety with a reduction in bunches shows that lower load increases the content of sugars, anthocyanins and tannins, while reducing titratable acids - effects that are key to improving quality (Liang et al., 2022).

The aim of the study was to assess the effect of a load of 10 and 16 buds per vine on productivity and bunch structure, as well as to establish the relationship between the load and the quality indicators of the grapes in clone 99 of the Syrah variety cultivated under the climatic conditions of the Plovdiv region.

MATERIALS AND METHODS

The study was conducted in the period 2024-2025. The vines were planted in the Training, Experimental and Implementation Base for Viticulture at the Agricultural University - Plovdiv, located in the land of the town of Kuklen, near the Brestnik village, Rhodope Municipality. The study used clone 99 of the red wine variety Syrah, grafted on the rootstock Berlandieri x Riparia SO4. *Syrah (clone 99)* is a French variety belonging to the Western European eco-geographical group. It is most widely distributed in southern France.

Agrobiological characteristics

The bunch is medium-sized (15.9-8.8 cm), conical and medium-compact with spherical, medium-sized (13.5-11.9 mm) the berry. The skin is thick, tough, blue-black in color and abundantly covered with a waxy coating. The average weight per bunch is 148 g. The weight of 100 berries is 152 g, respectively. The average number of bunches per shoot is 1.33. The percentage of developed buds is 78.07%.

Technological characteristics

The grapes ripen in mid-September. They accumulate about 23.40% sugars and have 6.8 g/l titratable acids. The wines contain 12.8% alcohol and 1.71 g/dm^3 titrable acid. The total extract is 28.77 g/l and 27.06 g/l sugar-free extract. Wines from "Syrah 99" often tend to have a sweetish tinge of dried fruits and chocolate. The taste is dense, well-balanced and harmonious. The body is dense and rounded, with a long-lasting, fine and pleasant aftertaste (Angelov & Stalev, 2011).

The vineyard was planted in 2000 with planting distance of 3.20 m between rows and 0.80 m between vines in the row. The training system is a medium-stemmed single cordon, with a stem height of 80 cm. The bud loading was carried out by pruning on spurs with two buds in two variants with a loading of 10 (V0) and 16 (V1) buds per vine. The inter-rows are grass covered, and the soil surface between vines is kept clean by applying herbicides. The vines are grown under non-irrigated conditions. The average terrain altitude is 194 m.

In the study, the following indicators characterizing *the actual fertility* were estimated: developed buds from spurs, (%); fruiting shoots from spurs, (%); fruiting shoots with 1, 2 and 3 bunches; coefficient of actual fertility (Cf); coefficient of fertility of 1 fruiting shoot (Cfs). These indicators were reported annually in June at a berry size of 5-6 mm (pea size phenological stage BBCH - 75).

Grape yield indicators: average number of bunches per vine; average mass per bunch, (g); average mass of 100 grains, (g); average yield per vine, (kg); average yield per ha, (kg).

Grape quality indicators:

– Estimation of sugar content with a laboratory Abbe refractometer, (%);

– Estimation of titratable acids by titration with 0.1 n NaOH, (g/dm^3);

– Mechanical bunch and berry structure - normal berries (%), bunches (%), skins (%), seeds (%), milleranded beries (%), mesocarp (%), theoretical yield, (%), average bunch size -

length and width (cm), average berry size - length and width (mm), chemical composition of grape juice - Sugars (%) and titratable acids (g/dm^3).

The indicators of actual fertility, yield and mechanical composition of the grapes were studied according to the methodology of Roychev (2014).

The determination of sugars and titratable acids was studied for asseement of technological ripeness (grape harvest) according to Bambalov (2009).

The climatic indicators include - maximum, minimum, average air temperature and precipitation. Soil moisture was determined at a depth of 50 cm. The data on the climatic indicators for the study period were taken from the meteo station located in the vineyard.

Selyaninov hydrothermal coefficient (HTC)

HTC was calculated for the period March - September according to the formula HTC = Sr/0.1 x St, where: HTC - Selyaninov hydrothermal coefficient; Sr - sum of precipitation for a period with average daily temperatures > 10°C; 0.1 - equalization coefficient; St - sum of average daily air temperatures > 10 °C for the period.

The data were analyzed using one-way ANOVA analysis of variance in Microsoft Excel, with results considered statistically significant at $p < 0.05$. Correlation analysis of the data was performed using Microsoft Excel. The second-degree polynomial regression was performed using the Polynomial Trendline (Order 2) function. The regression equation was obtained in the form $y = ax^2 + bx + c$.

RESULTS AND DISCUSSION

The average temperatures in April/May 2024 were above 16°C, in the summer months (June, July, August) respectively 26-28°C, with maximums above 34-36°C (Figure 1). The summer was hot with high maximum temperatures, low precipitation with risks of water stress. The spring of 2025 was colder. In February, the average temperature was 1.7°C, and the minimum 3.3°C. The amount of precipitation in 2025 was higher compared to 2024, but in both years, it was unevenly distributed across months during the growing season (Figure 2). The spring of 2025 was characterized by relatively high precipitation in March and May, while the summer was low compared to 2024.

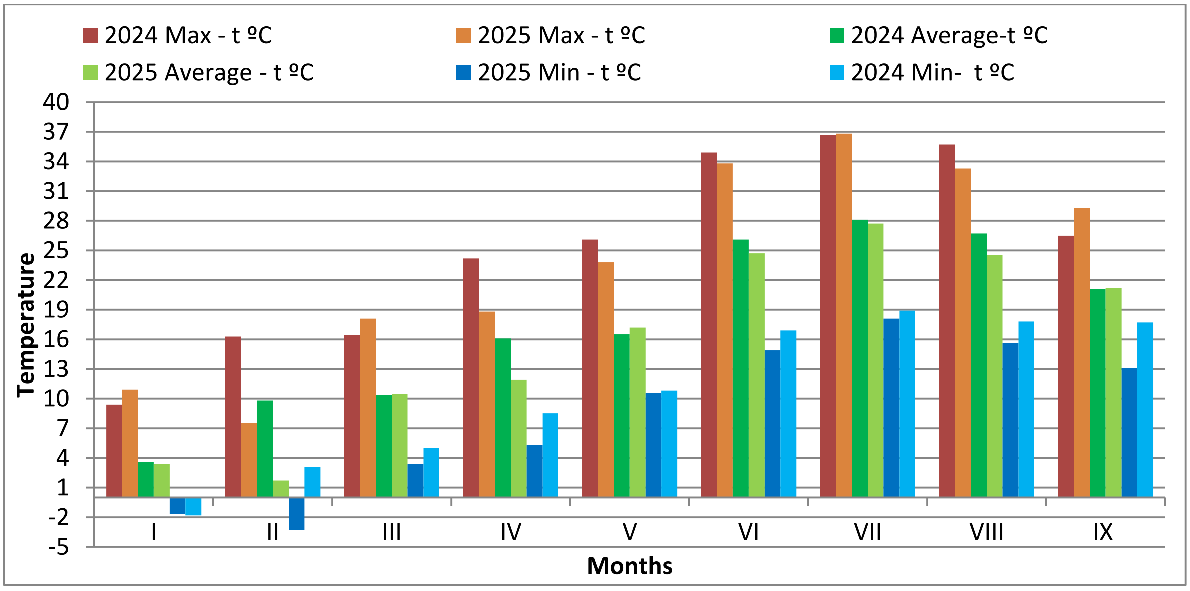

Figure 1. Average monthly maximum and minimum air temperature for the period January - September, 2024 and 2025

During the winter months (January-March) the differences in soil moisture at a depth of 50 cm were minimal (94-98 %), (Figure 2). In the spring (April to May) in 2025 the humidity was noticeably higher, especially in April (+12 %) as a result of more precipitation. In the summer (June-August) the difference was notable since in 2025 the humidity was 15-20 % higher, compared to 2024 – July to September (humidity 52-58 %), indicating a conditions for water stress.

The estimated HTC for the period March-September was 0.54 in 2024 (Figure 2). This was a result of drought, which adversely affected the growth and development of vines, especially during critical vegetation phases. In 2025, the estimated HTC was 0.73, indicating sufficient soil moisture. Climate conditions during 2025 was more favorable for vine development than 2024, but in general, the precipitation was low, which may partially limit the yield.

The percentage of developed buds remained practically unchanged at both load levels (Tables 1 and 2), ranging from 72.8 % (V1-2024) to 77.2% (V0-2025). Similar results were obtained for the percentage of fruiting shoots from 75.6 % (V1-2024) to 79.91% (V0-2025). The vines preserved their fruiting potential when loaded with 16 buds. The fertility coefficient increased from 0.94 (V0-2025) at a load of 10 buds to 1.22 (V1-2024) at a load of 16 buds per vine.

Similar results were also obtained for the coefficient of actual fertility per fruiting shoot from 1.22 (V0-2025) to 1.49 (V1-2024). Clone 99 has a high productive potential, stable fertility and the applied load did not affect the formation of inflorescences. No differences were observed in the percentage of fruiting shoots with 1 and 2 clusters as a result of the load.

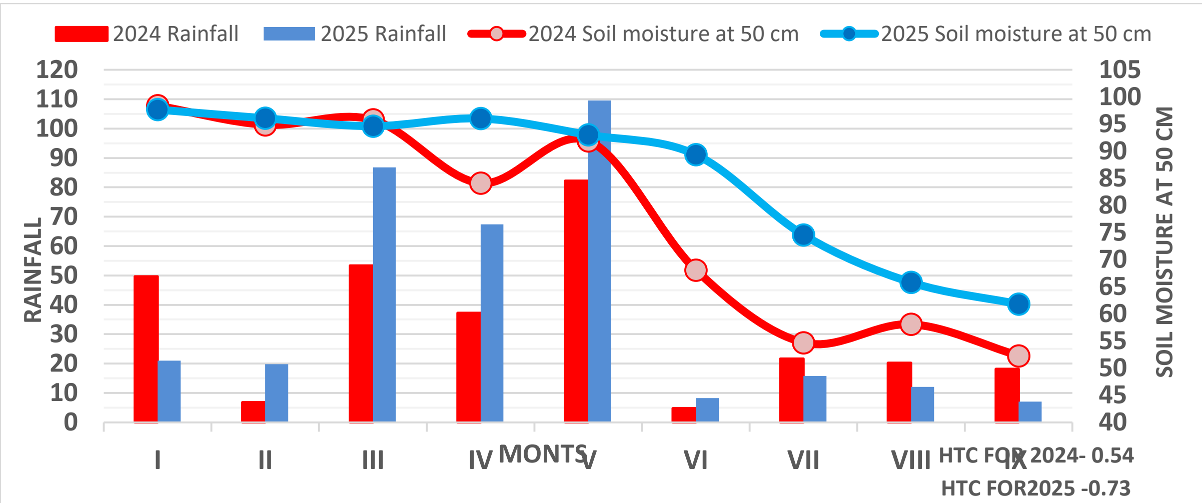

Figure 2. Precipitation and average monthly soil moisture at a depth of 50 cm for the period January - September, 2024 and 2025

Table 1. Influence of bud load on indicators characterizing actual fertility, 2024

Bud load	Developed buds, %	Fruiting shoots, %	Actual fertility rate, (Cf)	Coefficient of fertility per fruiting shoot, (Cfs)	Fruiting shoots, %		
					With 1 bunch	With 2 bunches	With 3 bunches
V0	73.9	76.06	0.99[a]	1.30[a]	53.12	44.32	2.56[a]
V1	72.8	75.60	1.22[b]	1.49[b]	54.19	44.43	1.38[b]

Legend: Values within a column followed by different superscript letters are significantly different ($p < 0.05$)

Table 2. Influence of bud load on indicators characterizing actual fertility, 2025

Bud load	Developed buds, %	Fruiting shoots, %	Actual fertility rate, Cf)	Coefficient of fertility per fruiting shoot, (Cfs)	Fruiting shoots, %		
					With 1 bunch	With 2 bunches	With 3 bunches
V0	77.2	79.91	0.94^{a}	1.22^{a}	51.43	45.71	2.86^{b}
V1	76.1	77.4	1.15^{b}	1.43^{b}	53.23	45.16	1.61^{a}

Legend: Values within a column followed by different superscript letters are significantly different ($p < 0.05$)

Table 3. Influence of bud load on indicators characterizing yield, 2024

Bud load	Number of bunches per vine	Yield per vine, (kg)	Yield per hectar, (kg/ha)	Average weight per bunch,(g)	Average mass per 100 berries, (g)
V0	15.45^{a}	1.56^{a}	6080.4^{a}	101^{b}	169.20^{b}
V1	21.2^{b}	1.93^{b}	6590.1^{b}	91^{a}	132.6^{a}

Legend: Values within a column followed by different superscript letters are significantly different ($p < 0.05$)

Table 4. Influence of bud load on indicators characterizing yield, 2025

Bud load	Number of bunches per vine	Yield per vine, (kg)	Yield per hectar, (kg/ha)	Average weight per bunch,(g)	Average mass per 100 berries, (g)
V0	13.75^{a}	1.89^{a}	7370.1^{a}	132^{b}	185.91^{b}
V1	22.5^{b}	2.36^{b}	9200.4^{b}	105^{a}	158.72^{a}

Legend: Values within a column followed by different superscript letters are significantly different ($p < 0.05$)

With the increase of 10 to 16 buds, the number of clusters per vine increased from 13.75 (V0-2025) to 22.50 (V1-2025) (Tables 3 and 4). The yield in 2024 was lower than in 2025, due to unfavorable climatic conditions - low soil moisture during the summer period combined with high temperature.

A higher yield was estimated of the vine during the two years study when the load was 16 buds per vine. It ranged from 2.36 kg (V1-2025) to 1.56 kg (V0-2024) when the load was 10 buds, and respectively from 9200.40 kg/ha (V1-2025) to 6080.40 kg/ha (V0-2024). The increase in yields was attributed to the larger number of clusters when the load was 16 buds per vine.

With the increase in the number of clusters, the average mass per bunch decreased 101 g (V0-2024) for the period when the load was 10 buds per vine, and further to 91 g (V1-2024) when the load was 16 buds per vine. Similar data are available for the mass of 100 berries, where with the increase in the load from 10 to 16 buds, the mass decreased from 169.20 g (V0-2024) to 132.6 g (V1-2024).

When loaded with 16 buds, an increase in the percentage of cluster parts by 12.76% was observed, which was attributed to the greater competition for assimilates at high load, leading to a relatively large participation of the cluster in the total mass.

The proportion of healthy berries was higher at a load of 10 buds per vine – 94.75%, compared to 87.24% at V1.

The percentage of milleranded berries was higher at a load of 16 buds per vine – 4.86% (V1-2025), compared to a load of 10 buds per vine – 0.75% (V0-2025). There was no change in the percentage of raisined berries for the period of the study in both variants 0.06 (V1-2025) -3.09% (V1-2024). The theoretical yield reached from 71.74% (V0-2024) to 78.73% (V1-2025), (Tables 5 and 6). The difference was insignificant, which indicated that increasing the load did not lead to an increase in the theoretical yield. Bunch length for the period was 14.85 cm (V0-2025) and decreased to 12.59 cm (V1-2024). The width of the bunch at low load was 6.42 cm (V0-2024), and at high, it increased to 7.50 cm (V1-2025). The differences are statistically significant. The proportion of skins at V0-2025 was 11.65%, and at V1-2024 – 14.06 (Tables 7 and 8). The difference was minor, but indicated a tendency towards increase of skins at a load of 16 buds per vine. The percentage of seeds varied from 5.80 % (V0-2024) to 4.24 (V1-2025) at a high load. They did not account for differences in the percentage of mesocarp.

Table 5. Influence of bud load on the bunch structure, 2024

Bud load	Clusters parts, %	Normal berries , %	Mileranded berries, %	Raisined berries, %	Teoretical yield, %	Average bunch sizes	
						lentgh, mm	Width, mm
V0	10.93[a]	89.07	1.43[a]	2.96[a]	71.74	13.98[b]	6.42[a]
V1	12.76[b]	87.24	2.36[b]	3.09[b]	70.20	12.59[a]	7.11[b]

Legend: Values within a column followed by different superscript letters are significantly different ($p < 0.05$)

Table 6. Influence of bud load on the bunch structure, 2025

Bud load	Clusters parts, %	Normal berries , %	Mileranded berries, %	Raisined berries, %	Teoretical yield, %	Average bunch sizes	
						Lentgh, mm	Width, mm
V0	5.25[a]	94.75	0.75[a]	0.08	78.71	14.85[b]	6.82[a]
V1	6.06[b]	93.94	4.86[b]	0.06	78.73	13.05[a]	7.5[b]

Legend: Values within a column followed by different superscript letters are significantly different ($p < 0.05$)

Table 7. Influence of bud load on the berry structure, 2024

Bud load	Skins, %	Seeds, %	Mezocarp, %	Seeds in100 berries	Avg. seeds mass in 100 berries, g	Average berry size		Chemical composition of grape must	
						Width, mm	Lenght, mm	Sugar, %	Acids, g/dm³
V0	13.64[a]	5.80[b]	80.56	261[b]	8.69[b]	14.01[b]	11.97[b]	24.4[b]	6.68[a]
V1	14.06[b]	5.47[a]	80.47	205[a]	6.45[a]	12.57[a]	11.08[a]	22.7[a]	7.61[b]

Legend: Values within a column followed by different superscript letters are significantly different ($p < 0.05$)

Table 8. Influence of bud load on the berry structure, 2025

Bud load	Skins, %	Seeds, %	Mezocarp, %	Seeds in100 berries	Avg. seeds mass in 100 berries, g	Average berry size		Chemical composition of grape must	
						Width, mm	Lenght, mm	Sugar, %	Acids, g/dm³
V0	11.65	5.25[b]	83.1	279[b]	9.25[b]	14.6[b]	12.40[b]	25.0[b]	6.20[a]
V1	11.95	4.24[a]	83.81	223[a]	6.85[a]	13.2[a]	11.45[a]	22.9[a]	7.29[b]

Legend: Values within a column followed by different superscript letters are significantly different ($p < 0.05$)

Significant statistical difference in the number of seeds in 100 berries from 205 pieces (V1-2024) to 279 pieces (V0-2025) was found. Similar results were observed during the experiment in the seeds mass in 100 berries, which varied from 9.25g (V0-2025) to 6.45g (V1-2024). The decrease in these indicators at a load of 16 buds was due to stronger competition for nutrients, which can limit the normal formation and development of berries. In terms of the length and width of the berry, the significant difference was found. There was decreasing trend when the load increased from 10 to 16 buds. Additionally, the increased load negatively affected production quality. The content of sugars in the grape must at a load of 10 buds was 25.0% (V0-2025), and at a load of 16 buds it decreased to 22.7% (V1-2024). Titratable acids increased of 6.20 g/dm^3 (V0-2025) to 7.61 g/dm3 (V1-2024). At low bud load, the assimilates were concentrated into reduced number of berries, which resulted in higher sugar content and improved grape quality.

For variant V0, was established a strong positive correlation between yield and sugar content (r = +0.78). At high load (V1), the correlation remained positive, but significantly less pronounced (r = +0.32). This indicates that at low load the plant maintains a better physiological balance, in which increasing yield does not lead to changes in sugar content (Table 9). At high load, relationships become positive and stronger, which indicates that the vine adapts and distributes assimilates more effectively, which leads to an increase in yield. The results from correlation analysis could be used as indicators that the load optimization is a key approach of achieving a balance between quantity and quality, relevant to improving agrotechnical practices and increasing productivity.

Correlation coefficients between yield and grape quality indicators are almost identical (Table 10). This is related to the stability and repeatability of the physiological responses of the vine, regardless of climatic differences over the years, allowing reliable prediction of yield according to the number of bunches and bud load.

The regression analysis gives a strong positive linear relationship between bud load and the number of bunches (Figure 3). When the load increases from 10 to 16 buds, the number of bunches increases. The high values of the coefficient ($R^2 > 0.96$) show over 96% of the variation in the number of bunches depends on the level of bud load. It is a key factor that practically determines the formation of the bunch numbers, while the influence of other factors (climatic conditions) is weak.

Table 9. Correlation analysis of selected yield and quality indicators by variants

Parameters	Bud load	
	10 buds (V0)	16 buds (V1)
Yield per vine ↔ Average bunch weight	r = +0.97	r = + 0.99
Yield per vine ↔ Sugar content	r = + 0.78	r = + 0.32
Yield per vine ↔ Average mass of 100 berries	r = +0.99	r = + 0.99

Table 10. Correlation analysis of selected yield and quality indicators

Parameter	Year	
	2024	2025
Bud load ↔ Yield	r = +0.96	r =+ 0.97
Bud load ↔ Bunch numbers	r =+ 0.97	r = +0.98
Bunch numbers ↔ Yield per vine	r = +0.99	r = + 0.99
Average bunch weight ↔ Sugar content	r = +0.99	r = +0.98
Bud load ↔ Average bunch width	r = +0.76	r = +0.97
Bud load ↔ Average seed width	r = +0.99	r = +0.89

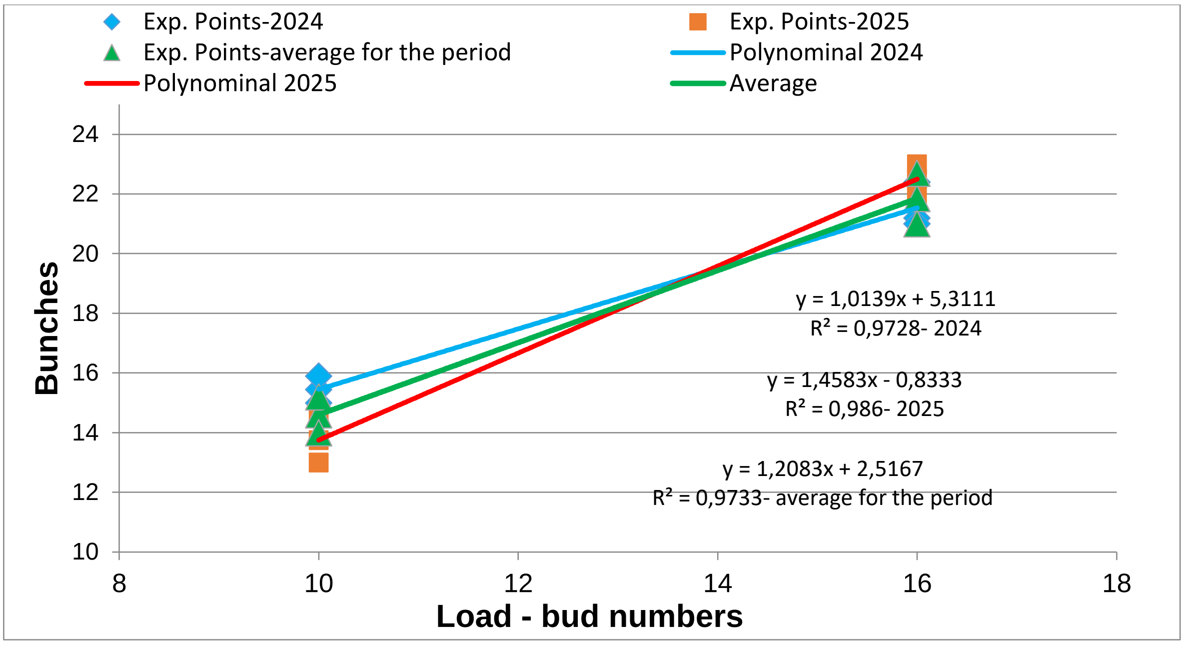

Figure 3. Dependence between bud load and number of bunches

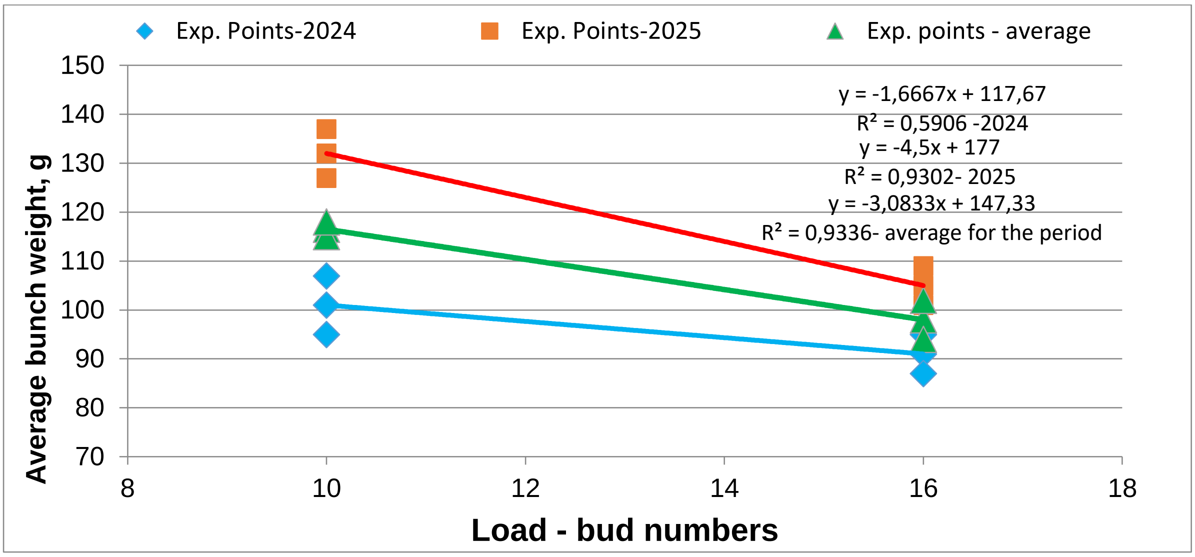

Figure 4. Relationship between bud load and average bunch weight

A moderate to strong regression relationship is established between the bud load and the average bunch mass (Figure 4). In 2024, the coefficient is $R^2 > 0.59$, and for 2025, the relationship is very strong - $R^2 > 0.93$, which indicates the presence of a strong annual influence. In 2024, the influence of the bud load is less pronounced, in addition to the load, other factors (climatic conditions) have an impact on the average bunch mass. The bud load affects the mass of the bunch, but the relationship is moderate to strong, showing a complex formation mechanism of this indicator and dependence on the specific conditions during the year. The regression analysis of the relationship between the number of bunches and the yield gives a strong positive regression relationship and on average for the period has values above $R^2 > 0.95$ (Figure 5). A large part of the variation in the yield (over 95%) is explained by the change in the number of bunches.

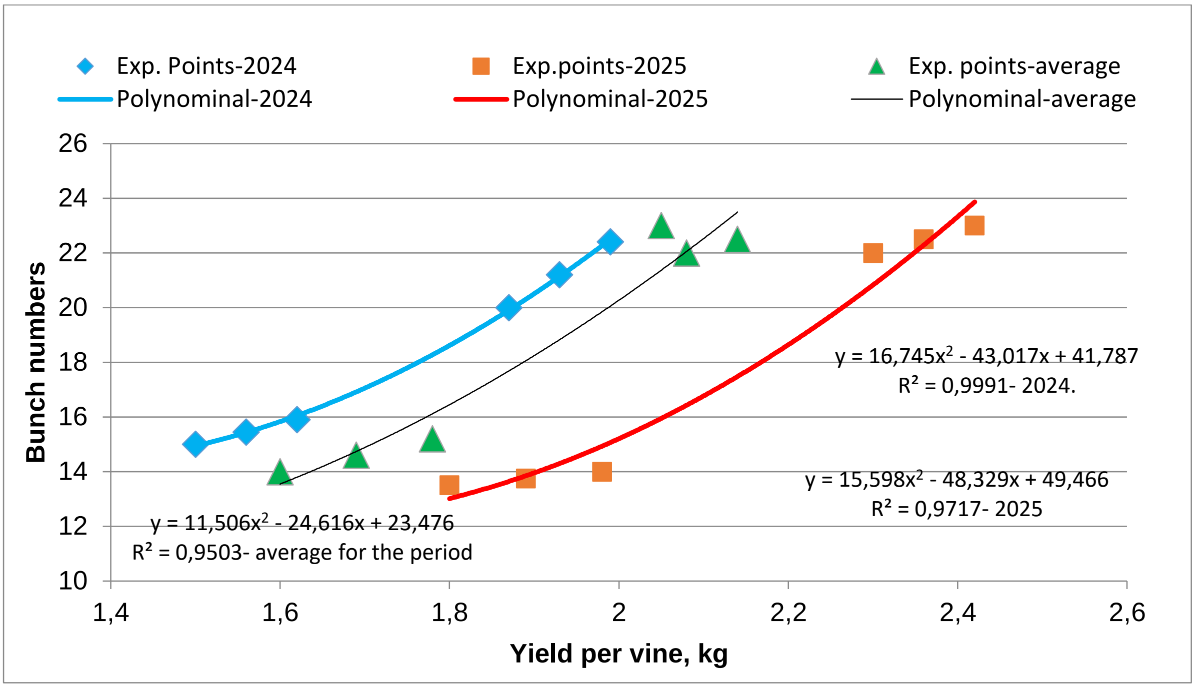

Figure 5. Relationship between the number of bunches and grape yield

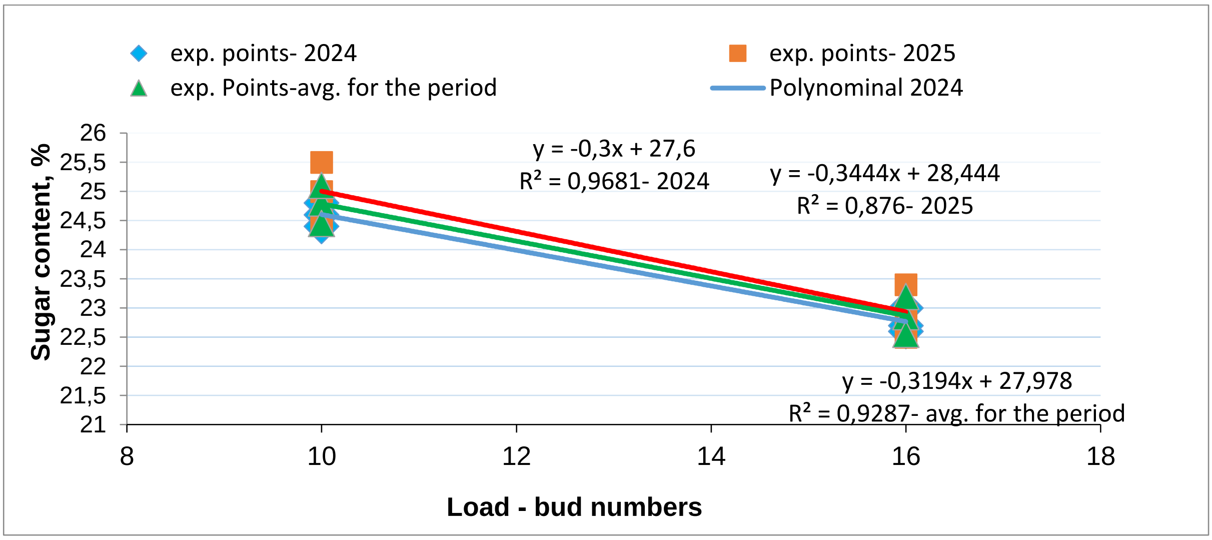

Figure 6. Relationship between bud load and sugar content

The number of bunches is more important than the individual bunch mass. Their increase results in an increase in the total yield, but the high values of the regression coefficients confirm that the management of the number of bunches is a key factor for yield optimization.

There is a very strong regression relationship between bud load and sugar content (Figure 6). Regression coefficients above $R^2 > 0.95$ over the years show over 95% of the variation in sugar content is due to the bud load level. Increasing bud load leads to a decrease in sugar content, which is essential for the product quality. High regression coefficients confirm the decisive role of bud load in the formation of the chemical composition and grapes quality.

CONCLUSIONS

Clone 99 of the Syrah variety has a good compensatory ability and stable fertility. The bud load mainly affects the yield, number and mass of bunches, berries and the content of sugars and titratable acids, but does not affect the fruiting potential. The main factor determining the yield is the bunch number. When bud loading with 16 buds per vine, the average number of clusters per vine increased from 13.75 to 22.50, which increased the yield per vine from 1.56 kg to 2.36 kg and, respectively, from 6080.40 to 9200.40 kg/ha. The mass of 100 berries decreased from 169.20 g when loading with 10 buds per vine to 132.60 g when loading with 16 buds. The bud load was the main factor in the formation of the grape mass, but in individual years its influence was weak and the importance of environmental factors increased. The bud load of 16 buds per vine affected the chemical qualities of the must, by reducing the sugar content from 25.0 to 22.7% and increasing the titratable acids from 6.20 g/dm^3 to 7.61 g/dm^3.

At a bud load of 10 buds per vine, more favorable conditions were provided for both fruiting and the overall quality of the production. The correlation analysis shows high stability and repeatability of the vine physiological reactions at the estimated bud load levels, regardless of the climatic differences during the years of the study. Furhtermore, regardless of the bud load level, the trends in the correlations are consistent. This allows for long-term recommendations for optimal bud load of vines and management of grape yield and quality.

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