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ARTICLE

Comparative mathematical analysis of economically important ampelographic indicators in white wine vine varieties (*Vitis vinifera* L.)

Venelin Roychev[1], Neli Keranova[2]*

[1]Agricultural University-Plovdiv, Faculty of Horticulture with Viticulture, Plovdiv, Bulgaria
[2]Agricultural University-Plovdiv, Faculty of Economics, Plovdiv, Bulgaria

ABSTRACT A comparative mathematical analysis of economically important ampelographic indicators was performed in 32 local, introduced and newly bred white wine vine varieties. It was found that depending on the similarity and remoteness of the values of the studied indicators, the varieties are grouped into three generalized clusters. In the first, the varieties are characterized by a longer budding period and relatively lower productivity. In the second, they have similarities in the length of the budding period, long period of budding - technological maturity, moderate productivity, and close content of volatile acids in the wine. In the third, the newly bred two varieties Gergana and Misket Markovski, which are the most fertile and productive and with the smallest number of seeds in the berries. There is a high variability of the individual white wine varieties according to the studied economically valuable indicators. The indicators of bunch length and average weight per 100 berries have a stronger direct effect on the formation of the yield in individual varieties, and the average bunch weight, bunch width, percentage of mesocarp in berries, berry length and width, as well as the theoretical yield significantly affect indirectly the productivity of vines. **Acta Biol Szeged 66(2):106-115 (2022)**

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***Corresponding author**
E-mail: nelikeranova@abv.bg

Introduction

The area of white wine varieties and their branches is about 36% of all wine vineyards in Bulgaria. Most of the districts suitable for their cultivation are in the northeastern part of the country, where soil and climatic conditions favor the production of grapes with low sugar content and high content of titratable acids. There are suitable habitats for these varieties in southern Bulgaria, mainly in the sub-Balkan valleys of Karlovo and Sungurlare, as well as in some districts near water basins, rivers, and mountains. The most famous local (autochthonous) varieties from the Black Sea ecological-geographical group (convarietas *pontica* Negr., subconvarietas *balcanica*) for white wines are Dimyat, Misket red and Keratsuda, and from the Eastern ecological-geographical group (convarietas *orientalis* Negr.) – Tamyanka and Misket of Vratsa.

Economically the most important group determining this direction in wine production in our country consists mainly of varieties of the Western European ecological-geographical group (convarietas *occidentalis* Negr.) - Chardonnay, Sauvignon Blanc, Riesling, Riesling Italian, Traminer rose, Muscat Otonel, June Blanc, Aligote, etc. Viognier, Chenin Blanc, Grenache Blanc, Prosecco and Gewürztraminer have spread during the last few decades (Roychev 2012). Although in smaller areas, there are also varieties for white wines newly bred by sexual hybridization. The existing soil and climatic diversity suggest great specificity in the adaptation, especially of the introduced varieties, to the conditions of the external environment. In view of the choice of the applied agrotechnical procedures in their cultivation and grape vinification technologies, of utmost interest is the information related to their phenotypic proximity and remoteness, which can explain a number of their ampelographic features and reactions in the complex genotype-environment interactions. Mathematical approaches and methods (Cejudo-Bastante et al. 2011; Giovenzana et al. 2015; Socha et al. 2015; Geana et al. 2019) are increasingly used in this type of research. The purpose of the current investigation is, by means of the application of mathematical methods of studying multiannual biometric data for a large group of vine varieties for white wines, to reveal and explain in more detail some of their agrobiological and technological characteristics, allowing their more efficient microzoning.

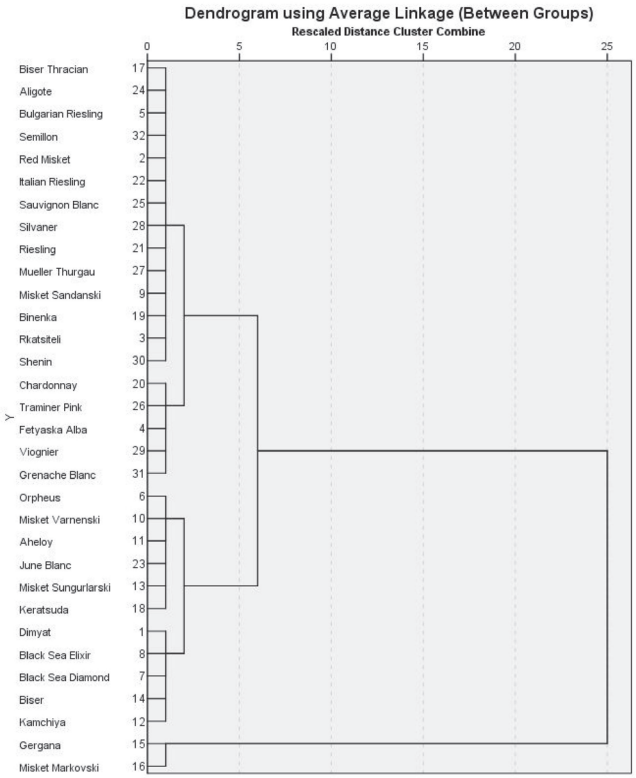

Figure 1. Grouping of the studied white wine vine varieties according to all ampelographic indicators in Tables 1-4.

Materials and Methods

The experimental work includes 32 local, introduced and newly bred white wine vine varieties grown in the ampelographic assortment of the Agricultural University, Plovdiv. The vines were grafted on the rootstock *Berlandieri* x *Riparia* Teleki, selection Kober 5BB, and are Mosercordon trained. For five consecutive years indicators related to phenological, agrobiological and technological characteristics were determined for each variety as well as the chemical composition of the obtained wines (Bulgarian Ampelography 1990; Roychev 2014). Some of the data on the duration (days) of the individual phenophases and periods are not integers due to the presentation of their averages for a five-year period.

To establish clusters (groups) of varieties with similar ampelographic characteristics, hierarchical cluster analysis was applied by the method of intergroup connection and measure of similarity the quadratic Euclidean distance. The clustering procedure is visualized by a dendrogram. The combination of the cluster analysis with other statistical evaluation methods is due to the need to verify the statistical reliability of the results obtained. For the qualitative description of the clusters and the reasons for the unification of the different varieties, a single-factor analysis of variance was applied using the Duncan method, with a significance level of 0.05.

The influence of the different groups of ampelographic indicators (independent variables) on the average yield per decare (dependent variable; 1 decare = 0,1 hectare) was studied. Pearson's correlation coefficient, at significance levels of 0.05 and 0.01, and the coefficient of determination were calculated. In case of proven from moderate to high correlation between the respective indicators, linear regression equations have been compiled, which present in analytical form the relationship between them and create a prerequisite for their application in forecasting research. The coefficient β was calculated, as well as the corresponding Path coefficients in the case of multiple regression models (Scheiner et al. 2000).

Numerous models have been compiled for the indicators from the separate groups, which have a complex influence on the yields of the studied vine varieties. Given the presence of several independent variables, they are denoted by the corresponding symbol (x_1, x_2, ..., x_9). Only the statistically significant correlation coefficients the value of which is higher than 0.3 and prove the presence of moderate to high correlation dependence are presented. The links between all other indicators are weak and are not the subject of research and analysis.

The IBM SPSS 23 software product (Giudici and Figini 2009; Arkkelin 2014) was used for statistical data processing.

Results and Discussion

As a result of the applied hierarchical cluster analysis, it was found that the studied 32 white wine vine varieties are grouped into three clusters (Fig. 1). The first includes the most varieties that are characterized by a longer budding period, with relatively lower productivity due to the smaller berry sizes - Thracian Pearl, Aligote, Bulgarian Riesling, Semillon, Red Misket, Italian Riesling, Sauvignon Blanc, Sylvaner, Riesling, Mueller Thurgau, Misket of Sandanski, Vinenka, Rkatsiteli, Chenin Blanc, Chardonnay, Traminer Pink, Fetyaska Alba, Viognier, Grenache Blanc and Orpheus. The second cluster unites Misket of Varna, Aheloy, June Blanc, Misket Sungurlarski, Keratsuda, Dimyat, Black Sea Elixir, Black Sea Diamond, Biser and Kamchiya. These varieties have similarities in the duration of the budding period (between 6 and 7 days), a long period of budding - technological maturity, up to 174 days in June Blanc, moderate productivity and similar volatile acid content in wine.

The last cluster consists of Gergana and Misket Markovski and joins at the maximum Euclidean distance to

Table 1. Comparative evaluation of the studied white wine vine varieties according to the indicators of their phenological characteristics

Cluster	Variety	Budding days	Flowering days	Berry softening days	Berry growth days	Budding-flowering days	Flowering-berry softening days	Berry softening-technological maturity days	Budding-technological maturity days
I	Biser Thracian	9^{ab}	8^{ghi}	12^{bcdef}	70^{def}	60.66^{efgh}	75^{hijk}	46^{efgh}	162^{fg}
	Aligote	9,66^{a}	10.66^{cde}	12^{bcdef}	64^{jk}	65.66^{b}	73^{kl}	44^{h}	160^{ghi}
	Bulgarian Riesling	8^{abcd}	10^{def}	13.33^{abcd}	70^{def}	56^{kl}	7733^{defg}	51^{cd}	160.33^{gh}
	Semillon	7^{cdef}	9^{efg}	15^{a}	73^{abc}	63^{cde}	80^{abc}	45^{fgh}	165.66^{d}
	Red Misket	5.33^{f}	9^{efg}	10^{f}	67.33^{ghi}	60^{fgh}	75^{hijk}	53.33^{b}	170^{bc}
	Italian Riesling	7^{cdef}	8.33^{fgh}	10.66^{f}	63^{k}	65^{bc}	70.33^{m}	40^{i}	155^{j}
	Sauvignon Blanc	8.66^{abc}	10^{def}	13.66^{abc}	67^{hi}	62^{defg}	75^{hijk}	36^{j}	150^{k}
	Silvaner	7.33^{bcde}	10^{def}	12^{bcdef}	66.66^{hi}	55^{l}	75.66^{fghi}	41.33^{i}	151.33^{k}
	Riesling	9^{ab}	10^{def}	13^{abcde}	66^{hij}	59^{hij}	73^{kl}	45^{fgh}	154^{j}
	Mueller Thurgau	9^{ab}	8.33^{fgh}	13^{abcde}	71.33^{abcde}	61^{efgh}	78^{cde}	47^{ef}	165de
	Misket Sandanski	7^{cdef}	11^{cd}	13^{abcde}	65^{ijk}	57^{jkl}	74^{ijkl}	51^{cd}	158.66^{hi}
	Vinenka	8.33^{abcd}	8^{ghi}	14^{ab}	70.33^{def}	59.66^{ghi}	75^{hijk}	56^{a}	171.66^{b}
	Rkatsiteli	9.33^{a}	13.33^{a}	14.33^{a}	70.33^{def}	65^{bc}	82^{a}	50.66^{d}	169^{c}
	Shenin	6.66^{def}	7.33^{ghi}	11.66^{cdef}	72^{abcd}	56.33^{kl}	77^{defgh}	47^{ef}	161.66^{fg}
	Chardonnay	9^{ab}	12^{abc}	13.33^{abcd}	70^{def}	56.33^{kl}	79^{bcd}	35.66^{j}	147.33^{l}
	Traminer Pink	6.66^{def}	7^{hi}	12^{bcdef}	72^{abcd}	56^{kl}	77^{defgh}	40^{i}	154^{j}
	Fetyaska Alba	8.33^{abcd}	8^{ghi}	11^{ef}	68.33^{fgh}	61.33^{efgh}	74.33^{ijkl}	31.33^{k}	147.33^{l}
	Viognier	6^{ef}	11^{cd}	12^{bcdef}	65^{ijk}	55.66^{kl}	73.33^{jkl}	44^{h}	151^{k}
	Grenache Blanc	8^{abcd}	7.66^{ghi}	13.33^{abcd}	70^{def}	59.66^{ghi}	76^{efghi}	56^{a}	169^{c}
	Average	*7.86*	*9.4*	*1*	*68.49*	*59.7*	*75.79*	*45.28*	*159.16*
II	Orpheus	6.66^{def}	8.33^{fgh}	11.33^{def}	70.66^{cdef}	56^{kl}	77.66^{def}	46.33^{fgh}	161^{fgh}
	Misket Varnenski	7.33^{bcde}	11.33^{bcd}	13^{abcde}	58^{l}	70^{a}	67.66^{n}	55^{ab}	168^{c}
	Aheloy	6.66^{def}	8^{ghi}	12^{bcdef}	71^{bcde}	56^{kl}	78^{cde}	45^{fgh}	160^{ghi}
	June Blanc	6.66^{def}	8.66^{fgh}	11^{ef}	72.33^{abcd}	62.33^{def}	78^{cde}	53^{bc}	174^{a}
	Misket Sungurlarski	6.66^{def}	7.66^{ghi}	11^{ef}	67^{hi}	64^{bcd}	74^{ijkl}	44.33^{gh}	162.33^{fg}
	Keratsuda	6^{ef}	8.33^{fgh}	14^{ab}	73.33^{ab}	64^{bcd}	81^{ab}	47^{ef}	171.66^{b}
	Dimyat	7^{cdef}	8.66^{fgh}	13.33^{abcd}	73.66^{a}	55.66^{kl}	79^{bcd}	56^{a}	170^{bc}
	Black Sea Elixir	7^{cdef}	10^{def}	12^{bcdef}	67.33^{ghi}	57.33^{jkl}	75.33^{ghij}	46^{efgh}	157,66^{i}
	Black Sea Diamond	6,66^{def}	9^{efg}	13.33^{abcd}	69.33^{efg}	57.33^{jkl}	75.66^{fghi}	44^{h}	154^{j}
	Biser	6.66^{def}	11^{cd}	11^{ef}	73^{abc}	61.66^{defg}	82^{a}	41.33^{i}	163^{ef}
	Kamchiya	7^{cdef}	6.33^{i}	10^{f}	70.66^{cdef}	62.66^{de}	74^{ijkl}	40^{i}	160.66^{fgh}
	Average	*6.76*	*8.58*	*12*	*69.67*	*60.64*	*76.58*	*47.09*	*16388*
III	Gergana	6.66^{def}	9^{efg}	11.33^{def}	65^{ijk}	62^{defg}	72.33^{l}	47.33^{f}	162.^{fg}
	Misket Markovski	5.66^{ef}	13^{ab}	14^{ab}	70^{def}	58^{ijkl}	82^{a}	25^{l}	137.00^{m}
	Average	*6.17*	*11*	*12.67*	*67.5*	*60*	*77.17*	*36.17*	*149.5*
Average		7.38	9.31	12.4	68.83	60.04	7615	4533	160.18
SEM		0.136	0.190	0.159	0.370	0.391	0.351	0.728	0.860
P-Value		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Values that have a different superscript letter (a, b, c, ...) differ significantly ($p < 0.05$) among each other.

the other two, which proves the existence of significant differences in the characteristics of these two varieties and all others. The reasons for their differentiation into a separate cluster are the maximum productivity per vine - up to 9.34 kg and per decare - up to 2632.67 kg. These varieties are characterized by the lowest number of seeds in the berry, as well as a high percentage of mesocarp - from 91.65% to 92.49%.

The varieties for white dry wines grown in our country are medium to late ripening, with the exception of Misket Markovski, which is early ripening, and June Blanc - very late ripening. The grapes of all studied varieties for white dry wines ripen from the beginning (September 2) to the end of September (September 30). The duration of the

Table 2. Comparative evaluation of the studied white wine vine varieties according to the indicators of fertility and yield.

Cluster	Variety	Developed buds (%)	Fruiting shoots (%)	Fertility coefficient	Average yield per vine (kg)	Average yield per decare (kg)
I	Biser Thracian	85.41^{de}	89.12^{c}	1.22^{ghij}	3.25^{mn}	1215.00^{ijk}
	Aligote	78.67^{hij}	84.16^{gh}	1.67^{ab}	3.49^{m}	1209.67^{jk}
	Bulgarian Riesling	86.31^{cde}	77.57^{jk}	1.24^{ghi}	6.78^{d}	1199.33^{jk}
	Semillon	88.32^{bc}	85.53^{fg}	1.48^{e}	3.34^{mn}	1228.33^{ij}
	Red Misket	77.55^{ijk}	75.34^{lm}	1.30^{fg}	4.28^{jkl}	1240.00^{ij}
	Italian Riesling	77.72^{ijk}	81.33^{j}	1.69^{ab}	5.21^{gh}	1313.00^{hi}
	Sauvignon Blanc	81.28^{fgh}	83.18^{h}	1.27^{fgh}	4.01^{l}	1040.00^{lm}
	Silvaner	75.62^{kl}	87.11^{de}	1.60^{abc}	3.58^{mn}	1050.00^{lm}
	Riesling	68.71^{n}	69.52^{o}	1.21^{hij}	4.01^{l}	1050.00^{lm}
	Mueller Thurgau	80.44^{fgh}	85.35^{fg}	1.50^{de}	3.00^{no}	1065.33^{lm}
	Misket Sandanski	75.10 ^{l}	76.45^{kl}	1.30^{fg}	3.32^{mn}	1026.67^{lm}
	Vinenka	77.44^{ijk}	71.41^{n}	0.83^{l}	5.06^{g}	1121.00^{kl}
	Rkatsiteli	94.05^{a}	87.72^{cde}	1.60^{abc}	2.88^{opq}	1086.67^{lm}
	Shenin	92.41^{a}	78.43^{jk}	1.19^{hij}	2.38^{qr}	975.00^{mn}
	Chardonnay	81.30^{fg}	87.67^{cde}	1.68^{ab}	2.64^{opq}	725.33^{pq}
	Traminer Pink	72.15^{m}	74.42^{m}	1.30^{fg}	2.43^{qr}	696.67^{q}
	Fetyaska Alba	81.23^{fg}	80.64^{j}	1.30^{fg}	2.61^{pq}	873.33^{op}
	Viognier	93.36^{a}	83.59^{h}	1.15^{jk}	2.30^{qr}	895.67^{no}
	Grenache Blanc	85.48^{de}	76.25^{kl}	1.17^{ij}	2.19^{r}	809.67^{op}
	Average	*81.71*	*80.77*	*1.35*	*3.51*	*1043.19*
II	Orpheus	89.34^{b}	84.27^{gh}	1.47^{e}	4.66^{i}	1393.33^{gh}
	Misket Varnenski	82.02^{f}	85.45^{fg}	1,.7^{cd}	4.59^{ij}	1448.67^{fg}
	Aheloy	93.47^{a}	92.53^{b}	1.56^{cd}	6.36^{ef}	1519.33^{ef}
	June Blanc	87.94^{bc}	77.61^{jk}	1.08^{k}	5.31^{gh}	1513.33^{ef}
	Misket Sungurlarski	76.68^{jkl}	88.73^{c}	1.43^{e}	5.53^{g}	1544.33^{ef}
	Keratsuda	77.54^{jkl}	86.54^{ef}	1.35^{f}	6.68^{de}	1611.00^{de}
	Dimyat	85.00 ^{e}	95.00^{a}	1.60^{abc}	4.49^{ijk}	1993.33^{b}
	Black Sea Elixir	79.38^{ghi}	76.27^{kl}	1.30^{fg}	7.92^{c}	1945.00^{b}
	Black Sea Diamond	81.98^{fgh}	75.53^{lm}	1.61^{abc}	4.17^{kl}	1775.33^{c}
	Biser	80.33^{fgh}	81.36^{j}	1.50^{de}	6.11^{f}	1793.33^{c}
	Kamchiya	71.60^{m}	75.41^{lm}	1.20^{hij}	7.80^{c}	1703.00^{cd}
	Average	*82.29*	*83.51*	*1.42*	*5.78*	*1658.18*
III	Gergana	72.54^{m}	72.31^{n}	1.59^{bc}	9.34^{a}	2626.67^{a}
	Misket Markovski	87.15^{cd}	88.61^{cd}	1.64^{abc}	8.75^{b}	2632.67^{a}
	Average	*79.84*	*80.46*	*1.61*	*9.04*	*2629.67*
Average		81.80	81.70	1.39	4.64	1353.75
SEM		1.19	1.13	0.04	0.35	84.44
P-Value		0.000	0.000	0.000	0.000	0.000

Values that have a different superscript letter (a, b, c, ...) differ significantly ($p < 0.05$) among each other.

period from budding to technological maturity is 136-174 days. A comparative evaluation of the studied white wine vine varieties on phenological indicators showed that Aligote has the longest budding period - between 9 and 10 days, and Misket red - the shortest one - up to 5 days (Table 1).

Misket Markovski stands out with the longest phenophase of flowering - up to 13 days, Semillon - of berry softening - 15 days, Dimyat - of berry growth - almost 74 days. The budding-flowering period is the longest in Misket Varnenski - up to 70 days, and in the flowering-berry softening in Misket Markovski - 82 days. Dimyat is also characterized by a maximum period of berry softening - technological maturity, reaching 56 days, and

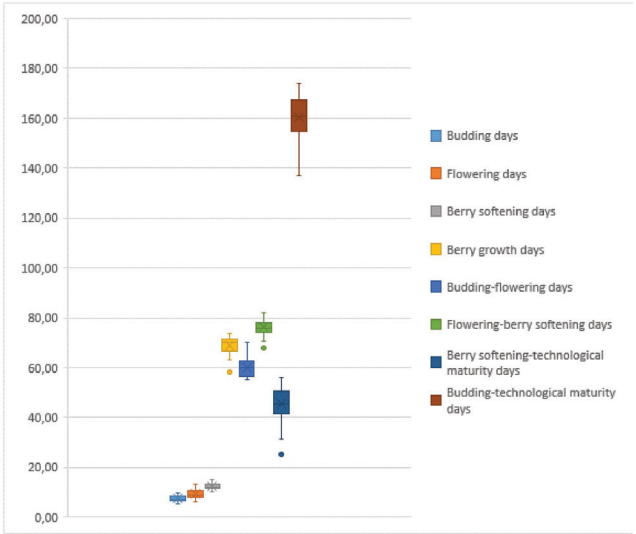

Figure 2. Change in phenological indicators in the studied white wine varieties.

June Blanc - budding - technological maturity - 174 days.

Sauvignon Blanc has the maximum number of developed buds - 94.05% and Misket Varnenski - 93.47%, which statistically significantly distinguishes them from other varieties in this indicator (Table 2). Dimyat has the highest percentage of fruiting shoots - 95%, followed by Misket Varnenski - 92.53%. All varieties (excluding Rkatsiteli) are characterized by medium and high fertility rates (1.00-1.70), average yield of vines depending on the formation and pruning system (2.000-10.000 kg) and relatively high theoretical yield per decare (700-2700 kg). Maximum fertility rate was reported in Chardonnay – 1.68, followed by Misket Markovski – 1.64. Gergana has the highest average yield per decare and vine – 9.34 kg / vine and 2626.67 kg / dka), and Misket Markovski – 8.75 kg / vine and 2632.67 kg / dka.

The bunches vary in size from small (8.9 / 7.1 cm) to medium (11.3 / 7.3-18.0 / 13.0 cm) and large (18.4 / 10.6-22.6 cm). Their average weight is 100-362 g. The berries are small (12.2 / 12.5-12.7 / 12 mm) and medium-sized (13.2 / 12.4-17.3 / 16.2 mm). Only the berries of the Dimyat variety are large. The average weight of 100 berries is from 136 g to 330 g. The mechanical analysis of the bunches and berries shows that they are typically wine varieties with sugar content of 15.8% - 26.0% and titratable acids - 5.9 - 10.8 g / dm^3. The theoretical yield of the must is from 72.50% to 88.67% In terms of the mechanical properties of the variety, the bunches of the Gergana variety have proven to be the heaviest – 366.67 g (Table 3).

Misket Markovski stands out with its long bunches – 22.47 cm, Dimyat - with its wide bunches (16.4 cm). The bunches of Misket Sandanski have the highest percentage of stems – 4.64%, Rkatsiteli has the highest percentage of berries – 98.5%, of skins - Mueller Turau – 11.79%, of seeds - Orpheus – 6.59%, of mesocarp - Misket Markovski (92.49%). Gergana has the highest value for weight of one hundred berries - 357 g, which also have a maximum length - up to 19.7 mm. The widest berries are in Semillon – 20.1 mm. Misket Sandanski has the most sugars in the grapes – 24.63%, and the least - Vinenka – 16.23%. The highest content of acids was reported in Riesling Bulgarian – 9.35 g / dm^3, and the lowest - in Keratsuda – 5.04 g / dm^3. Misket Markovski stands out as a variety with a high theoretical yield of must, reaching up to 89.10%.

Regarding the wine characteristics of the varieties, the wine produced by Misket Sandanski has the maximum alcohol content - 13.83 vol.%, followed by Misket Markovski - 13.17 vol.% (Table 4). Semillon wine has relatively more residual sugars - 4.63%, and Dimyat has minimal - 1.03%. The highest amount of sugar-free extract is in Misket Sandanski - 27.43 g / dm^3, of titratable acids - June Blanc - 8.00 g / dm^3, of volatile acids - Misket Sandanski - 0.76 g / dm^3, pH in Orpheus – 3. 43, as well as Riesling Italian and Sauvignon Blanc - 3.41. The richest in total phenols are the wines produced by Chardonnay - 229.33 mg / dm^3, and the poorest at Vinenka - 149.67 mg / dm^3.

The organoleptic properties of white wines are directly dependent on the specific taste characteristics of individual varieties and the degree of technological maturity of the grapes. Long-term observations have shown that our different soil types and climatic conditions make it possible for the grapes of Chardonnay, Rkatsiteli, Sauvignon Blanc, Riesling, Aligote, Muscat Otonel and others to reach full technological maturity for the production of quality white wines, almost every year and in most growing areas. Late ripening varieties, Dimyat, Misket red, June Blanc, Rkatsiteli and others, cannot reach optimal maturity in poor vintages, and are therefore often used to produce wine distillate. Specific to our conditions are the white wines of the Misket red variety from the terroirs of the sub-Balkans and the Sungurlare Valley, which are characterized by a delicate aroma and mild harmonious taste. The tasting evaluation score of the wines is the highest in Traminer rosé – 17.83, followed by those of Aligote and Riesling – 17.7, Riesling Italian – 17.6. It is the lowest in Grenache Blanc – 16.7.

The information presented in Tables 1-4 on the comparative evaluation of the studied white wine varieties, according to the groups of indicators, shows the wide range of variation of ranks - from *a* to *p*. This circumstance proves the existence of a large polymorphism between them, due to the variability of the studied indicators.

According to Fig. 2, showing the variation of each of the studied indicators from the respective group in the set of all researched white wine vine varieties, the

Table 3. Comparative evaluation of the studied white wine vine varieties according to the indicators of the mechanical analysis of bunches and berries

Cluster	Variety	Average bunch weight (g)	Bunch length (cm)	Bunch width (cm)	Stems (%)	Berries (%)	Skins (%)	Seeds (%)	Mesocarp (%)	Average weight per 100 berries (g)	Berry length (mm)	Berry width (mm)	Sugars (%)	Acids (g/dm³)	Theoretical yield (%)
I	Biser Thracian	125^{opq}	12.03^{pqr}	7.4^{jk}	3.80^{def}	96.19^{klm}	6.54^{lmn}	6.32^{ab}	87.33^{kl}	205^{k}	14.07^{ijk}	13^{hi}	20.43^{fghi}	8.01^{cde}	83.51^{jk}
	Aligote	131.33^{no}	13.7^{lm}	8.77^{gh}	3.82^{cde}	96.18^{lmn}	9.66^{de}	4.30^{ef}	86.04^{n}	200^{k}	14.3^{hij}	14.07^{f}	19.33^{jkl}	7.05^{fghi}	82.07^{lmno}
	Bulgarian Riesling	162.33^{l}	11.6^{qr}	7.63^{jk}	3.42^{gh}	96.58^{ij}	6.29^{mno}	3.74^{hij}	89.97^{fg}	176.67^{mn}	14.97^{gh}	11.97^{kl}	1933^{jkl}	9.35^{a}	86.34^{cdefgh}
	Semillon	160.67^{l}	14.67^{jk}	11.1^{de}	3.61^{fg}	96.39^{jk}	8.24^{hi}	3.68^{ijk}	88.08^{ij}	179.33^{m}	14.13^{ijk}	20.1^{a}	21.97^{cd}	6.35^{jkl}	85.08^{ghij}
	Red Misket	230^{g}	15.17^{hij}	9.07^{fgh}	2.68^{k}	97.32^{g}	8.46^{gh}	3.46^{jkl}	88.08^{ij}	212.33^{j}	14.03^{ijk}	11.03^{mn}	18.2^{mn}	5.53^{no}	85.40^{efghij}
	Italian Riesling	121.33^{pqr}	12.5^{opq}	6.9^{k}	3.39^{h}	96.61^{i}	8.03^{hi}	5.98^{bc}	85.99^{n}	121.33^{r}	12.33^{pq}	13.93^{fg}	19.37^{jkl}	8.26^{cd}	82.94^{klm}
	Sauvignon Blanc	129^{op}	11.5^{r}	7.60^{jk}	2.91^{j}	97.09^{g}	9.02^{fg}	2.87^{nop}	88.11^{ij}	165.33^{p}	13.67^{jkl}	14.23^{ef}	23.07^{b}	7.25^{fgh}	84.91^{ghoj}
	Silvaner	120.67^{qr}	12.03^{pqr}	7.1^{jk}	3.51^{gh}	96.49^{ij}	10.36^{bc}	4.61^{e}	85.03^{o}	179.67^{m}	11.57^{r}	15.87^{cd}	21.3^{cdef}	7.12^{fghi}	80.52^{no}
	Riesling	109.33^{s}	11.67^{qr}	7.77^{ij}	2.43^{mn}	97.57^{cd}	7.82^{hij}	2.99^{mno}	89.19^{h}	179^{m}	12.07^{qr}	13.83^{fg}	19.03^{jkl}	7.53^{ef}	87.08^{bcdef}
	Mueller Thurgau	119.67^{qr}	13.37^{lmno}	9.6^{f}	3.54^{gh}	96.46^{ij}	11.79^{a}	3.63^{ijk}	84.58^{o}	179.33^{m}	15.3^{efg}	15.37^{d}	18.03^{n}	7.21^{fghi}	81.15^{mno}
	Misket Sandanski	240.67^{f}	15.57^{hi}	8.4^{hi}	4.64^{a}	95.36^{p}	5.19^{q}	3.05^{mno}	91.77^{b}	193^{l}	12.9^{mnop}	12.37^{ijk}	24.63^{a}	6.68^{hijkl}	87.36^{abcd}
	Vinenka	240^{f}	13.33^{lmno}	9.5^{fg}	2.71^{k}	97.29^{g}	6.97^{kl}	3.20^{lmn}	89.82^{g}	234.33^{gh}	15.77^{ef}	13.7^{fg}	16.23^{o}	8.21^{cd}	87.27^{abcd}
	Rkatsiteli	205^{i}	17.03^{ef}	9.23^{fg}	1.50^{p}	98.50^{a}	8.03^{hi}	3.79^{ghij}	88.18^{ij}	224.33^{hi}	15.97^{de}	11.17^{mn}	18.53^{lmn}	8.56^{bc}	86.3^{cdefgh}
	Shenin	310.33^{b}	13.47^{lmn}	10.5^{e}	3.12^{i}	96.88^{h}	9.00^{fg}	2.82^{op}	88.18^{ij}	176.33^{mn}	13.57^{jkl}	16.53^{b}	20.67^{fghi}	6.24^{kl}	85.21^{fghij}
	Chardonnay	113.33^{rs}	11.9^{pqr}	7.4^{jk}	3.75^{efg}	96.25^{klm}	9.27^{ef}	3.97^{fgh}	86.77^{lm}	127^{r}	12.7^{opq}	13.73^{fg}	22^{cd}	8.05^{cde}	81.53^{mno}
	Traminer Pink	100^{t}	9,03^{s}	7,63^{jk}	3,19^{i}	96,81^{h}	10,25^{bcd}	6,17^{bc}	83.48^{p}	140,33^{q}	13.2^{lmno}	14.73^{e}	20.5^{fghi}	7.98^{de}	80.36^{o}
	Fetyaska Alba	111^{s}	17,97^{cd}	13,5^{b}	3,49^{gh}	96,51^{ij}	5,71^{pq}	3,26^{lm}	91,03^{cde}	148,33^{p}	12.8^{nopq}	11.63^{lm}	20.9^{efgh}	6.7^{hijk}	88.01^{abc}
	Viognier	165,33^{l}	12,63^{nop}	7,5^{jk}	4,02^{bc}	95,98^{no}	10,31^{bc}	3,37^{klm}	86,32^{mn}	136^{q}	1217^{pqr}	16.30^{bc}	21.23^{cdef}	6.12^{lm}	82.31^{lmn}
	Grenache Blanc	233,67^{fg}	14,07^{kl}	11,37^{d}	3,17^{i}	96,83^{h}	7,65^{ij}	1,79^{q}	90,57^{ef}	191,33^{l}	12.47^{pq}	16.9^{b}	20.5^{fghi}	5.64^{mn}	86.52^{cdefg}
	Average	*164,67*	*13,33*	*8,84*	*3,3*	*96,7*	*8,35*	*3,84*	*87,82*	*177,32*	*13.58*	*12.65*	*20.28*	*7.25*	*84.41*
II	Orpheus	142,33^{m}	14,2^{kl}	10,77^{de}	3,88^{bcd}	96,12^{mno}	9,9^{cd}	6,59^{a}	83,51^{p}	167,67^{o}	14.2^{ijk}	12.23^{jkl}	21.87^{cde}	6.39^{jkl}	80.62^{no}
	Misket Varnenski	137,33^{mn}	12,97^{mno}	6,9^{k}	3,51^{gh}	96,49^{ij}	6,34^{lmno}	5,85^{c}	87,81^{jk}	180^{m}	15.2^{fg}	12.47^{ijk}	21.2^{defg}	6.65^{ijkl}	84.5^{hijk}
	Aheloy	165^{l}	14,73^{ijk}	9,03^{fgh}	3,11^{i}	96,89^{h}	8,34^{h}	3,04^{mno}	88,62^{hi}	220,67^{l}	14.93^{gh}	12.57^{hijk}	19.97^{hijk}	6.18^{kl}	85.49^{defghi}
	June Blanc	227,33^{g}	18,8^{c}	11,07^{de}	2,48^{lm}	97,52^{de}	6,06^{nop}	3,01^{mno}	90,93^{de}	231,33^{h}	14.3^{hij}	14.03^{f}	19.87^{ijk}	8.10^{cd}	87.63^{abc}
	Misket Sungurlarski	281^{d}	15,93^{gh}	11,4^{d}	2,35^{mn}	97,65^{cd}	8,49^{gh}	3,65^{ijk}	87,86^{jk}	251,67^{f}	14.67^{ghi}	12.73^{hij}	21.77^{cde}	7.22^{fghi}	85.42^{efghij}
	Keratsuda	204^{i}	16,9^{ef}	9,23^{fg}	2,07^{o}	97,93^{b}	6,74^{klm}	4,10^{fgh}	89,16^{h}	240,33^{g}	16.9^{c}	13.27^{gh}	20.17^{ghij}	5.04^{o}	86.48^{cdefgh}
	Dimyat	255^{e}	21,2^{b}	16,4^{a}	2,35^{mn}	97,65^{cd}	6,37^{lmno}	2,08^{q}	91,54^{bcd}	330,33^{b}	19.37^{a}	10.93^{n}	19.97^{hijk}	6.83^{ghij}	88.63^{ab}
	Black Sea Elixir	192,67^{j}	16,43^{fg}	10,97^{de}	3,62^{fg}	96,38^{jkl}	725^{jk}	1,84^{q}	90,91^{de}	311^{c}	16.9^{c}	12.30^{ijk}	21.07^{defg}	7.10^{fghi}	87.38^{abcd}
	Black Sea Diamond	217,33^{h}	17,77^{de}	12,17^{c}	3,9^{bcd}	96,1^{mno}	8,27^{hi}	2,63^{p}	89,10^{h}	271,33^{e}	16.6^{cd}	12.27^{jkl}	21.93^{cd}	7.35^{fg}	85.28^{fghij}
	Biser	178,67^{k}	14,23^{kl}	11de	3,84^{bcd}	96,16^{mno}	10,73^{b}	4,15^{fg}	85,15^{o}	172,66^{mno}	13.47^{klmn}	12.83^{hij}	20.87^{efgh}	7.16^{fghi}	81.43^{mn}0
	Kamchiya	273,67^{d}	17,37^{de}	12,5^{c}	2,63^{kl}	97,36^{f}	8,10^{hi}	5,47^{d}	86,43^{mn}	171no	13.97^{ijk}	12.60^{hijk}	21.26^{cdef}	8.86^{ab}	84.18^{ijk}
	Average	*206,76*	*16,41*	*11,04*	*3,07*	*96,93*	*7,87*	*3,86*	*88,28*	*231,64*	*15.5*	*14.31*	*20.9*	*6.99*	*85.18*
III	Gergana	366,67^{a}	18,03^{cd}	11,03^{de}	4,034^{bc}	95,96^{o}	6,50^{lmn}	1,86^{q}	91,65^{bc}	357^{a}	19.7^{a}	12.83^{hij}	21.07^{defg}	7.39^{fg}	86.78^{bcdefg}
	Misket Markovski	302.67^{c}	22.47^{a}	12.47^{c}	2.26^{n}	97.74^{c}	5.76^{opq}	1.75^{q}	92.49^{a}	294^{d}	17.63^{b}	12.93^{hij}	22.23^{bc}	5.31^{no}	89.1^{a}
	Average	*334.67*	*20.25*	*11.75*	*3.15*	*96.85*	*6.13*	*1.8*	*92.07*	*325.5*	*18.67*	*18.32*	*21.65*	*6.35*	*87.94*
Average		189.76	14.821	9.77	3.21	96.7	8.04	3.72	88.24	205.25	14.55	13.58	20.578	7.11	84.90
SEM		7.07	0.304	0.23	0.07	0.07	0.17	0.14	0.25	5.85	0.21	0.20	0.170	0.11	0.27
P-Value		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0000	0.000	0.000	0.000

Values that have a different superscript letter (a, b, c, ...) differ significantly ($p < 0.05$) among each other.

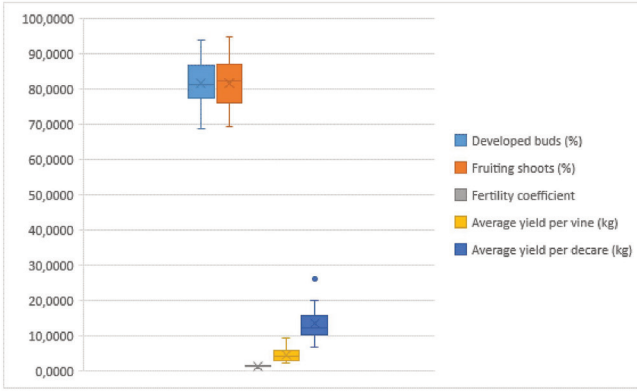

Figure 3. Changes in fertility and yield indicators in the investigated white wine varieties.

varieties whose values are around and above the average for the whole studied group, prevail during some of the phenological periods - berry growth, flowering-berry softening, berry softening-technological maturity, budding-technological maturity. There are more varieties with a shorter budding-flowering period than the average for the group - about 60 days. In terms of fertility and yield - percentage of developed buds and fruiting shoots, there is an even distribution of all varieties (Fig. 3). The peculiarities of the varieties are most clearly expressed in the percentage of berries in the bunch and the average weight per 100 berries (Fig. 4). Predominant are varieties whose percentage of berries in the bunch is around or below the average of all, and in relation to the average weight per 100 berries - the distribution of varieties is more balanced. According to the statistical indicators characterizing the qualities of the wine (arithmetic mean, first and third quartiles), it can be assumed that they vary around the average values for the whole group in the predominant part of the varieties (Fig. 5).

The duration of the budding period has a moderate, negative effect on the yield (-0.382 **). The fertility rate and the average yield per vine have a strong, positive effect on increasing the yields per decare (0.849 **). From the complex effect on the average yield per decare and the values of the Path coefficients it follows that the average yield per vine has a strong, positive effect, and the fertility rate - a significant, indirect effect.

There are proven moderate, positive relationships between the average yield per decare and the average weight per bunch (0.584 **), bunch length (0.698 **), bunch width (0.504 **), the mesocarp of the berry (0.376 *) and the theoretical yield (0.342 **). High, positive correlations were found between yield and average weight per 100 berries (0.764 **), berry length (0.753 **) and berry width (0.765 **). The content of skins in the berry has a moderate, negative effect on yields (-0.328 **).

The compiled regression models confirm the dependences established by the correlation coefficients, demonstrated by the sign in front of the independent variable, which determines the direction of the relations between the two indicators (Table 5). According to the reported complex influence and the calculated Path coefficients, the average weight of a bunch, the bunch width, the mesocarp in the berry and its length have a strong, positive, indirect effect on the yield per decare. The bunch length and the average weight of 100 berries have a more pronounced direct effect than indirect. Berry width and the theoretical yield have a stronger indirect effect on productivity.

The calculated correlation coefficients representing the relationships between the characteristics of the wine and the average yield per decare show that the yield has a moderate, negative effect on the pH level (-0.346 **). For all other indicators, the value of the correlation coefficient is less than 0.3 in absolute value and should not be interpreted.

Conclusions

Depending on the similarity and remoteness of the values of indicators related to phenological, agrobiological and technological characteristics, the studied 32 white wine vine varieties are grouped into three generalized clusters. The first one includes the most varieties that are characterized by a longer budding period and relatively lower productivity due to relatively smaller berry sizes. The varieties in the second cluster have similarities in

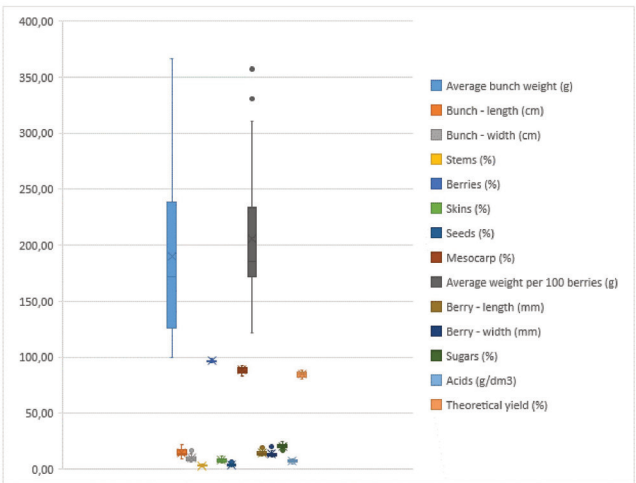

Figure 4. Change in the indicators from the mechanical analysis of bunch and grain in the studied white wine varieties.

Table 4. Comparative evaluation of the studied white wine vine varieties according to the technological characteristics of wine

Cluster	Variety	Alcohol (v/v%)	Sugars (g/dm³)	Sugar-free extract (g/dm³)	Titratable acids (g/dm³)	Volatile acids (g/dm³)	pH	Total phenols (mg/dm³)	Tasting evaluation
I	Biser Thracian	12.37^{defghi}	1.34^{ijkl}	20.33^{de}	6.73^{ef}	0.65^{ab}	3.38^{bcd}	206^{efg}	17.37^{cdefgh}
	Aligote	11.73^{ijkl}	1.29^{ijklmn}	19.44^{efg}	7.17^{cd}	0.43^{bcdefg}	3.21^{jik}	181^{m}	17.7^{ab}
	Bulgarian Riesling	11.47^{jkl}	2.23^{e}	21.41^{cd}	6.17^{hij}	0.56^{abcdefg}	3.30^{defghi}	217.33^{bc}	17.4^{cdefgh}
	Semillon	12.10^{hij}	4.63^{a}	21.26^{cd}	5.57^{lm}	0.57^{abcdef}	3.25^{ghijk}	209.33^{def}	17.17^{efghij}
	Red Misket	11.23^{l}	1.09^{mnop}	17.41^{ij}	5.73^{klm}	0.55^{abcdefg}	3.32^{cdefgh}	216.67^{bcd}	17.33^{cdefghi}
	Italian Riesling	11.80^{ijkl}	1.14^{lmnop}	18.77^{fgh}	5.17^{n}	0.36^{edf}	3.41^{abc}	180.66^{m}	17.6^{abc}
	Sauvignon Blanc	13.67^{ab}	1.08^{op}	23.05^{b}	5.83^{jkl}	0.35^{fg}	3.41^{abc}	181.33^{m}	17.27^{defghi}
	Silvaner	11.33^{kl}	1.32^{ijkl}	21.30^{cd}	6.9^{de}	0.44^{bcdefg}	3.29^{efghi}	190.33^{kl}	17.37^{cdefgh}
	Riesling	11.73^{ijkl}	1.32^{ijkl}	20.57^{de}	6.5^{efgh}	0.43^{bcdefg}	3.25^{ghijk}	220^{b}	17.7^{ab}
	Mueller Thurgau	11.27^{l}	1.15^{klmnop}	20.53^{de}	4.63^{op}	0.5^{bcdefg}	3.37^{bcd}	182^{m}	17.2^{efghi}
	Misket Sandanski	13.83^{a}	1.26^{jklmn}	27.43^{a}	4.3^{p}	0.76^{a}	3.26^{hijk}	190^{kl}	17.10^{ghij}
	Vinenka	10.53^{m}	1.27^{jklmno}	15.31^{kl}	6.5^{efgh}	0.6^{abcd}	3.34^{bcdef}	149.67^{o}	17.37^{cdefgh}
	Rkatsiteli	1140^{kl}	1.76^{fg}	20.22^{de}	6^{efg}	0.4^{defg}	3.22^{hij}	210^{cde}	17.03^{ij}
	Shenin	12.37^{defghi}	4.32^{bc}	17.99^{hi}	6.57^{efgh}	0.51^{bcdefg}	3.27^{fghij}	196.67^{hijk}	16.73^{k}
	Chardonnay	13.00^{cd}	4.21^{c}	19.56^{fgh}	6.27^{ghi}	0.43^{bcdefg}	3.38^{bcd}	229.33^{a}	17,.53^{bcd}
	Traminer Pink	12.07^{hij}	1.4^{ij}	20.64^{de}	5.33^{mn}	0.35^{fg}	3.39^{abcd}	196.67^{hijk}	17.83^{a}
	Fetyaska Alba	12.47^{defgh}	1.60^{gh}	20.49^{de}	5.10^{n}	0.51^{bcdefg}	3.41^{abc}	211^{cde}	17.23^{efghi}
	Viognier	12.60^{cdefgh}	2.14^{e}	17.93^{hi}	5.63^{klm}	0.5^{bcdefg}	3.36^{bcde}	180.66^{m}	17.47^{bcdef}
	Grenache Blanc	12.27^{ghi}	4.45^{b}	17.42^{hij}	5.63^{klm}	0.35^{fg}	3.17^{k}	191.33^{jk}	16.7^{k}
	Average	*12.06*	*2.05*	*20.06*	*5.91*	*0.48*	*3.31*	*196.84*	*17.32*
II	Orpheus	12.97^{cde}	1.13^{lmnop}	20.83^{de}	6.33^{fghi}	0.53^{bcdefg}	3.43^{ab}	179.66^{m}	17.33^{cdefghi}
	Misket Varnenski	12.33^{efghi}	1.79^{f}	20.38^{de}	6.63^{efg}	0.58^{abcde}	3.35^{bcdef}	208.67^{ef}	17.43^{bcdefg}
	Aheloy	12.40^{defghi}	1.4^{ij}	16.52^{jk}	6^{ijk}	0.52^{bcdefg}	3.31^{cdefgh}	183.68^{lm}	17.17^{efghij}
	June Blanc	11.73^{ijkl}	1.25^{jklmnop}	20.69^{de}	8.0^{a}	0.42^{cdefg}	3.24^{ghijk}	199^{ghij}	17.17^{efghij}
	Misket Sungurlarski	12.93^{cdef}	1.3^{ijklm}	20.07^{def}	7.47^{bc}	0.5^{bcdefg}	3.25^{ghijk}	200^{ghi}	17.53^{bcd}
	Keratsuda	11.23^{l}	1.07^{op}	15.43^{kl}	5.6^{klm}	0.63^{abc}	3.17^{k}	122.67^{p}	17.6^{abc}
	Dimyat	11.93^{hijk}	1.03^{p}	18.52^{gh}	6.57^{efgh}	0.39^{defg}	3.18^{k}	202^{fgh}	17.13^{fghij}
	Black Sea Elixir	11.53^{jkl}	2.12^{e}	14.41^{l}	6.4^{fghi}	0.6^{abcd}	3.24^{ghijk}	165.33^{n}	17.4^{cdefgh}
	Black Sea Diamond	12.77^{cdefg}	2.11^{e}	19.62^{efg}	7.17^{cd}	0.61^{abcd}	3.40^{abc}	193^{jk}	17.7^{ab}
	Biser	12.50^{defgh}	1.29^{ijklmn}	20.23^{de}	6.73^{ef}	0.57^{abcdef}	3.36^{bcde}	212.33^{cde}	17.07^{hij}
	Kamchiya	12.47^{defgh}	1.49^{hi}	20.34^{de}	5.13^{n}	0.44^{bcdefg}	2.35^{m}	179^{m}	17^{j}
	Average	*12.25*	*1.45*	*18.82*	*6.55*	*0.53*	*3.21*	*185.94*	*17.32*
III	Gergana	12.30^{fghi}	2.46^{d}	17.04^{ij}	7.67^{ab}	0.34^{g}	2.61^{l}	220.33^{b}	17.10^{ghij}
	Misket Markovski	13.17^{bc}	1.08^{op}	22.27^{bc}	4.73^{o}	0.49^{bcdefg}	3.47^{a}	180.33^{m}	17.43^{bcdefg}
	Average	*12.73*	*1.77*	*19.66*	*6.2*	*0.41*	*3.04*	*200.33*	*17.27*
Average		12.172	1.83	19.61	6.149	0.49	3.26	193.31	17.318
SEM		0.08	0.107	0.26	0.09	0.01	0.02	2.23	0.03
P-Value		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Values that have a different superscript letter (a, b, c, ...) differ significantly ($p < 0.05$) among each other.

the length of the budding period, long budding period - technological maturity, moderate productivity and close content of volatile acids in the wine. The third cluster includes the newly bred two varieties Gergana and Misket Markovski, which are the most fertile and productive and have the smallest number of seeds in the berries.

There is a high variability of the individual white wine varieties according to the studied economically valuable indicators, which should be analyzed obligatorily in future ampelographic studies. The indicators of bunch length and average weight per 100 berries have a stronger direct effect on the formation of the yield in individual varieties, and the average bunch weight, bunch width, percentage of mesocarp in the berry, berry length and width, and

Table 5. Correlation coefficients and regression models representing the relationship between the studied ampelographic indicators and the average yield per decare.

Indicators	Coefficient of correlation	Coefficient of determination	Regression models	Significance level of the regression model α = 0.05	β-coefficient	Path-coefficient
Budding	-0.382**	0.146	y=2358.501-136.237x	0.000		
Fertility coefficient (x_1)	0.849**	0.720	y=395.91+206.466x	0.000	0.239	0.610
Average yield per vine (x_2)	0.849**	0.720	y=396.9+206.47x	0.000	0.821	0.028
Complex influence	0.881	0.776	y=-317.8+534.5x_1+199.724x_2	0.000		
Average bunch weight (x_1)	0.584**	0.341	y=589.157+4.029x	0.000	0.085	0.499
Berry length (x_2)	0.698**	0.488	y=-297.79+111.434x	0.000	0.485	0.213
Berry width (x_3)	0.504**	0.255	y=308.98+106.846x	0.000	-0.150	0.654
Berry skins (x_4)	-0.328**	0.108	y=2101.412-92.942x	0.000	0.083	-0.411
Berry mesocarp (x_6)	0.376*	0.142	y=-5079.9+72.912x	0.000	0.043	0.333
Average weight per 100 berries (x_7)	0.764**	0.584	y=54.628+6.329x	0.000	0.413	0.351
Berry length (x_8)	0.753**	0.568	y=-1237.187+177.995x	0.000	0.031	0.722
Berry width (x_9)	0.765**	0.585	y=-1160.474+185.181x	0.000	0.279	0.486
Theoretical yield (x_{10})	0.342**	0.117	y=-3836,871+61,139x	0.000	-0.136	0.478
Complex influence	0.861	0.741	y = -497.382 + 0.588x_1 + 77.354x_2 - 31.827x_3 + 23.619x_4 + 84.692x_5 + 8,313x_6 + 3.42x_7 + 7.276x_8 + 67.616x_9 - 24266x_{10}	0,000		

* Significance level α = 0.05
** Significance level α = 0.01

the theoretical yield, significantly affect indirectly the productivity of vines.

The combined application of a set of mathematical approaches allows the differentiation of the influence of individual ampelographic indicators in the overall phenotypic balance of varietal populations. The results of the analysis of the regularities, revealing the dynamic dependencies between the separate indicators, form the complex assessment for the economic significance of each studied variety.

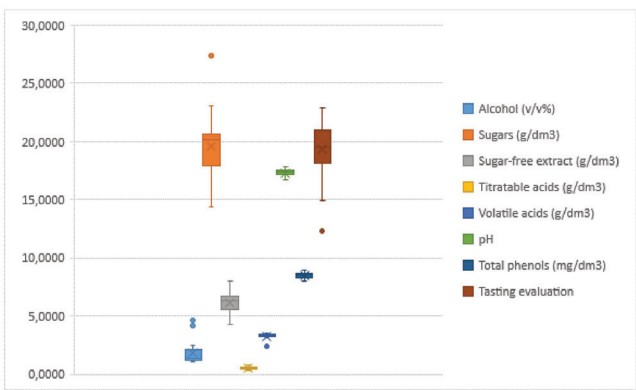

Figure 5. Change in the wine parameters of the investigated white wine varieties.

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