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MATHEMATICAL APPROACH TO EVALUATION OF THE INFLUENCE OF CLIMATE INDICATORS ON QUALITY OF GRAPES IN SYRAH CLONES

Anelia POPOVA, Velika KUNEVA, Ivaylo DINTCHEV, Veselin IVANOV

Agricultural University Plovdiv, 12 Mendeleev Blvd, Plovdiv, Bulgaria

Corresponding author email: aneliyapopova@abv.bg

Abstract

The aim of the present study is to apply a mathematical approach (correlation and factor analysis) to assess the similarity and remoteness of the impact of climate indicators in some clones of Syrah variety. Their grouping is based on phenological, and technological indicators. Temperatures during the individual experimental years have a dominant influence on the quality of grapes in the individual clones included in the study. As a result of analysis, correlations were established between phenological indicators like follow: sap, bud burst, first leaf separation, flowering, fruit set, veraison, ripeness and technological ones - average mass per bunch, normal and undeveloped berries, percent of clusters and damaged berries, average bunch size (width and length). The phenological indicators - sap flow, flowering and fruit set "pea size" and technological - undeveloped berries, damaged berries have high factor weights in the first component, which is a summary of these indicators, with the highest relative weight in the vines grouping.

Key words: *Syrah clones, phenology, quality components, correlation, factor analysis.*

INTRODUCTION

Climate represents one of the main inputs necessary for plants to complete their growing cycle, having a direct impact on the set and duration of phenological stages and development of crops.

The effects of climate on crop phenology (bud burst, flowering, fruit set and harvest time) were investigated by means of regression analysis.

Meteorological information has a significant effect on the set of the grapevine phenological stages (Marta et al., 2010; Kizildeniz et al., 2015).

An accurate model for estimating the timing of seasonal phenological stages of the grapevine (*Vitis vinifera* L.) would be a valuable tool for crop management (Schrader et al., 2020).

Unfavourable trends have been identified in the evolution of climate factors (temperatures, precipitation, etc.) over the past years, with a direct impact on the vegetative and productive potential of the vine. This calls for a reassessment of climate resources and adaptation of the cultivation technologies to the new conditions.

The tendency for increasing the average annual temperature and decreasing precipitation amounts is a point to a marked warming of the vineyard climate, especially after 2000.

High temperatures, corroborated with soil water deficit, determined an intensification of the atmospheric and pedological drought, a shift in vegetation stages, shortened development periods and a forced berry ripening, with a negative impact on yields, which fluctuated from one year to another (Zaldea et al., 2021).

Grapevine yield in is determined by the cluster numbers and their weight. Number of clusters per vine, is determined by the number of canes, and cane productivity is measured by the cluster-cane ratio. Earlier studies have revealed that increase in the number of canes does not result in proportionate increase in cluster number per vine (Shikhamany et al., 2015).

Ambient radiation and temperature are global factors of grapevine growth, yield and composition, and wine quality. Knowledge of the implications of vineyard row orientation, microclimate is required for taking a decision in current and future macro and meso climate conditions (Hunter et al., 2021).

In particular, temperature is a main factor in controlling grapevine phenological development and ripening. Phenology models have been developed for a wide range of

species, including grapevines, and using observational data from many different countries and regions.
Several previous studies have been performed in order to create a model for the phenological stages, e.g., enabling a classification of varieties for technical purposes, to predict phenology or to assess the impact of climate change on it (Costa et al., 2019).
The global climate change consequences have appeared during the last decades, with increasing weather variability in many world regions. The use of aerobiological and meteorological studies for crop yield prediction has been widely used in different crops that are important engines for economy development. This enables growers to adapt their crop management and adjust the spent resources (González-Fernández et al., 2020).
The aim of the present study is to establish the correlation between the studied indicators, using the possibilities of factor analysis, to reduce their number by combining those that correlate with each other in new factors.

MATERIALS AND METHODS

The field experiment was conducted in the training and experimental station of the Agricultural University - Plovdiv, using two-year data (2020, 2021).
The scheme of the experimental work includes the following variants of research with four branches of the Syrah variety (Figures 1-4):

Figure 1. V1 - Syrah variety, clone 100

Figure 2. V2 - Syrah variety, clone 174

Figure 3. V3 - Syrah variety, clone 470

Figure 4. V4 - Syrah variety, clone 524

Sixty vines (4 repetitions x 15 vines) are included in each variant. All Syrah clones are grafted on Berlandieri x Riparia SO4 rootstock. The bud loading of the vines in all variants is ensured by a short pruning system, using spurs with two buds, a total of 6 spurs (12 buds per vine).
The experiment is based on the grouping of phenological indicators (sap movement - x_1, bud burst - x_2, first leaf - x_3, flowering - x_4, fruit set to "pea size" -x_5, veraison -x_6 and technological ripeness-x_7), and technological indicators of grapes (normal berries-%, bunches-%, undeveloped berries-%, damaged berries%, average sizes of one grape bunch, length and width in cm).
Phenological observations were made for each of the four clones numbered 100, 174, 470, and 524 of the Syrah variety for each development stage. For this purpose, normally developed vines that have entered full fruiting have been selected. The beginning of the stage is the day when 5% of the vines entered it, the mass entry - 50% of the vines, and the end when 95% of the vines entered the separate stage (Braykov et al., 2005; Roytchev 2012).
The duration in days of the main phenological periods was reported: from sap movement to bud burst, from budding to the appearance of the first leaf, from the first leaf to flowering, from flowering to the "pea" phase, from "pea" to layering, from layering to technological maturity and from bud burst to technological ripeness.
The air temperature data were taken from the meteorological station located in the experimental vineyard of the Agricultural University. The evaluation of the tested regimes is based on the phenological and technological indicators of the grape performed by correlation analysis (Lakin, 1990), aiming to establish the presence of statistically significant correlations between the studied indicators. In the next stage, the study was continued, applying the technique of factor analysis (Kline, 1994) in order to reduce the number of initially included indicators.
Factor analysis was performed by the principal components method (PCA). The number of principal components is determined by the number of eigenvalues of the correlation matrix that are greater than 1 (Kaiser's criteria). Eigenvalues show the contribution of the eigenfactor in explaining the total variance in the variables.
Adequacy assessment of the factor analysis was performed by using the Kaiser – Mayer – Olkin (CMO – test) and Bartlett tests.
A similar approach has been used in the evaluation of wheat, cotton and tomatoes (Ganchev, et al., 2019; Gospodinova, et al., 2020; Stoyanova, et al., 2019). The statistical program SPSS 26.0 was used for processing the experimental data.

RESULTS AND DISCUSSIONS

The agro-meteorological conditions for the considered years are quite close (Figures 5, 6 and 7).

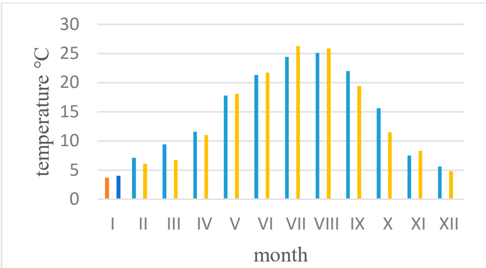

Figure 5. Average monthly air temperature in ˚C

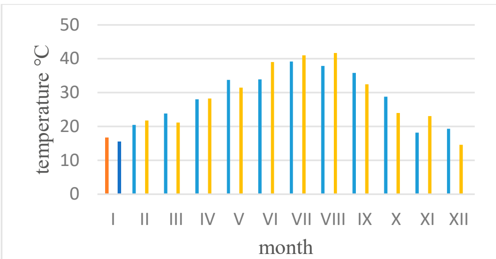

Figure 6. Average monthly maximum air temperature in ˚C

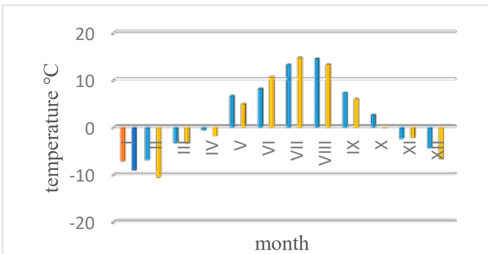

Figure 7. Average monthly minimum air temperature in ˚C

Correlation analysis are used to describe the strength and direction of dependence between the indicators under consideration. The correlation coefficients expressing the relationship between the studied phenological indicators, which are indicated in the correlation matrix (Table 1).

Table 1. Correlation matrix of the phenological indicators

	x1	x2	x3	x4	x5	x6	x7
x1	1	-0,223	0,445	-0,884**	0,942**	0,501	0,534
x2		1	0,748*	-0,228	0,118	0,729*	0,705
x3			1	-0,734*	0,713*	0,957**	0,980**
x4				1	-0,977**	-0,830*	-0,832*
x5					1	0,761*	0,787*
x6						1	0,993**
x7							1

*Correlation is significant at the 0.05 level (2-tailed)
**Correlation is significant at the 0.01 level (2-tailed)

A strong positive correlation was found between first leaf separation (x_3) and veraison (x_6), technological ripeness (x_7) with correlation coefficients (r = 0.957, r = 0.980), as well as between the indicators: sap (x_1) and fruit set "pea size" (x_5) - r = 0.942.
The strongest is the relationship between the indicators veraison (x_6) and technological ripeness (x_7) with a correlation coefficient r = 0.993. Negative correlation is reported between the indicators of flowering (x_4) and fruit set "pea size" (x_5), veraison (x6) and technological ripeness (x_7), respectively, with coefficients r = - 0.977; r = - 0.830; r = - 0.832.
All these correlation are statistically proven at the level of significance $\alpha = 0.001$.
The performed correlation analysis and the established high, statistically proven values of 'r' give us a reason to apply the methodology of factor analysis.
When performing factor analysis, applying the method of principal components, it turns out that two factors have values of eigenvectors greater than 1, which determined the choice of two principal components (Figures 8 and 9).
Table 2 shows the factor weights and the distribution of variation between the main components of phenological indicators.
They explain 98.9% of the total variance of the sample. The first main component (the first factor) explains 74.45% of the variance and the second - 24.45% of it.

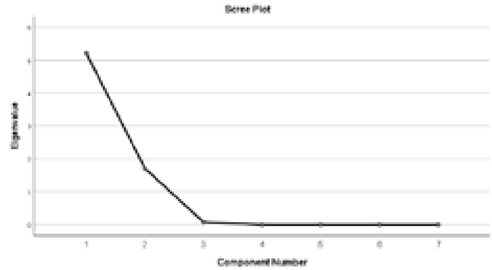

Figure 8. Values of eigenvectors of phenological indicators

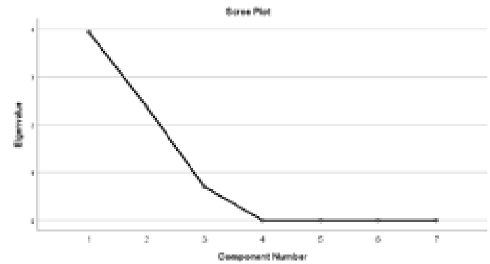

Figure 9. Values of eigenvectors of technological indicators

Table 2. Factor matrix of phenological indicators obtained by the principal components method

N	Indicators	Main components		Signes
		1	2	
1	SAP	0.999	-0.021	x_1
2	Bud burst	-0.200	0.978	x_2
3	First leaf	0.455	0.869	x_3
4	Flowering	-0.900	-0.408	x_4
5	Fruit set „PEA SIZE"	0.948	0.316	x_5
6	Veraison	0.523	0.847	x_6
7	Technological ripeness	0.551	0.834	x_7
Percentage of the total variation, %		74.45	24.45	
Cumulative percentage of the total variation, %		74.45	98.90	

The indicators of SAP, flowering and fruit set "pea size" have high factor weights in the first component. We could define this factor as a summary for those indicators that have the greatest relative weighting grouping.
The second component is mainly related to budding, the appearance of the first leaf, veraison and technological ripeness.
Depending on the technological indicators for grape structure in the studied Syrah clones, the

correlation relationships are less pronounced than in the phenological ones (Table 3).
A positive correlation was found between the indicators of damaged berries and the width with a correlation coefficient r = 0.999; average mass and length, r = 0.954.
Strong negative dependence is observed between the indicators normal berries and bunches r = -0.999, as well as between the indicators undeveloped berris and cluster length r = -0.965.

Table 3. Factor matrix of technological indicators, obtained by the method of the main components

	Average mass, g	Normal berries, numbers	Bunches numbers	Undeve-loped berries, numbers	Damaged berries, numbers	Width, cm	Length, cm
Average mass	1	0,477	-0,505	-0,847	-0,556	0,954*	-0,565
Normal berries		1	-0,999**	0,029	0,201	0,231	0,172
Clusters			1	0,006	-0,189	-0,265	-0,160
Undeve-loped berries				1	0,607	-0,965*	0,598
Damaged berries					1	-0,565	0,999**
Width						1	-0,565
Length							1

*Correlation is significant at the 0.05 level (2-tailed)
**Correlation is significant at the 0.01 level (2-tailed)

Table 4 shows the factor weights and the distribution of variation between the main components of the technological indicators.

Table 4. Correlation matrix of technological indicators

N	Indicators	Main components	
		1	2
1	Average mass per bunch, g	-0.847	0.524
2	Normal berries, %	0.018	0.976
3	Clusters, %	0.009	-0.982
4	Undeveloped berries, %	0.910	-0.077
5	Damaged berries, %	0.871	0.279
6	Average bunch size, (width) cm	-0.895	0.321
7	Average bunch size, (length) cm	0.868	0.254
Percentage of the total variation,%		56.20	33.86
Cumulative percentage of the total variation, %		56.20	90.05

They explain 90.05% of the total variance of the sample. The first main component (the first factor) explains 56.20% of the variance, and the second, respectively, 33.86% of it.
Indicators underdeveloped berries, damaged berries have high positive factor weights in the first component.
We could define this factor as a summary for those indicators that have the greatest relative weight in the vineyards grouping. The second component is mainly related to normal grains and bunches.

CONCLUSIONS

The conducted correlation and factor analysis give us a reason to determine the presence of two main factors in the grouping of vineyards - phenology and technological indicators characterizing the grape quality. The strong positive correlation between the stages of separation of the first leaf, veraison and technological ripeness, respectively, with correlation coefficients r = 0.957; r = 0.980; r = 0.993, gives us a reason to say that even the slightest change in environmental factors would affect the quality of grapes. The phenological indicators of sap flow, flowering and fruit set "pea size" and technological - undeveloped berries, damaged berries have high factor weights in the first component, which is a summary of these indicators, with the highest relative weight in the grouping of vines. The classification of the included options allows to increase the objectivity in assessing the impact of the studied indicators. The results of the factor analysis allow more efficient planning of the experiment.

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