

## MODEL OF VINES PRODUCTION VARIATION IN RELATION TO PHYSIOLOGICAL INDICES

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### Abstract

*The study analyzed the interdependence relationship of the production with the physiological indices in vines, under conditions of differentiated fertilization (organic, mineral and foliar fertilizers). The study was carried out within the Fruit and Vine Research Center of BUSAMV Timisoara, 2011-2012 period. Biological material was represented by the 'Silvania' grape variety. Organic fertilizers (manure), complex fertilizers (NPK, 1:1:1), and foliar fertilizers (Fertitel, Cropmax, Waterfert, Calcium chloride) were used. By applying fertilizing resources, 12 experimental variants (T2 - T13) were obtained, and a control variant T1 (Ct) was used. Physiological indices (leaf area - LA, chlorophyll content - Chl), yield per plant (Ypl) and yield per ha (Yha) were determined. The interdependence relationship between LA and Chl was described by a polynomial relation of degree 2, under conditions of  $R^2=0.899$ ,  $p<<0.001$ . Regression analysis led to obtaining some models of variation of Ypl depending on LA ( $R^2=0.913$ ,  $p<<0.001$ ), Ypl according to Chl ( $R^2=0.929$ ,  $p<<0.001$ ), Yha depending on LA ( $R^2=0.907$ ,  $p<<0.001$ ), and Yha depending on Chl respectively ( $R^2=0.934$ ,  $p<<0.001$ ). Multiple regression analysis led to models that described the Ypl and Yha variation depending on the two physiological indices as simultaneous action. Models of the type  $y = f(x,y)$  were obtained, under statistical safety conditions ( $R^2=0.998$ ,  $p<<0.001$  for Ypl, and for Yha). Within PCA, PC1 explained 96.806% of variance, and PC2 explained 1.6334% of variance. Cluster analysis led to the grouping of variants under statistical safety conditions (Coph.corr. = 0.843).*

**Key words:** grape production, model, PCA, physiological indices, vine

### INTRODUCTION

Vine is a very old crop plant, within the horticultural crops, but of great importance and of great interest worldwide for the wine products and by-products of that it provides [63], [38], [41]. The rich assortment of genotypes makes the vines grown for table grapes, wine grapes, raisins or by-products such as seed oil, food supplements, pharmaceuticals, etc. [40], [31], [8], [12], [74].

The numerous genetic resources of vines, natural and improved genotypes, have led to a series of studies and researches regarding the identification of new resources of valuable germplasm [16], [21]. Vine breeding programs have also been developed to improve the vineyards regarding resistance to pathogens, stressors, the quality of grape production [56], and were produced in new, hybrid forms, as a prospect for sustainable viticulture [15].

In view of the consecrated wine areas and centers for vineyards worldwide, as well as areas that are smaller in size, but important through the specificity and local imprint that they induce on wine products, a number of studies have evaluated the relationship of the vine with the soil and climate factors [59], [22], [11], [25], [68].

Elements of viticulture technology, such as soil works, irrigation, fertigation, maintenance work, integrated protection, etc. have been studied in relation to the vineyard in terms of efficiency, production, quality, sustainable viticulture [5], [47].

In the context and significance of the 'terroir' concept, a series of studies was performed that evaluated the particular relation of the vines with the soil in order to give a specific imprint to the grapevine products [67], [72].

The relation of the horticultural plants to the mineral elements has also been intensively studied, due to the close connection between the quality of the horticultural products in

general, and especially of the viticultural ones, and the plants nutritional status [35], [7], [70], [39], [24]. The optimization of the vine nutrition, in relation to the conditions of soil and vegetation, genotype, and the destination of the grape production, represents an important method in ensuring the production and the quality of vine products [46], [36], [75].

Methods based on the image analysis [29], [30] have found applicability also to the vine in evaluating the state of vegetation, nutrition, quality of grapes and optimal harvest time [26], [14], [42], [44], [45]. Also, software applications have been developed for the study of leaf area, and of the attack of pathogens on plants, which can be easily adapted to the vine [19], [20], [9].

Numerous studies in direction of testing different types of fertilizers and application methods in vines have been carried out [18], [62], [61], [69]. As effects of fertilization on vines were evaluated physiological indices [10], [60], [55], productivity elements and yield [4], [19], [13], and quality indices for grapes, must or wine [17], [1], [69].

The present study evaluated the model of grape production variation in relation to physiological indices, under differentiated fertilization conditions.

## MATERIALS AND METHODS

The study analyzed the interdependence relationship between physiological indices, and the grape production variation in relation to the physiological indices in vine, under conditions of differentiated fertilization, based on organic, mineral and foliar fertilizers.

The study was carried out within the Fruit and Vine Research Center of USAMVB Timisoara, in 2011 - 2012 period. Biological material was represented by the 'Silvania' grape variety. The planting distance was 2.2 m between rows and 1 m between plants per row, with a density of 4545 plants per ha.

There were used three categories of fertilizers in various doses, which gave the experimental variants (T2-T13); organic fertilizers (manure) in doses of 30 t ha<sup>-1</sup> (T2), 40 t ha<sup>-1</sup> (T3), and 50 t ha<sup>-1</sup> (T4); NPK complex fertilizers (1:1:1)

in doses of 50 kg a.s. ha<sup>-1</sup> (a.s. - active substance) (T5), 100 kg a.s. ha<sup>-1</sup> (T6), and 150 kg a.s. ha<sup>-1</sup> (T7); foliar fertilizers, in two treatments, Fertitel (T8), Fertitel + Ca (T9), Cropmax (T10), Cropmax + Ca (T11), Waterfert (T12) and Waterfert + Ca (T13). Calcium was supplemented in two foliar treatments, in the form of calcium chloride (CaCl<sub>2</sub>). For comparing the results, a variant without fertilizers was considered as control variant (T1 - Ct).

Leaf area (LA) and the chlorophyll content (Chl) as physiological indices, average production per plant (Ypl), average production per ha (Yha), as production parameters, were evaluated. Leaf area (LA) was determined based on the leaf size elements and a correction factor (CF), after a general relation of the type LA=L·W·CF. The chlorophyll content was determined by a non-destructive method, with a portable device SPAD 502 Plus (Konica Minolta), with an accuracy of ± 0.2 SPAD units. Production per plant (Ypl) was determined with a technical balance (accuracy of ± 0.50 g).

The processing and statistical analysis of the experimental data was done with the statistical calculation module in EXCEL and with the PAST software [28]. Wolfram Alpha software was used to produce 3D and isoquants graphics [73]. ANOVA test, correlation analysis, regression analysis, Principal Component Analysis (PCA), and Cluster Analysis (CA) were performed. The parameters p, F-test, standard error (SE), correlation coefficient (r), regression coefficient (R<sup>2</sup>), and cophenetic coefficient (Coph.corr.) were used, as safety statistical parameters of the results.

## RESULTS AND DISCUSSIONS

Fertilization variants, in the form of organic fertilizers, complex mineral fertilizers and foliar fertilizers, differentially influenced the physiological indices (LA and Chl), and vine production parameters analyzed (Ypl and Yha). Leaf area (LA) recorded values between 108.48±4.07 cm<sup>2</sup> (T1 - Ct) and 159.89±4.07 cm<sup>2</sup> (T7). Chlorophyll content (Chl) recorded values between 31.24±0.77 SPAD units (T1 -

Ct) and  $40.72 \pm 0.77$  SPAD units (T7). Average yield per plant (Ypl) ranged from  $1.894 \pm 0.086$  kg/plt (T1 - Ct) and  $2.895 \pm 0.086$  kg/plt (T7).

In relation to the values of the average production per plant (Ypl), the average production per ha (Yha) varied in the range  $8.143 - 12.302 \pm 0.363$  t ha<sup>-1</sup>.

The experimental results for physiological indices and vine production parameters are presented in Table 1.

Table 1. Values of physiological indices and production in 'Sylvania' grape variety, average values 2011 - 2012

Trial	LA	Chl	Yplt	Yha
	(cm <sup>2</sup> )	SPAD units	Kg plt <sup>-1</sup>	T ha <sup>-1</sup>
V1 (Ct)	108.48	31.24	1.894	8.143
V2	125.00	33.67	2.183	9.315
V3	140.41	36.03	2.701	11.393
V4	150.03	37.98	2.801	12.047
V5	129.94	35.99	2.413	10.408
V6	148.95	39.47	2.735	11.554
V7	159.89	40.72	2.895	12.302
V8	117.76	32.57	2.083	8.914
V9	124.70	33.70	2.211	9.540
V10	120.06	33.03	2.106	8.922
V11	137.02	34.59	2.265	9.660
V12	126.92	33.15	2.249	9.482
V13	141.50	34.70	2.429	10.333
SE	$\pm 4.07$	$\pm 0.77$	$\pm 0.086$	$\pm 0.363$

Source: original data, resulted from experiment.

The graphical distribution of the variation interval of the physiological indices and the production parameters, in the form of a box plot, accompanied by the standard error (SE), is presented in figure 1.

Based to the ANOVA test, the presence of the variance in the experimental data set, and the statistical certainty of the data were confirmed, according to  $p \ll 0.01$ ,  $F > F_{crit}$ , for Alpha= 0.001.

High level of variance (215.8961) was recorded in the set of leaf area (LA) physiological index values. At the level of chlorophyll (Chl), the variance was 7.86859. In the case of production per plant (Ypl) the variance had the value of 0.0976, and at the level of production per ha (Yha) the variance had the value of 1.72209.

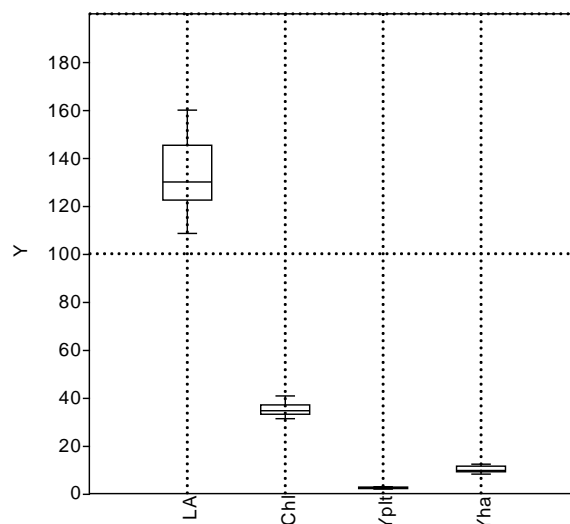


Fig. 1. Box plot graphical distribution of values for experimental parameters, accompanied by SE  
 Source: original graph based on the experimental data

The correlation analysis showed the existence of very strong correlations between the studied physiological indices, LA and Chl ( $r=0.937$ ), as well as between production and physiological indices, Ypl and LA ( $r=0.956$ ), Ypl and Chl ( $r=0.950$ ), Yha and LA ( $r=0.952$ ), Yha and Chl respectively ( $r=0.951$ ).

Regression analysis was used to describe the interdependence relationship between physiological indices (Chl and LA), as a result of differentiated fertilization.

Interdependence relation between the two physiological indices was described by a polynomial equation of degree 2, equation (1) under conditions of  $R^2=0.899$ ,  $p \ll 0.001$ ,  $F=44.417$ . The graphical distribution of the Chl variation with respect to LA is presented in Figure 2.

$$\text{Chl} = 0.001819 \cdot \text{LA}^2 - 0.3102 \cdot \text{LA} + 43.84 \quad (1)$$

Based on the levels of correlations found between the physiological indices (LA, Chl) and production (Ypl, Yha), the regression analysis was used to analyze the variation of production according to the two physiological indices.

Regression analysis led to the finding of models in the form of polynomial equations of degree 2, under statistical safety conditions.

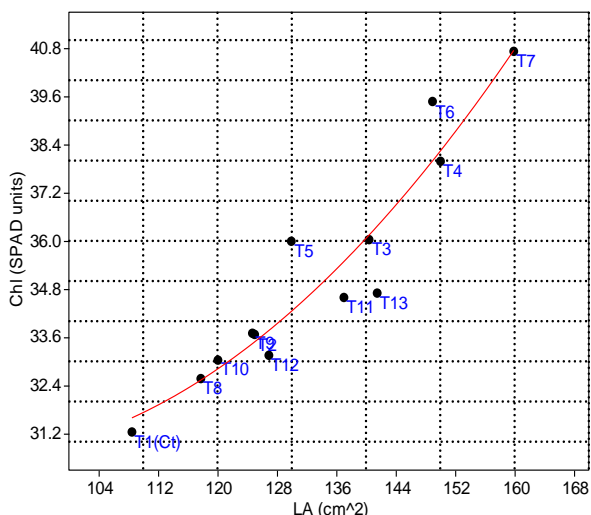


Fig. 2. Graphical distribution of Chl values in relation to LA, 'Sylvania' grape variety  
 Source: original graph, based on the experimental data

Thus, the variation of average production per plant (Ypl) relative to LA was described by equation (2), under conditions of  $R^2=0.913$ ,  $p \ll 0.001$ ,  $F=52.946$ . The variation Ypl relative to Chl was described by equation (3) under conditions of  $R^2=0.929$ ,  $p \ll 0.001$ ,  $F=65.535$ , and the graphical distribution is presented in Figure 3.

$$Ypl = 2.197E - 05 \cdot LA^2 + 0.01441 \cdot LA + 0.06934 \quad (2)$$

$$Ypl = -0.006809 \cdot Chl^2 + 0.5972 \cdot Chl - 10.15 \quad (3)$$

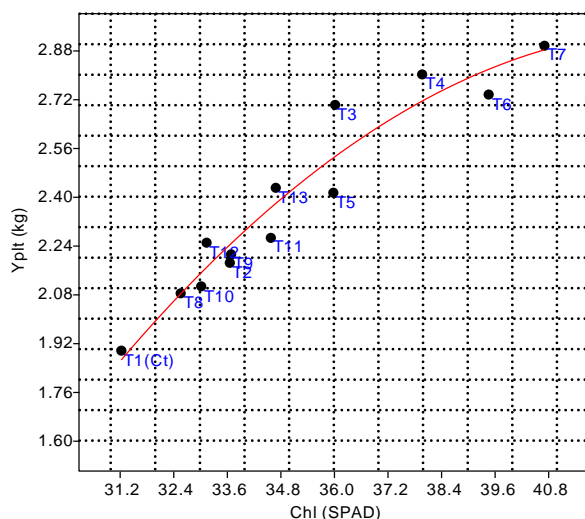


Fig. 3. Graphical distribution of Ypl values in relation to Chl, 'Sylvania' grape variety  
 Source: original graph, based on the experimental data

Grape production per ha (Yha) was described by equation (4) in relation to LA ( $R^2=0.907$ ,  $p \ll 0.001$ ,  $F=48.793$ ), and by equation (5) in relation to Chl ( $R^2=0.934$ ,  $p \ll 0.001$ ,

$F=70.934$ ).

$$Yha = 0.0001295 \cdot LA^2 + 0.05023 \cdot LA + 1.148 \quad (4)$$

$$Yha = -0.0298 \cdot Chl^2 + 2.596 \cdot Chl - 44.05 \quad (5)$$

Based on the values of the correlation coefficients ( $R^2$ ), and on the values of the F-test associated with the regression equations (2), (3), (4) and (5), was identified a stronger relation of Ypl and Yha with chlorophyll content (Chl), compared with the leaf area (LA).

Multiple regression analysis facilitated the finding of some models to describe the production variation (Ypl, Yha), depending on the associated influence of the two physiological indices studied, LA and Chl.

Grape production per plant (Ypl) in relation to Chl and LA,  $Ypl=f(LA,Chl)$ , was described by equation (6), under general safety statistical conditions, according to  $R^2=0.998$ ,  $p \ll 0.001$ ,  $F=4264.499$ . The 3D graphical distribution of Ypl according to the values of Chl and LA is presented in Figure 4.

$$Ypl = ax^2 + by^2 + cx + dy + exy + f \quad (6)$$

where:  $x$  – LA – leaf area ( $cm^2$ );  
 $y$  – Chl – Chlorophyll content, SPAD units;  
 $a, b, c, d, e, f$  - the equation (6) coefficients;  
 $a = -0.000491140145853946$ ;  
 $b = -0.00705247917163731$ ;  
 $c = 0.00754085620700632$ ;  
 $d = 0.0193940357912801$ ;  
 $e = 0.00387350656446163$ ;  
 $f = 0$ .

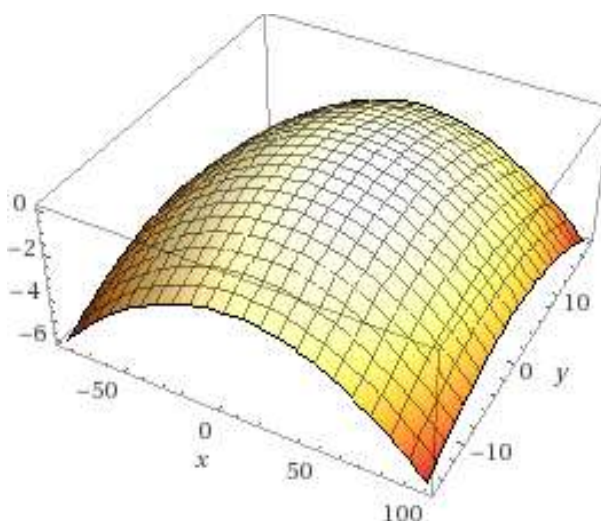


Fig. 4. 3D graphical distribution of Ypl values relative to LA (x-axis), and Chl (y-axis), 'Sylvania' grape variety  
 Source: original graph based on the experimental data  
 The graphical distribution in the form of isoquants of the Ypl values according to Chl

and LA is presented in Figure 5.

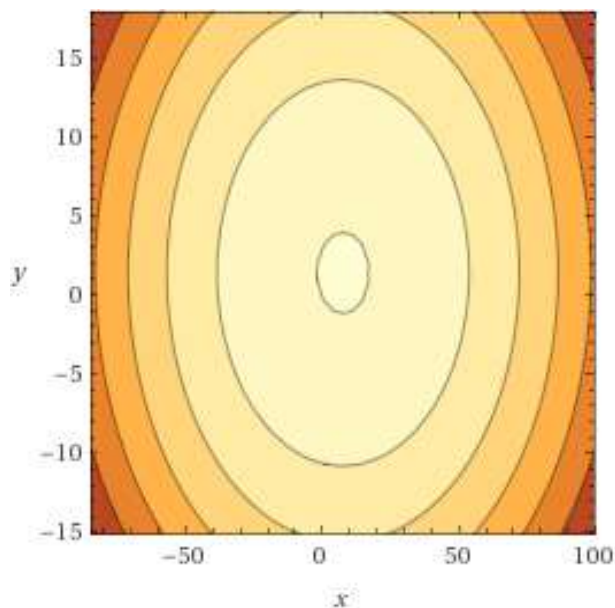


Fig. 5. Graphical distribution in the form of isoquants of Ypl values with respect to LA (x-axis) and Chl (y-axis), 'Sylvania' grape variety  
 Source: original graph based on the experimental data

Grape production per ha (Yha) according to the two physiological indices, as a simultaneous action,  $Yha=f(LA,Chl)$  was described by equation (7) under general statistical safety conditions of the equation, according to  $R^2=0.998$ ,  $p \ll 0.001$ ,  $F=4091.884$ . The graphical distribution of Yha according to the Chl and LA values, in the form of 3D, is presented in Figure 6.

$$Yha = ax^2 + by^2 + cx + dy + exy + f \quad (7)$$

where:  $x$  – LA – leaf area ( $cm^2$ );  
 $y$  – Chl – Chlorophyll content, SPAD units;  
 $a, b, c, d, e, f$  - the equation (7) coefficients;  
 $a = -0.00111331775926283$ ;  
 $b = -0.0151247485454284$ ;  
 $c = 0.0337283253687043$ ;  
 $d = 0.0727054170385543$ ;  
 $e = 0.00887831338165124$ ;  
 $f = 0$ .

Optimal values for  $x$  (LA) and  $y$  (Chl), which provide optimal Yha under the study conditions, were found at  $x_{opt}=145.23 \text{ cm}^2$ , respectively  $y_{opt}=40.22 \text{ SPAD units}$ . The graphical distribution of the Yha values according to LA and Chl, in the form of isoquant, is presented in Figure 7.

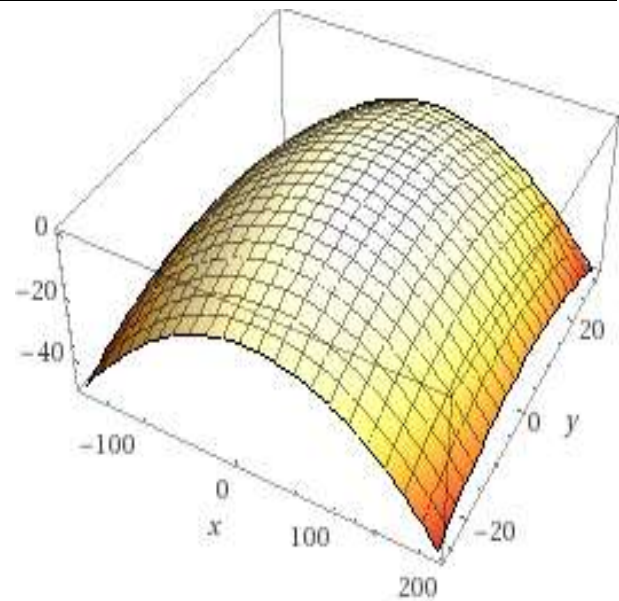


Fig. 6. 3D graphical distribution of Yha values with respect to LA (x-axis) and Chl (y-axis), 'Sylvania' grape variety  
 Source: original graph based on the experimental data

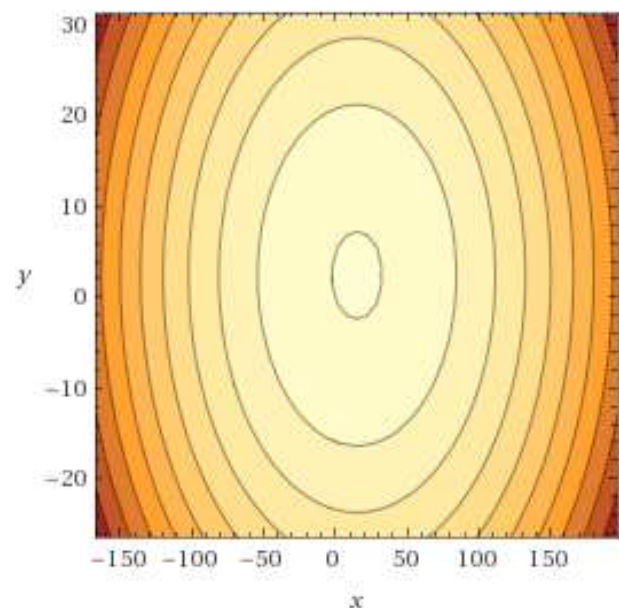


Fig. 7. Graphical distribution in the form of isoquants of Yha values with respect to LA (x-axis) and Chl (y-axis), 'Sylvania' grape variety  
 Source: original graph based on the experimental data

PCA analysis generated the spatial distribution of the variants in relation to the physiological indices (Chl, LA) and production parameters (Ypl, Yha), evaluated in the 'Sylvania' grape variety. PC1 explained 96.806% of variance, and PC2 explained 1.6334% of variance, Figure 8.

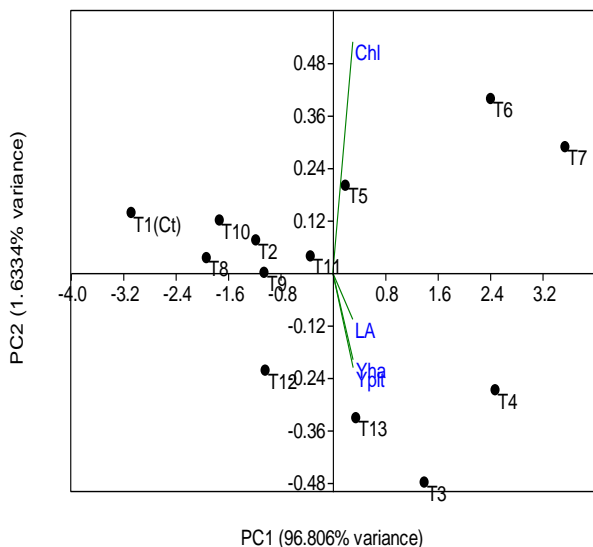


Fig. 8. PCA diagram with the variants (T1-T13) distribution, in relation to LA, Chl, Ypl, Yha, at 'Sylvania' grape variety  
 Source: original graph based on the experimental data

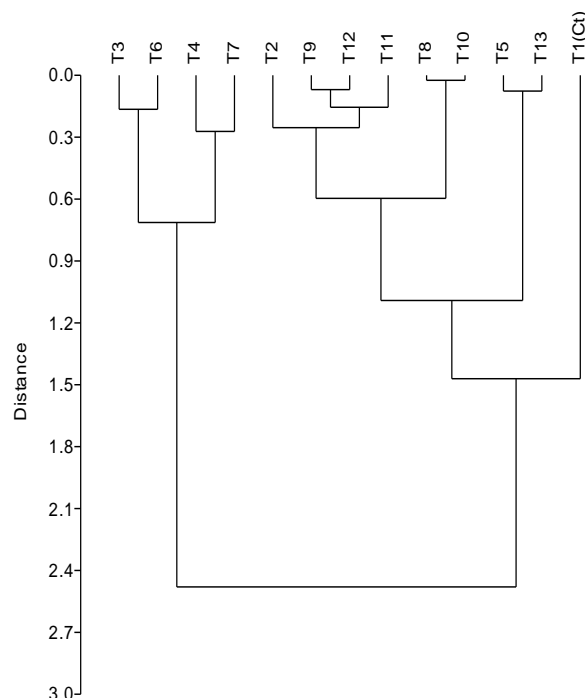


Fig. 9. Clusters diagram in relation to Ypl and Yha, 'Sylvania' grape variety  
 Source: original diagram, based on the experimental data

Cluster analysis generated the grouping of variants based on Euclidean distances, in relation to the values of the production parameters Ypl and Yha (Fig. 9). The statistical safety of the analysis was confirmed by the Cophenetic coefficient (Coph. corr.= 0.843).

The values for similarity distance indices (SDI), related to the experimental variants grouping, are presented in Table 2.

Table 2. Values for Similarity and Distance Indices (SDI) in relation to Ypl and Yha, 'Sylvania' grape variety

	T1(Ct)	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13
T1(Ct)		1.2069	3.3485	4.0077	2.3235	3.5129	4.2775	0.7936	1.4323	0.8071	1.5615	1.3850	2.2542
T2	1.207		2.1416	2.8010	1.1169	2.3060	3.0707	0.4133	0.2267	0.4005	0.3546	0.1796	1.0473
T3	3.349	2.142		0.6616	1.0262	0.1646	0.9295	2.5549	1.9167	2.5416	1.7870	1.9637	1.0943
T4	4.008	2.801	0.662		1.6843	0.4974	0.2718	3.2142	2.5755	3.2014	2.4464	2.6237	1.7539
T5	2.324	1.117	1.026	1.684		1.1904	1.9544	1.5300	0.8912	1.5174	0.7625	0.9404	0.0767
T6	3.513	2.306	0.165	0.497	1.190		0.7649	2.7193	2.0811	2.7061	1.9514	2.1282	1.2588
T7	4.278	3.071	0.929	0.272	1.954	0.765		3.4839	2.8454	3.4709	2.7161	2.8930	2.0234
T8	0.794	0.413	2.555	3.214	1.530	2.719	3.484		0.6390	0.0244	0.7679	0.5918	1.4606
T9	1.432	0.227	1.917	2.576	0.891	2.081	2.845	0.639		0.6269	0.1316	0.0693	0.8224
T10	0.807	0.400	2.542	3.201	1.517	2.706	3.471	0.024	0.627		0.7549	0.5780	1.4475
T11	1.562	0.355	1.787	2.446	0.763	1.951	2.716	0.768	0.132	0.755		0.1787	0.6927
T12	1.385	0.180	1.964	2.624	0.940	2.128	2.893	0.592	0.069	0.578	0.179		0.8698
T13	2.254	1.047	1.094	1.754	0.077	1.259	2.023	1.461	0.822	1.448	0.693	0.870	

Source: original data calculated based on experimental values (Table 1)

From the analysis of the generated dendrogram, Figure 9, it was found the formation of two distinct clusters. A C1 cluster comprised 9 variants, and a C2 cluster comprised 4 variants. Within the C1 cluster,

the T1 variant (Ct) was independently positioned, with the lowest values for production parameters (Ypl, Yha). The other 8 variants were grouped into several sub-clusters; sub-cluster C1-1, with variants

(T5, T13); sub-cluster C1-2, with variants (T8, T10), sub-cluster C1-3, with variants [(T9, T12), T11], T2], with a common root. Cluster C2 grouped the variants [(T4, T7), (T3, T6)]. The analysis of SDI values (similarity distance indices) in relation to the clusters group, confirmed the highest degree of similarity in the variants T8, T10 (SDI = 0.024), followed by variants T9, T12 (SDI = 0.069), and by variants T5, T13 (SDI = 0.077), table 2. The overall analysis of the SDI values, presented in Table 2, explained the association and grouping of the experimental variants according to the degree of affinity to ensure the production per plant (Ypl) and the production per ha (Yha), under the experimental conditions.

The relationship between the values of the physiological indices (LA, Chl) and the values of the production parameters (Ypl, Yha) was analyzed. Thus, in the case of the ratio LA: Ypl, values between 51.990 and 60.485 units LA/ unit Ypl were found. In the case of the LA:Yha ratio, values between 12.324 and 14.181 LA units / Yha unit were found. From the comparative analysis, with the graphical representation of the values for Ypl and LA / Ypl, it was found the presence of a "scissor" type relationship between the two values categories.

From the analysis of the Chl:Ypl ratio were found values between 13.339 and 16.488 units Chl / Ypl unit, and from the analysis of the Chl:Yha ratio were found values between 3.152 and 3.836 Chl units / one Yha unit.

Leaf area and numerous other aspects of plant leaves have been studied in relation to nutrients [57], [58], with stress factors [34], with production, etc. [71].

Foliar indices such as LAI (leaf area index) have been calculated and used in different studies to evaluate and express the relationship of CO<sub>2</sub> plants, photosynthetic efficiency, response to stress factors, increased production, etc. [23], [43], [50].

Leaf Area Index at vine was also studied in relation to methods of determination [49] but also with elements of productivity, quality and yield [66].

The leaf-fruit ratio presented interest and has been studied in several vine varieties in

relation to fruit production and composition [27].

The "scissor" effect identified in the comparative analysis of LA with LA/Ypl leads to the need to control the leaf surface on vine plants in order to balance LA:Ypl.

Vine products represent a special category of horticultural products, and numerous studies have addressed the problem of grape production from the plot to the consumer. In order to optimize the production, numerous studies evaluated the pedoclimatic conditions, the cultivated varieties, the viticulture technologies and the inputs under quantitative and qualitative aspect [18], [3], [16], [47], [25], [72].

Numerous studies have focused on aspects regarding the quality and the typicality of the wine products [17], [2], [48], [2], [64], [67], [14]. There have been studies on economic and trade aspects, specific to the wine sector, especially in relation to the production, consumption and specificity of the wine products [6], [37], [65]. Tourism and wine tourism have also been the subjects of valuable studies aimed at promoting specific values, local, regional or national, on the international market [53], [33], [32] [51], [52], [54].

In the context of the interest for the wine products, highlighted by the specialized literature, the present study communicated models of approach for optimizing the production of grapes, the case study being carried out in the 'Silvania' grape variety.

Of the 12 fertilization variants, the methods of analysis and investigation used highlighted both the best and alternative variants based on similarity. Thus it brought useful information for choosing fertilization variants in relation to the type of plantation (conventional, intensive, ecological), but also with specific aspects of vineyard practices.

## CONCLUSIONS

The relationship of interdependence between the physiological studied indices (LA, Chl) and production parameters (Ypl, Yha), under different fertilization conditions, has been described by mathematical models obtained

by regression analysis, under statistical safety conditions.

The optimum level of LA and Chl were determined from the equations found, ensuring the optimal values of Ypl and Yha.

Based on Cluster Analysis, similarities of the experimental variants in the assurance of Ypl and Yha values, in statistical safety conditions, were identified.

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