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EFFECT OF THE GENOTYPE – ENVIRONMENTAL INTERACTION ON PHENOTYPE VARIATION OF THE BUNCH WEIGHT IN WHITE WINE VARIETIES

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Abstract - The aim of this paper is to establish the interaction of phenotypical variations, components of yield for the widest spread wine varieties and external factors of the Danube region in the central Serbia. The number of fruitful buds per vine for twenty-one varieties was the same, whereas the yield and the components of the yield were different. The growing season, from bud burst to full ripening of the grapevine and the sum of active temperatures for the same period, were of crucial importance. In the factor analysis, three factors have been singled out: the first factor couples the mean air temperature; the second factor delineates the values according to genotype characteristics, sugar content and acids in the must, and the third factor indicates that bunch weight had the major effect on the yield of grapes. By the application of bunch analysis, a hierarchy tree was formed to include the four groups of varieties. The most numerous group, consisting of 18 varieties, is characterized by top quality grapes (21.5% sugar content), medium yield (1.52 kg/m^2) and a proportional relation of total acids (7.5 g/l) and this is achieved during the middle of the ripening period.

Key words: *Vitis vinifera* L., phenotype fluctuation, yield, bunch weight, must quality

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INTRODUCTION

The quality of grapes and quality and type of wines depend on natural and human factors. The research and obtained results, according to Howell, (2001) in the last century, have been shown to encourage and instigate the discussion: balance of grape yields, development of vine and leaf surface. The yield and quality of the processed grapes are equally important economic indicators. Yield is a complex feature consisting of quantity components which are polygenetic in character (Sivčev et al., 2000). As early as 1926 Sartorius indicated a negative correlation between yield and the sugar content of the must. According to Bäder, as reported by Eibaich (1990), the correlation between quantity and quality is not identical for each grapevine variety; the correlation is more expressed between the sugar content of must and bunch weight than to sugar content and number of bunches per vine. We intend to create conditions for sustainable production and we are focused on the vine and its capacity for abiotic and biotic stress phases. The offered methods for achieving the balance will be different in macro-climate and mezzo-climate conditions, particularly in the cold climate conditions in the northern hemisphere. Most of the wine compounds are produced by the plant itself or the training system on vine growth, leaves (sugar and acids), and berries (acids and phenols) (Conde et al., 2007). Average growing season temperatures typically define the climate-maturity ripening potential for premium quality wine varieties grown in cool, intermediate, warm and hot climates (Jones et al., 2005). Duchêne and Schneider (2005) found that potential alcohol levels of Riesling at harvest in Alsace have increased by 2.5% (in volume) over the last 30 years and that this correlates highly to significantly warmer ripening periods and earlier phenology. To place viticulture and the wine industry in the context of climate suitability and the potential impact of climate change, various temperature-based metrics (e.g., degree-days, cool night temperatures, mean temperature of the warmest month, average growing season temperatures) can be used for establishing optimum regions (Gladstones, 1995). In general, the types of grapes that can be grown and overall wine style that a region produces are a result of the baseline climate, while climatic variability determines vintage-to-vintage quality differences (Jones and Hellmann, 2003). The present study has the aim of establishing the expressiveness of the genes interacting with the environment and their influence on the phenotype values of variability, changeability, stability and adaptive capacity of the bunch weight, yield, content of sugar and acids in must characteristics in the white wine varieties.

MATERIAL AND METHODS

The trials were conducted in 21 white wine varieties grafted on K5BB rootstock and planted at the ampelographic collection. The vineyard is situated southeast of Belgrade in the central grape growing region of Serbia (φ=44° 77" N, λ=20° 35" 18′, H=124 m). It has a continental climate with an annual average temperature of 11.2°C, seasonal average temperature of 16.6°C, 401 mm of precipitation during the growing season, and a total annual precipitation amounting to 646 mm (during the period 1980-2006). The plantation is a registered gene bank for grapevines with the international organizations O.I.V. and IBGR/ (Alleweldt and Detweiller, 1986). The vineyard is on a south-facing slope, with a rectangular arrangement of vine: 3 m x 0.75 m. The training system is of cordon type, and mixed-type pruning is practiced. Phenological observation included bud burst-shoot growth, fluorescence, véraison and full ripeness. The number of days (Pheno), sum of active (Active) and effective (Effective; t>10°C) temperatures were established for each phenological stage (Pheno1 - number of days between bud burst and fluorescence; Pheno2 - number of days between fluorescence to véraison; Pheno3 - number of days between véraison to full ripeness, Pheno4 - period between bud burst to full ripeness), 12 features in totals. The parameters of fruitful buds and yield were established based on three replications in each variety in the period 1991-1993. The number of buds per vine averaged thirty. Grape yield was established by measurements done at the time of grape technological ripeness per vine. Concurrently, the number of bunches (bunch/vine) and mean bunch weight (g) were also established. Calculations of mean yield per vine and per unit area (yield kg/m^2) were also done. The contents of sugar and acids were determined by standard methods applied to the sample taken for each variety.

The data were treated with the application of a mathematical-statistical method (program STATGRAF), factor analysis and cluster analysis for variety, grape yield, bunch weight, number of bunches per vine, and must quality (content of sugar and acids) is being the basis for comparison.

RESULTS AND DISCUSION

The experimental period covered two years with extreme values: 1991 was characteristic for the early initiation of the vine, a long, humid and cold vegetation period, and 1992 was dry and hot, particularly at the time of véraison, which resulted in a considerably shorter vegetation period.

Tab. 1 Factor Loading Matrix After Varimax Rotation

	Factor *1*	Factor *2*	Factor *3*
Activ2	0,94308	-0,0069859	0,0233745
Activ4	-0,442227	0,800222	0,180074
Pheno2	0,932085	-0,00307501	0,029248
Pheno3	-0,67697	0,537082	0,120362
Pheno4	-0,46248	0,78669	0,171133
Sugar Content	0,233962	-0,334611	-0,690092
Bunch Weight	0,20501	0,0495489	0,868985
Yield Grape	-0,014547	-0,150901	0,790569
Total Acids	0,194071	0,670473	-0,137036

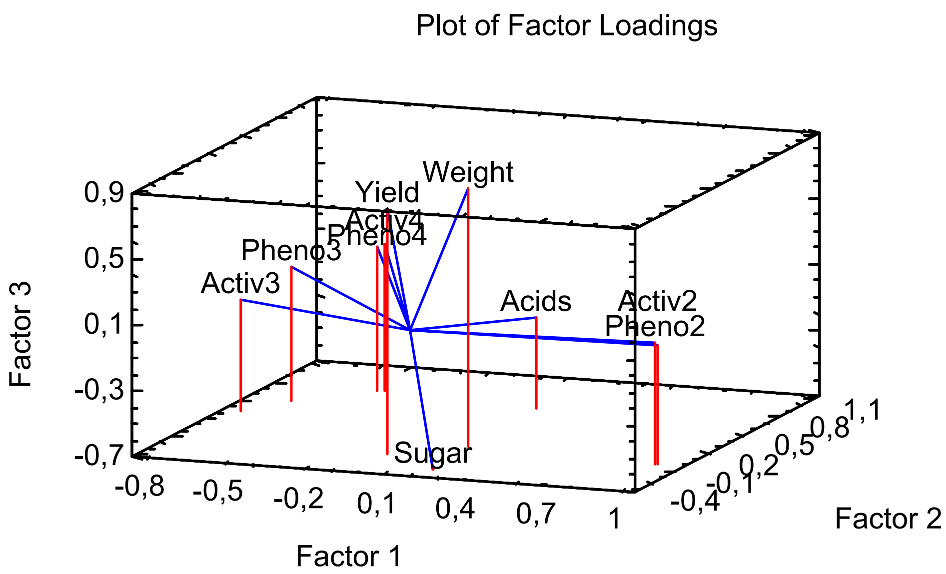

Fig.1 Graphical presentation of mutual dependence of factor analysis

The average length of the vegetation period (Pheno4) was between 155 days (cv. Pinot Blanc) and 183 days (cv. Dymiat). 12 phenological features were monitored in total and in multi-dimensional space, and our aims were to reduce the original set of data and examine some of the variations mutual to all variants, in our case the ones to which phenological features had a primary impact for all studied varieties, reviewing them through quality and quantity yield indicators.

By applying factor analysis, five phonological features were identified as having a significant impact on the components of grape yield (Table 1).

The diagram (Fig. 1) clearly identifies two isolated indicators Activ2 and Pheno2 in comparison to all other features. The sum of active temperatures (Activ2) and the number of days (Pheno2) from blooming to véraison have the greatest impact on the yield and yield components. The favorable heat conditions in this phenophase shorten the period of grape ripening, offer the optimal differentiation of dormant buds (Pheno 3) and shorten the vegetation period in general (Pheno4).

The supply of carbohydrates is thus crucial for the achievement of grapevine reproduction (Caspari et al., 1998). High absolute values within Factor 1 confirm the same manner of reaction of varieties, i.e., the same genetic origin. Lebon et al., (2008) suggest that young levels are capable of photosynthesis very early during their growth period, although they become the source of assimilates. As reported above, sugars devoted to the development of reproductive structures are supplied either by wood reserves, photosynthesis in the leaves or fluorescence, depending on the stage of development. On average, the difference between the full ripeness of the earliest and the latest ripening varieties is 28 days, which influences the differences in sugar content and total acid amount in the must.

Tab. 2 Cluster Summary and Centroids

Cluster	Members Varieties	*Percent*	*Sugar %*	*Total Acids g/l*	*Yield Kg/m²*
1	18	85.71	21.6	7.5	1.52
2	1	4.76	16.6	9.4	2.11
3	1	4.76	22.7	8.7	2.17
4	1	4.76	18.4	9.2	2.56

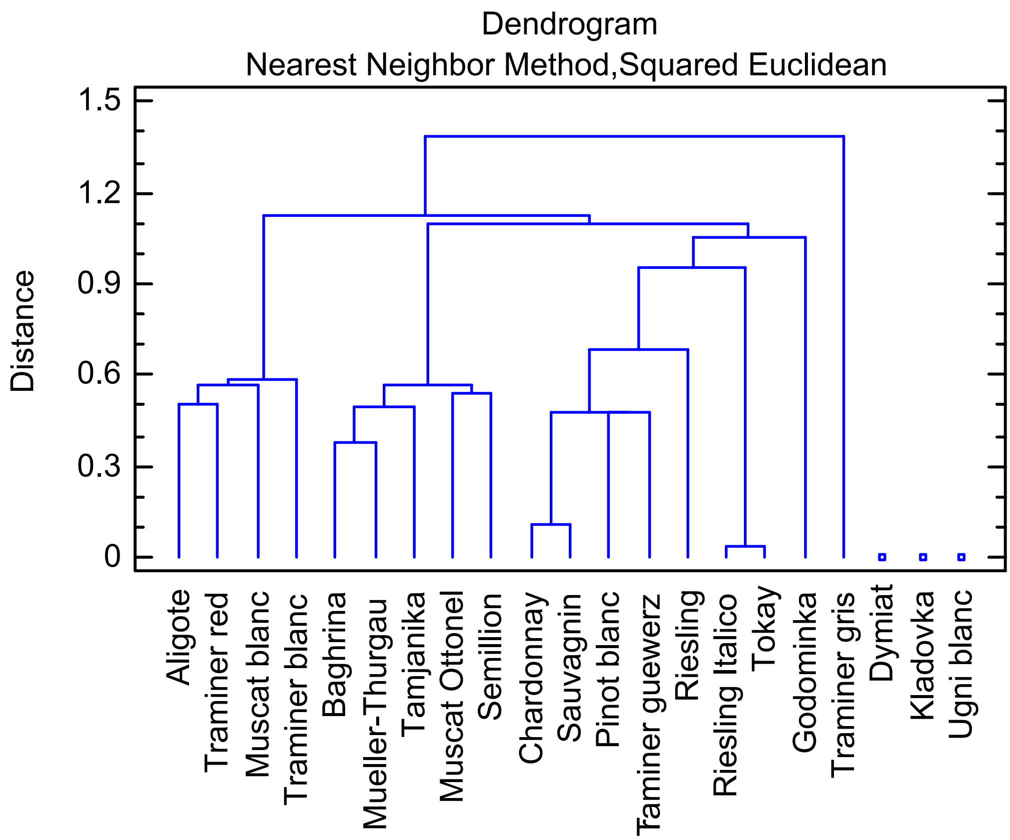

Fig. 2 Grouping of varieties according to quality and quantity characteristic

The most important component of the yield is the size of the grape; this can be clearly seen in diagram (Fig. 1). Especially in cool climates, the increasing exposure of the fruit to sunlight through optimization of the training system is typically positive. The grape quality and vineyard management techniques include the genetic control of grapevine reproduction and yield. The seasonal variations in yield are usually >15% and often >35% (Antcliff et al., 1965; Fanizza, 1979; Clingeleffer, 1984; Cvetković et al., 1999; Bramley and Hamilton, 2004; Keller et al., 1997; Fanizza et al., 2005; Clingeleffer, 2006).

In our results, we performed a cluster analysis for yield (kg/m^2), bunch weight and content of sugar and acids. Environmental, genotype, and management treatments have the most influence on the final yield (kg/m^2), from fluorescence initiation within the latent bud to final harvest of the grape.

We compared the number of clusters and the weight of the clusters in the year of vine blossoming and grape picking to Clingeleffer (2006) who monitored the year of initiation of inflorescence. It is also typical to use the same term, "bunch number", and to subsequently attribute it to the period it refers to in the year that precedes blooming or in the year of blooming and generating fruit. According to our results, the cluster weight for the studied group of 21 varieties contributed most to the amount of yield and quality of grapes (Tab. 2, Fig. 2). Lebon et al. (2008) suggest that the formation of the reproductive organs in the grapevine is a complex phenomenon extending over two successive years and interrupted by winter dormancy. Differences in climate and management on a global level make it difficult to be specific when discussing factors affecting yield (Vuković et al. 2009). Clingeleffer (2006) emphasizes that the bunch number per vine accounted for

58-88% of the seasonal variation, with bunch weight accounting for 11-13%. On average, and according to our results, the grape yield amounted to 0.76 kg/m^2 (Traminer Gris) to 2.5 kg/m^2 (Ugni Blanc). The slight variation and high level of yield homogeneity are characteristic for these two varieties and the varieties Dymiat and Kladovka. The absolute amount of this data is extreme, but it is in all of them a genotype characteristic. Dymiat belongs to the typical Balkan Peninsula variety, *subconavrietas balcanica*, Ugni Blanc belongs to the typical Iberian Peninsula variety *subconvarietas iberica*. These two varieties do not achieve the same ripeness under local climatic condition. The observed genetic differentiation among vine-growing regions suggested that varieties could possibly be assigned to their regions of origin according to their genotypes (Duchine et al., 2003). Most varieties (85.71%) which grow in the central region of Serbia are characterized by high yield homogeneity and high quality of must. The ripening of these eighteen varieties occurred at the end of the summer. There are Chardonnay, Sauvignon Blanc, Pinot Blanc, Gewürztraminer, Riesling and Riesling Italico. Apart from Bagrhina, from Dardagan-Romania, which has female type flowers, all the other varieties are widespread in the many vine growing areas. This feature explains the high level of genotype-environmental adaptability. We included 21 varieties with the same number of buds per vine in winter pruning, and the yield composition was different. The major effect on dormant buds, with variety differences, was observed by the number of fruitful canes, number of buds per cane and node position of the bunch on the cane. The number of investigated varieties which produced grapes of better quality was high, eighteen in total. Regarding the acid content of the must, differences between the groups of varieties were prominent (Tab. 2). Carmona et al. (2008) says that an indefinable term, "quality", has crept into some of the scientific literature about the grape. The term "grape composition" is more appropriate for scientific studies and would be a valuable starting point in the characterization of wine grape "quality" as the metabolite composition of grape and wine can be measured and quantified.

The dimension of a seasonal variation for accurate yield forecast occurs prior to harvest. The increased awareness of climate change and potential effects on yield composition could help us to understand the response between axon genotype interaction and development of genotype wine varieties.

CONCLUSION

Observing the features in a multidimensional area, our aim was to decrease the original group of data to investigate some of the variations common to all variables. The phenological features with primary significance for all the investigated varieties are defined in our case.

The factor analysis approbated that point of departure. We included nine indices in the environmental conditions: Active2, Active4, Pheno2, Pheno3, Pheno4, sugar content, bunch weight, yield and total acids. Factor analysis pointed to variation between the experimental features that are common to all the genotypes/varieties included in our investigation. The following factors have been singled out. The first factor couples the average air temperature (Active2, Active3), and the number of days (Pheno2, Pheno3 and Pheno4), i.e. they are highly positively correlated. The second factor links the values according to genotype characteristics: sugar content and total acids in the must. The results show that the quality declines with the increase of total acids.

On average, the grape yield amounted to 0.76 kg/m^2 (Traminer Gris) to 2.5 kg/m^2 (Ugni Blanc). The slight variation and high level of yield homogeneity are characteristic for these two varieties and the varieties Dymiat and Kladovka (new white, late ripening wine variety, parentages are Pinot Noir (N) x Prokupac (N)). The absolute amount of these data is extreme, but all of them are genotype characteristic. Most of the varieties (85.71%) are characterized by high yield homogeneity. These are: Chardonnay, Sauvignon, Pinot Blanc, Gewürztraminer, Riesling, Riesling Italico, Tokay and Godominka (new white, early ripening wine variety, created by self-pollination cv. Dymiat).

The number of investigated varieties which produced better quality grapes was high, eighteen in total. Only three varieties were characterized with a medium level of sugar content in the must and high level of acids: Dymiat, Kladovka and Ugni Blanc.

The impacts of climate change on grape quality are evidenced through the phenotype variability and confirmed by the genotype stability of eighteen white wine varieties for the central grape growing region in Serbia.

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