Improvement of *Vitis vinifera sativa* D. C. taxonomy

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S u m m a r y : A method of mathematical statistics for evaluation of the taxonomic usefulness of characters included in the *Vitis vinifera sativa* D. C. cultivar clustering has been developed. The method works as follows: The irregularity of the distribution of characters in taxons is calculated, and the probability of achieving such estimates is calculated when all taxons are assigned to the same general population after a certain character. The method does not depend on the type of the distribution of characters and is computer-programmed (a CM-4 computer). Using the method, it is possible to conclude that the higher the taxon hierarchy, the smaller is the amount of taxonomically useful characters the taxons differ in, i. e. in order to differentiate taxons of lower hierarchy a smaller amount of descriptive characters is necessary. Var. *transcaucasica* and var. *mediiasica* have been isolated in the taxon convar. *orientalis* subconvar. *caspica* Negr. and in the taxon subconvar. *antasiatica* Negr., while the taxon convar. *pontica* Negr. has been supplemented with subconvar. *meridionali-balcanica* and *georgica-caspica* along with subconvar. *balcanica* and *georgica* Negr.

Using discriminant analysis, assignment of many cultivars to proper taxons has been verified. The phenogenetic proximity of taxons has been established. Some problems of the theory of evolution and those of practical breeding are discussed.

K e y w o r d s : ampelography, biometry, systematics, taxonomy, variety of vine, gene resources, Asia, Europe, Africa.

Introduction

Progress in the theory and practice of grape breeding is due to achievements of ampelography and genetics used by originators in creating genotypes after the models of ideal cultivars (Golodryga and Troshin 1978). Understanding of the combining ability of gene complexes of the initial forms depends on their assignment to proper taxons.

Studies of wild grape in Bulgaria (Negroul *et al.* 1965), Moldavia (Yanushevich and Peliakh 1971), Daguestan (Pirmagomedov 1980), Georgia (Ramishvili 1988) and in the Crimea (Troshin and Sviridenko 1980) have shown a relationship between the local cultured and wild grape and have made it possible to establish its origin.

The origins of some large-fruited table grape cultivars still need elucidation. Vidal (1948) suggested that large-fruited wild grape growing in the Atlas Mountains may have been used as initial material for popular selection of large-fruited grape cultivars in North Africa.

Taking into account the vast area of wild grape distribution and its isolated location in certain regions with different natural and climatic conditions, it is impossible to consider the species *Vitis silvestris* Gmel. homogeneous (Vavilov 1931; Vasilchenko 1955). In every ancient centre of culture, wild grape has its own morphological and biological peculiarities, which makes it necessary to name it after the places of growth(the Daguestan grape, the Crimean grape, the East Georgean grape, the West Georgean grape, the Transcarpathian grape, etc.).

Local grape cultivars are also classified by authors after their places of origin.

According to the classification of Negroul (1946, 1968), grape cultivars are arranged into three ecological-geographical groups. Several hierarchic taxons have been isolated in two of these groups, but Negroul himself thought that the problem needed further elucidation. Studies on grape classification were also done by Ivanova (1947), Aliyev (1956), Nemeth (1967), Gramotenko (1975, 1978), Tsertsvadze (1986).

Materials and methods

Grapevines on their own roots (studied since 1970) and grafted plants (studied since 1983) were described and measured according to standard ampelographic methods. In the matrices of initial data, 30 quantitative characters were determined using a natural scale (scale of relations), and 74 qualitative characters were established using a numerical scale (scores 1-5) (Methodical Instructions on Grape Breeding, 1974). More recently, the O.I.V. numerical scale (1984) (scores 1-10) was used.

The quantitative characters included 11 morphometrical, 6 phenological, 9 biological-agricultural, 2 chemical-technological and 2 adaptive characters. Botanical, uvological, physiological and other characters were considered alternative (TROSHIN and FEDOROV 1988).

Grape cultivars were classified after complexes of characters according to their origin (GRAMOTENKO and TROSHIN 1988). The validity of the classification was checked using methods of cluster and discriminant analysis (KENDALL and STUART 1976).

In establishing patterns of a classification it is necessary to determine the taxonomic usefulness of characters. For this purpose, the criterion of KRUSKAL and WALLIS can be useful (ZAITSEV 1984), but we concluded that taxonomically useful characters were those minimizing transgression of clusters of the 'teaching' sampling. Of non-dimensional methods, the criterion of MANN-WHITNEY can be used as index of the transgression value (SACHS 1972), but its disadvantage is that, with more than two clusters and a considerable transgression among some of them, the value of the total criterion may become so large that even under condition of complex isolation of several clusters the character will be considered insignificant.

We suggest a criterion of our own which is based, for all pairs of clusters, on how many times cultivars of the first cluster are included into the variation range of the second cluster. Thus, the criterion is defined as follows:

$$\text{Criterion} = \sum_{j=1}^{N} \sum_{i=1}^{M_j} \sum_{k=1}^{N} A_{ijk} \; ; \text{ where:}$$

N – amount of groups
M_j – amount of cultivars in the jth group
A_{ijk} = 1 if the value of a character of the ith cultivar belonging to the jth group is included into the variation range of the kth group; otherwise,
A_{ijk} = 0.

In determining the significance of the criterion, we tried to make theoretical calculations of its critical values considering the values of the criterion between pairs of taxons to be an independent sampling from a corresponding distribution. But the check using the method of Monte Carlo (AFIFI and AZEN 1982) showed substantial systematic deviations from the values obtained. It is due to the fact that with 3 taxons, A, B and C, for instance, the value of the criterion for taxons A and B depends to a great extent on its values for A - B and B - C. Thus, the sampling cannot be considered independent. We failed to take into account the relationships and chose the method of Monte Carlo.

We made a special program for a CM-4 computer to calculate numerical values of the criterion to sort out characters according to the value of the criterion and to estimate the probability of error, when the assumption that all the taxons belong to the same general population after this or that character was omitted. In doing so, there is no need to produce the numerical value of the criterion as it is not the values themselves that count but the importance of every character for the classification.

The estimates of the taxonomic usefulness of characters do not depend on the type of distribution of large samplings and can be calculated with as few as two cultivars in a taxon;

naturally, the larger the amount of cultivars, the more reliable are the estimates (TROSHIN *et al.* 1988).

Results and discussion

The results obatined of the classification of grape cultivars made it possible to isolate some new taxons in addition to those already known (GRAMOTENKO and TROSHIN 1988).

Cultivars of the taxon convar. *boreali-africana* GRAM. are characterized by a long vegetation period, late budbreak, very late leaf fall and weak resistance to frosts and fungal diseases. The taxon contains local table and wine cultivars of Morocco, Algeria and Tunisia, e. g. Ahmar bou Ahmar, Farrana, Khadari, Ribier, etc. Their adaptivity in the European part of the USSR is poor, but they can be of interest there as initial material in breeding for large-fruitedness.

Cultivars of the taxon *orientali-mediterranea* GRAM. are characterized by a long vegetation period, weak frost resistance, firm berry flesh and tough berry skin; in many cultivars, muscat-flavoured fruit is common. As far as their morphological and biological characters are concerned, these cultivars have a certain phenotypic similarity to those of the previous group, but the East Mediterranean group is older and differs genetically from the other ones. Cultivar types of muscadine grape and Chasselas are examples of this group.

Grape cultivars of Spain, Portugal and the southern part of France differ substantially from those of Germany and the central part of France. The former cultivars are characterized by a long vegetation period, late leaf fall and weak frost resistance. As far as their biological characters are concerned, cultivars of the south-western part of Europe are closer to the North African ecological-geographical group though with regard to their geographical position they enter the West European group. That is why the subgroup subconvar. *pyrenaica* GRAM. was established within this group. In table cultivars, Bican, Vermentino, Gros Vert, Catalon d'Hiver are representatives of this subgroup, while Mourvedre, Morastel, Sersial are its representatives in wine cultivars.

The South Balkan subgroup subconvar. *meridionali-balcanica* TROSCH. can be considered analogous to the previous subgroup as far as its origin is concerned. The South Balkan subgroup contains cultivars Limberger, Kabassia, Kadarka, Maisky tcheurny, etc. characterized under conditions of the Crimea, the Don and the Kuban regions by low sugar content and larger size of leaves, berries and bunches. Greek and Albanian cultivars are also included into this subgroup.

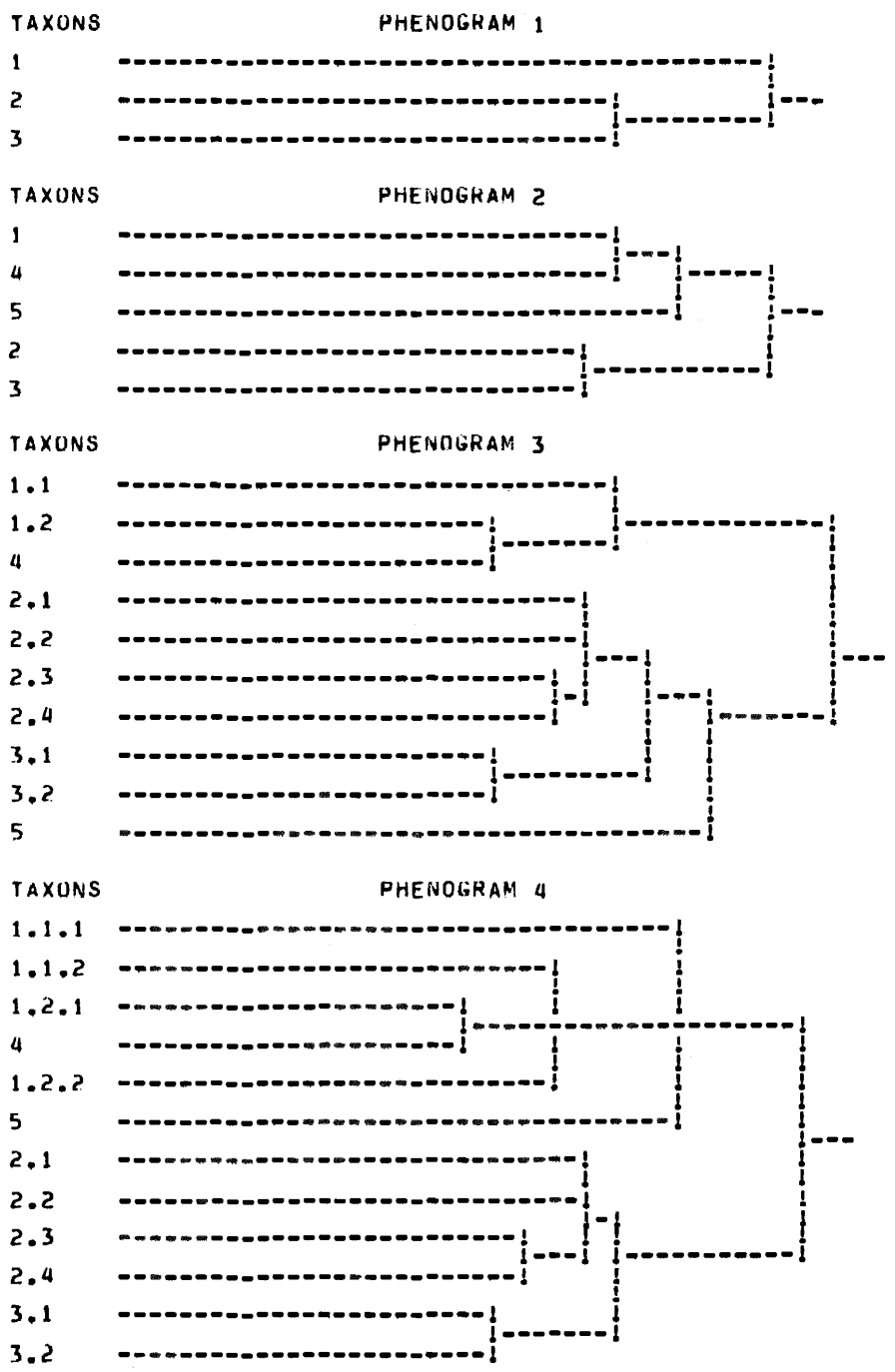
Some Georgean grape cultivars of this subgroup subconvar. *georgica* NEGR. which is included into the Black Sea Basin ecological-geographical group have characters of the group of eastern wine grape *orientalis caspica* NEGR. Their intermediate position between these ecological-geographical subgroups made it necessary to arrange them into the subgroup subconvar. *georgica-caspica* GRAM. contained by the Black Sea Basin ecological-geographical group. This separate subgroup contains cultivars Rkatziteli, Tchinouri, Boudechouri tetri, Sirgoula, Goroula, etc.

We developed the taxonomic scheme of NEGROUL having classified Transcaucasian and Middle Asiatic cultivars with regard to their uses, too.

While establishing phenogenetic relationships among taxons, we evaluated the taxonomic usefulness of characters. In doing so, values of quantitative characters were transformed into scores of the numerical scale as required by the use of methods of multidimensional analysis.

Having analyzed the taxonomic usefulness, estimates of 104 characters of 120 grape cultivars arranged into 12 taxons revealed the following correlation: the higher the taxon hierarchy and the larger the amount of taxons of the same level, the smaller the amount of taxonomically useful characters the taxons differ in. Thus, in order to classify taxons of a lower level (cultivar types, cultivar groups), a smaller amount of descriptive characters is necessary (TROSHIN and FEDOROV 1988).

Taxonomically useful characters ($P < 0.05$) for 12 taxons had the following probability estimates (%):



Phenograms of cluster analysis: Phenogram 1 - 3 taxons; Phenogram 2 - 5 taxons; Phenogram 3 - 10 taxons; Phenogram 4 - 12 taxons. The names of taxons are given in the text.

- cobwebby pubescence among veins of young leaf (O.I.V. descriptive character code 053): 100
- cobwebby pubescence among veins of mature leaf (084): 100
- berry size (220): 100
- berry shape (223): 100
- texture of berry flesh (235): 100
- cobwebby pubescence of shoot tip (004): 99
- duration of interphase period 'beginning of budbreak - beginning of bloom': 99
- coefficient of shoot fruiting (total of bunches/total of shoots ratio): 96
- field resistance of leaves to mildew: 95
- degree of lignification of terminal shoots: 89
- length of shoot internodes (353): 78
- bunch size (202): 75
- berry length (221): 68
- use of fruit: 66
- average bunch weight: 56
- coefficient of shoot fruitfulness: 44
- blistered aspect of upper surface of leaf blade (075): 39
- degree of shoot fruitfulness: 33
- titratable acidity of juice: 33
- density of fruit in bunch (204): 19
- color of berry skin (225): 14
- degree of lignification of shoots: 12

Taxons were arranged into clusters after taxonomically useful characters and congruence of cultivars with corresponding taxons was estimated using discriminant analysis. The results obtained are shown in phenograms (see Fig.).

Phenogram 1 shows that the taxons convar. *pontica* NEGR. (2) and convar. *occidentalis* NEGR. (3) reveal a greater degree of the phenogenetic similarity to each other after a complex of characters than, if compared separately, to the taxon convar. *orientalis* NEGR. (1). This disagrees with NEMETH's (1967) belief that the ecological-geographical group convar. *pontica* NEGR. is the oldest and the group convar. *occidentalis* NEGR. is the youngest. Cultivars of these two taxons could have been formed during thousands of years, both on the basis of local wild grape under artificial selection and as a result of introgression of genes of cultured forms coming from warmer Mediterranean countries.

The phenograms obtained show that the taxon convar. *orientalis* NEGR. differs from the taxons convar. *pontica* NEGR. and convar. *occidentalis* NEGR., longer lines in the phenogram of the former taxon indicating later evolutionary changes. Earlier, NEGROUL (1968) and SMIRNOV (1974) reported the origin of Middle Asiatic cultivars to be secondary.

Using ampelographic data of the two ecological-geographical groups established by GRAMOTENKO (1978) in doing cluster analysis made it possible to affirm the phenogenetic relationship between the taxons convar. *pontica* NEGR. and convar. *occidentalis* NEGR. and to reveal that the taxons convar. *orientalis* NEGR. and convar. *boreali-africana* GRAM. (4) formed another phenone showing in its turn a greater degree of similarity to convar. *orientali-mediterranea* GRAM. (5) than to each of the former 2 taxons (Phenogram 2). The intermediate position of the taxon convar. *orientali-mediterranea* GRAM. shows that genes of its cultivars are found in cultivars of the remaining 4 taxons. It agrees with literature data concerning the earlier origin of East Mediterranean cultivars, which reflects the development of human civilization since the Mycenaean times.

Phenogram 3 also shows the intermediate geographical position of the taxon convar. *orientali-mediterranea* GRAM. The phenone convar. *occidentalis* NEGR. is made by the subgroups subconvar. *gallica* NEM. (3.1) and subconvar. *pyrenaica* GRAM. (3.2), and the phenone convar. *pontica* NEGR. contains the subgroups subconvar. *georgica* NEGR. (2.1), *balcanica* NEGR. (2.2), *meridionali-balcanica* TROSCH. (2.3) and *georgica-caspica* GRAM. (2.4), the subgroups within each

phenone being closely related. It can be seen from the phenogram that the subgroup subconvar. *caspica* NEGR. (1.1) contained by the eastern ecological-geographical group of cultivars is older than the subgroup subconvar. *antasiatica* NEGR. (1.2), which agrees with the data of SMIRNOV *et al.* (1987).

Further arrangement of data into clusters made it possible to obtain Phenogram 4 showing that the taxons convar. *occidentalis* NEGR. and convar. *pontica* NEGR. preserved their hierarchy in regard to the other taxons. The taxons convar. *orientalis* NEGR., *boreali-africana* GRAM. and *orientali-mediterranea* GRAM. formed a separate phenone. Within this phenone, the taxons convar. *boreali-africana* GRAM. and convar. *orientalis* subconvar. *antasiatica* NEGR. var. *transcaucasica* GRAM. *et* TROSCH. (1.2.1), i. e. North African and Transcaucasian table cultivars, revealed the highest degree of relatedness. Transcaucasian wine cultivars (1.1.1) along with East Mediterranean cultivars are the oldest. Thus, it is possible to conclude that Middle Asiatic wine (1.1.2) and table (1.2.2) cultivars were formed later.

Conclusions

Based on ampelographic material including representatives of various ecological-geographical groups of cultured grape, we made an attempt to improve the natural system of classification.

As the results obtained show, the principal centre of cultured grape origin is the East Mediterranean region from where grapevine moved to the eastern, northern and western parts of Eurasia and to the north of Africa following great trade ways of ancient civilisations and with migrations of ancient tribes. This conclusion agrees with the opinion of DE CANDOLLE (1885).

Using methods of modern taxonomy in order to improve the natural system of *Vitis vinifera sativa* D. C. made it possible to find grounds for the relative independence of the 5 ecological-geographical groups and to establish the divergence of taxons within these groups.

The improved taxonomy of cultured grape with isolated hierarchic groups of cultivars of the Euro-Asiatic species makes it possible to provide a more rational introduction of planting material into new regions of culture, to develop agrotechnical methods aimed at increasing productivity and to more effectively use cultivars of various taxons in creating new adaptive genotypes.

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