Selection of highly productive grape variations using methods of multidimensional analysis

L. P. TROSHIN

National Institute for Grape and Products of Grape Processing 'Magarach', 31, Kirov Street, Yalta, Crimea, USSR

Summary: A method of clonal grape selection that allows the identification of genotypes with high productivity, based on phenotypes, with a substantial decrease in the duration of the process of selection is proposed.

Multi-stage selection of the best plants is carried out in the same stock nursery during 4-5 years. 5-6 % of the selected plants include mutated and modified variations characterized not only by high productivity, normal vigor, good quality of fruit and good sanitary condition of vines, but also by a stable expression of these desirable characters.

Key words: clone, selection, yield, fruit, must quality, growth, shoot, leaf, biometry, analysis, USSR.

Introduction

Progress in clonal selection achieved in viticulture of different countries of the world displays great potentials of using the vegetative variability of grape cultivars. Clonal selection has been performed in the Soviet Union since the 1930s (MERZHANIAN and ZELENIN 1932) and, as a result, highly productive plants have been selected for a number of recommended cultivars (GOLODRYGA *et al.* 1975, 1976, 1980; KARAJI and KAISYN 1977; SOLDATOV 1984; TULAYEVA 1986; GAVAKETASHVILI 1986; SERGIYENKO *et al.* 1986).

The USSR State Commission for the Testing of Agricultural Crops has officially registered eight of clones accepted for testing (JENEYEV *et al.* 1984). Presently, research is being performed according to the methodology approved at the First International Symposium for Clonal Selection in Western Germany (1984) and aimed at nearly 20 year testing (SCHÖFFLING 1984).

The complex nature and long duration of clonal selection make it necessary to use scientific achievements to increase the effectiveness of plant selection and to accelerate this process. We have developed a method of clonal selection that allows us to effectively identify genotypes of promising highly productive plants after their phenotypes, the duration of the process of selection thus being substantially reduced.

The method is based on computerized techniques for analysis of complexes of quantitative characters using the method of protein electrophoresis. The method includes two new elements: multi-stage selection for productivity and selection of highly productive clones based on a complex of characters (ZHIVOTOVSKY *et al.* 1984).

Genetic improvement of a cultivar is more effective and profitable when the method of multi-stage selection is used. This method should be used to establish basic vineyards that include representatives of all positive clones and clone stock nurseries consisting of the best clones that have been propagated.

Multi-stage selection of the best plants of a cultivar is carried out during 4 or 5 years in the same vineyard, stock nursery or stock nursery of primary selection. The process works as follows: In the first year, 50 % of the best symptomless plants with regard to a complex of desirable characters will be selected. This is the first stage of selection. In the second year, 50 % of the plants selected in the first year (or 25 % of the total amount of plants in the planting site) are selected. This is the second stage of selection. In the third year, 50 % of the plants selected in the second year (or 10-12 % of the initial amount of plants) are selected (the third stage of selection). In the fourth year,

Table 1: Variability of quantitative characters in the vegetative progeny at different stages of selection, cv. Aligoté

Characters	Vegetative progeny					
	First stage of selection			Second stage of selection		
	trunk height: 70 cm	trunk height: 120 cm	average	lower part of the terrace	upper part of the terrace	average
Yield per vine, kg	7.47	8.39	7.93	8.58	9.03	8.80
	49.0	41.7	45.4	37.3	34.6	35.9
Sugar, g/100 cm^3	15.3	15.3	15.3	16.9	17.1	17.0
	15.2	12.8	13.0	12.9	12.0	12.4
Increase in growth, m	12.7	13.2	13.0	19.5	19.3	19.4
	48.2	35.6	41.8	31.8	31.1	31.5
Coefficient of fruiting*	1.70	1.67	1.69	1.92	1.95	1.93
	23.0	19.2	21.1	19.8	15.1	17.5
Average weight of bunch, g	124.1	131.4	127.8	171.1	175.0	173.0
	29.0	23.1	26.0	20.9	18.7	19.8
Yield per shoot, g	196.6	202.3	199.5	310.5	329.9	320.2
	37.4	32.3	34.8	31.0	27.0	29.0
Shoot productivity: sugar, g	30.4	29.9	30.2	55.2	57.9	56.5
	37.9	35.3	36.6	31.5	30.2	30.9

* Total of bunches/total of shoots ratio

Upper lines give average values of the characters.

Lower lines give coefficients of variation of the same characters for the five-year period of observation.

50 % of the plants selected in the third year (or 5-6 % of the plants evaluated during the 3 years of selection of the best symptomless plants) are selected (the fourth stage of selection).

Individual records and observations are carried out according to standard ampelographic programs. If virus or other infectious diseases occur, they are registered annually in the adequate vegetation periods based on triple examination of plants sampled. In autumn of the fourth and the fifth years of selection, cuttings are taken from plants selected due to their positive characters. These cuttings are utilized to establish a clone testing site or a basic vineyard and testing for virus carriage is conducted simultaneously.

5-6 % of the plants selected include mutated and modified variations displaying not only high productivity, good quality of fruit, normal vigor and good sanitary condition of vines, but also stabile expression of these desirable characters.

Materials and methods

During 1966-69, the best Aligoté plants were selected from 10,000 vines at the Steppe Experimental Farm of the Institute 'Magarach'. Cuttings were taken from these plants and used to establish a cultivar stock nursery covering the area of 3.5 ha. 3 years after the nursery stock had been established, improving selection was begun to obtain phenotypically stable, healthy and highly productive plants. Cuttings were also taken from these plants and used to establish another own-rooted stock nursery (3 ha, vine spacing of 3.0 x 1.5 m) which contained the vegetative progeny of the first stage of selection. (This own-rooted stock nursery is situated in the central part of the third terrace of Alma River; trunk height of vines is 70 and 120 cm). The following year, 4 years after the cultivar stock nursery had been established, improving selection was undertaken again based on the pooled 2-year yield per vine, and cuttings from the selected plants were prepared. Grafted cuttings (Kober 5 BB used as rootstock) were grown and used to establish another stock nursery consisting of the vegetative progeny of the second stage of selection (6.1 ha, vine spacing of 3.0 x 1.5 m). (The nursery is situated in the lower and upper parts of the same terrace; trunk height of vines is 70 cm).

Results and discussion

Average yield per vine and coefficients of variation are given in Table 1 (1980-84). The sampling size for each of the 4 variants was constant for the 5 years of the experiment (50); the total amount of plants evaluated was 200; the same plants were always examined.

Especially demonstrative was the decrease in the variability of the complex of characters investigated when the pooled coefficient of variation was used, accounting for both the variability of individual characters and the extent of their interrelationship (Zhivotovsky 1980).

For the cultural characters studied, the pooled coefficients of variation for the vegetative progeny of the first and the second stages of selection were 18.3 and 13.9 %, respectively.

It is well known that any controlled selection, the method of multi-stage selection included, results both in an increase in the expression of a desirable character and in a disequilibrium between this very character and the other ones (Moser 1966; Altukhov 1981). That is why we think it is useful to practice clonal selection both for productivity and a complex of other quantitative characters. This approach makes it possible to reveal plants which differ from the remainder of a given population in a number of characters (not only in desirable characters).

In order to do it, one has to analyze not only cultural characters (yield per vine, sugar, increase in growth, average bunch weight, acidity, etc.), but also morphological ones that may not be directly related to productivity (Table 2). Using factorial analysis (Kendall and Stuart 1976), one can reveal the effect of factors influencing the variability of correlating characters and evaluated as main components that prove to be statistically independent (non-correlated). These 'masked' factors that cannot be measured directly seem to reflect the way genetic mechanisms work. One cannot always interpret these mechanisms, while the phenomenological interpretation of the factors is possible.

Such main components were obtained for the two groups of characters (cultural and morphological ones) based on Aligoté plants (Table 3). As far as cultural characters are concerned, they are interpreted as follows:

I: 'yield potential' is determined by pooled contribution of such factors as totals of buds, shoots and bunches per vine, vigor and productivity itself;

II: 'taste index' is determined by the sugar/acidity ratio;

III: 'dry matter' is determined by contents of dry matter in the juice.

It can be seen from Table 3 that the individual variability of the three largest components makes 80-90 % of the total variability of the characters analyzed. Thus, the method of main

Table 2: Values of cv. Aligoté parameters

Parameters	Arithmetic average	Coefficients of variation	symmetry	excess
1. Petiole length, mm	94.9	9.3	0.22	-0.34
2. Leaf length, mm	166.8	6.0	0.37	0.53
3. Leaf width, mm	177.7	7.2	0.63	0.64
4. Midrib vein length, mm	120.8	6.0	-0.32	0.13
5. Upper lateral vein length, mm	109.6	6.2	0.14	0.76
6. Lower lateral vein length, mm	80.8	7.6	-0.40	0.58
7. Distance from leaf centre to upper sinus, mm	85.9	6.3	-0.03	-0.32
8. Distance from leaf centre to lower sinus, mm	70.8	7.3	0.06	0.02
9. Angles °: alpha	50.0	5.4	0.30	0.02
10. beta	46.6	6.2	0.11	-0.32
11. gamma	43.0	7.5	0.35	0.31
12. Total of eyes per vine	36.0	25.9	0.62	0.29
13. Total of shoots per vine	31.2	24.0	0.68	0.97
14. Total of fruiting shoots per vine	28.5	23.5	0.72	0.96
15. Total of bunches per vine	61.7	25.9	0.52	-0.01
16. Yield per vine, kg	9.85	29.0	0.89	0.74
17. Sugar, g/100 cm^3	16.8	13.6	1.03	0.81
18. Titrable acids, g/dm^3	6.4	13.5	-0.03	1.22
19. Increase in growth, m	22.3	27.2	0.66	-0.10
20. Germinated eyes, %	95.6	3.7	-1.09	1.92
21. Fruiting shoots, %	91.4	7.1	-0.38	-0.68
22. Coefficient of fruiting	1.97	11.0	-0.28	-0.99
23. Coefficient of fruitfulness	2.16	8.4	-0.00	-0.46
24. Bunch weight, g	162.4	17.8	-0.46	-0.19
25. Yield per shoot, g	321.0	24.2	0.73	1.55
26. Shoot productivity: sugar, g	54.3	29.5	0.54	0.68

components makes it possible to reduce the multidimensional space of 8 or 11 characters mostly to the tri-dimensional space. The results of the analysis can then be plotted in the plane of the axes of the respective pairs of the components: I and II, I and III, II and III. In this case, the differences among the plants are much more pronounced than when the plants are compared based on the initial characters. Yet, one must admit that this approach is not always suitable as it is based on the visual estimate of deviations and because of the fact that using but the three main components results in the loss of certain information.

Taking into account the disadvantages of the method of main components, Zhivotovsky (1984) developed a statistic method for estimation of index do, the index of typicity in this paper.

Table 3: Influence of the main components on the variability of quantitative characters, cv. Aligoté

Years	Components, %			
	I	II	III	Total
	8 cultural characters			
1980*	68.1	14.7	7.8	90.6
1981	65.9	12.8	12.0	90.7
1982	71.5	10.8	9.0	91.3
1983	57.6	14.3	13.6	85.5
1984	55.0	20.2	12.3	87.5
	11 morphological characters			
1981	64.5	15.6	6.8	86.9
1982	59.2	14.8	9.9	83.9
1983	56.2	16.5	6.7	79.4
1984	60.4	11.5	9.4	81.3

* Titrable acidity was not taken into account.

The index of typicity is convenient for comparing 'distances' estimated after different sets of characters (Table 4), the 'distance' of a plant from the 'centre' of the distribution of characters in a given population being a measure of its typicity compared to the conventional plant with the average values of characters.

As it is seen from Table 4, one can reveal plants with maximum values of the index of typicity do (plants 36, 35, etc.) and those with minimum values of the index of typicity (plants 18, 28, etc.). Because each of these groups includes plants with different productivity, only the plants with the highest shoot productivity were taken for propagation (Troshin *et al.* 1976). Such are vines 35 and 22 placed into the group of 'extreme' plants and vines 18 and 28 placed into the group of 'central' plants. Genetic differences among the plants were established using the method of protein electrophoresis (Klochneva *et al.* 1989).

Thus, in order to maintain quality of Aligoté cultivar, it is necessary to propagate plants 18 and 28, while to improve the cultivar, plants 35 and 22 have to be propagated, so that one plant could be left for each direction of selection and those of smaller value could be rejected to provide the intraclonal stability in the vegetative progeny. Moreover, the plant taken as typical for a cultivar to be improved should be used as control for the plants that were selected in order to increase productivity of a cultivar.

It is necessary to emphasize that the new clones (35 and 22) do have certain specialities in their integral characters, both of them being highly productive, with an optimum sugar/acidity ratio. The sugar/acidity ratio for plants 35, 22, 18 and 23 in 1984 was 2.47, 2.97, 2.76 and 2.32, respectively.

Conclusions

The method of selecting highly productive clones results in a 3 to 4-fold decrease in the duration of clonal selection in grapevine and a substantial reduction in the size of the experiment. Thus, the process can be considered sufficiently effective and profitable (3,100 roubles/ha).

Table 4: Differentiation of cv. Aligoté variations depending on the index of typicity

Parameters	Phenotypes									
	"extreme"					"central"				
	11 morphological characters									
do, %	148	122	116	113	112	73	75	76	80	80
Numbers of vines	36	4	22	20	9	24	14	16	28	25
Shoot productivity: sugar, g	43	66	82	60	49	60	50	61	61	68
	8 cultural characters									
do, %	134	130	129	122	118	65	68	72	73	75
Numbers of vines	35	45	6	19	22	18	20	34	26	7
Shoot productivity: sugar, g	71	48	60	41	82	56	60	56	52	52
	Pooled									
do, %	122	121	116	111	102	76	78	80	82	82
Numbers of vines	36	35	45	47	22	18	28	24	34	16
Shoot productivity: sugar, g	43	71	48	54	82	56	61	60	56	61

The new method of selection for highly productive clones is being tested now at the Steppe Experimental Farm of the Institute, using Aligoté planting materials. Stock nurseries covering 146 ha have been established. 50 % of these vineyards are currently bearing.

Clonal grape selection with recommended cultivars is underway in the West Premountainous Region of the Crimea (Riesling planting materials) and in the southern part of the Crimea (planting materials White and Rosy Muscats, Alma and Sersial).

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