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Correlation, regression and path-coefficient analysis of physiological parameters associated with berry ripening in grape (*Vitis vinifera*)

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ABSTRACT

An experiment was conducted during 1990–93 to study genetic variability, correlation and direct and indirect effects of physiological parameters associated with crop duration in 15 genetically diverse genotypes of grape (*Vitis vinifera* L.). The genotypes showed significant difference for total duration of crop (from pruning to berry ripening), leaf area, leaf-area duration, shoot length, number of leaves at 75 days after pruning, leaf-expansion rate, chlorophyll content and stomatal density. It indicated that the magnitude of variability for all the parameters was very high. Shoot length at 75 days after pruning and leaf-area duration were found the most important physiological characters, contributing to the variation in duration of crop growth. Heritability and genetic advance were high for shoot length at 75 days after pruning.

Breeding for early maturity is one of the main objectives of crop improvement in countries, where grape (*Vitis vinifera* L.) is mainly grown for table purpose (Olmo 1980). It assumes prime importance in north India, where the period available between spring and monsoon being short for berry ripening, and rain during ripening causes extensive damage to the crop. Recently physiological parameters are being used as markers for early evaluation of hybrid progenies (Majumder and Sharma 1990). Information on the genetic basis of such characters associated with early-berry maturity in grape helps the breeders in selecting parental genotypes for hybridization to evolve early-maturing cultivars as well as to screen the hybrid progenies in seedling stage for early-berry maturity (Jindal 1990). Therefore the present study was undertaken to evaluate genetic variability and to determine correlation and direct and indirect effects of physiological parameters associated with crop duration in grape.

MATERIALS AND METHODS

Fifteen genetically diverse cultivars of grape (trained on head system) were grown during 1990–1993 at New Delhi. The genotypes included 10 cultivars, viz 'Julesky Muscat', 'Pearl of Csaba', 'Beauty Seedless', 'New Perlette', 'Madelein Angevine', 'Gold', 'Pusa Seedless', 'Hur', 'Fakhri' and 'Tas', and 5 hybrids, viz 'Baunqui Abyad' x 'Beauty Seedless 71-50', 'Hur' x 'Beauty Seedless 70-56', 'Hur' x 'Beauty Seedless 76-64',

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'Hur' x 'Cardinal 76-1' and 'Madelein Angevine' x 'Rubired 76-2'. All the plants were pruned uniformly on the same date every year, retaining 12 canes/plant. Observations were recorded on 3 random plants on total duration of crop growth (from pruning to berry ripening), leaf area, leaf-area duration, shoot length and number of leaves at 75 days after pruning (the minimum number of days required from pruning to flowering), leaf expansion rate, chlorophyll content and stomatal density. Correlation, regression and path-coefficient analysis were carried out as per the procedure of Robinson *et al.* (1951), Gomez and Gomez (1984) and Dewey and Lu (1959) respectively. The heritability and genetic advance of the parameters which contributed significantly to the variation in duration of crop growth were also worked out (Allard 1960).

RESULTS AND DISCUSSION

The genotypes showed significant difference for all the characters studied, indicating high magnitude of variability for all the characters (Table 1). The duration of crop growth (from pruning to ripening) ranged from 129.67 days ('Julesky Muscat') to 176.00 days ('Tas').

Shoot length and number of leaves/shoot recorded at 75 days after pruning varied from 5.0 cm ('Hur') to 72.49 cm ('Pearl of Csaba') and 3.97 ('Hur') to 31.93 ('Pearl of Csaba') respectively. The shoot length at 75 days after pruning showed very high negative correlation ($r = -0.879$) with total duration of crop growth (Table 2). It indicated that early-bud burst helped the early-ripening genotypes to attain sufficient shoot growth before flowering, whereas late-maturing cultivars showed the less shoot growth at the time of flowering. The leaves/shoot at 75 days after pruning also showed similar trend ($r = 0.858$). However, the leaves/shoot at the time of flowering did not show significant correlation with the duration of crop growth. It indicates that the leaves/shoot in the early stages before flowering are more important for early maturity than the leaves at flowering stage. At the time of flowering the leaf production per shoot might have passed the optimum level of 13 matured leaves/shoot, as reported earlier by Kingston and Epenhuijesen (1989), leaving the character non-significant. Though the leaves/shoot at the time of flowering was not significantly correlated with duration of crop growth, leaf area/shoot at flowering showed significant correlation. This may be due to the variation in leaf size among the genotypes, stage of maturity of leaves and the parasitic nature of young leaves for metabolites and their competition with young berries, causing delay in berry development (Martinez 1982).

Leaf-area duration, leaf-expansion rate and chlorophyll content also had significant correlation with duration of crop growth.

Data on leaf production and leaf area indicated that early development of leaf area is essential for early ripening of berries. The result confirms the findings of Schrader (1932) and Hamilton (1953). Step-wise regression analysis of physiological characters with duration of crop growth as dependent variable indicated that leaf-chlorophyll content, leaf-area duration and shoot length at 75 days after pruning regressed significantly with duration of crop growth. Shoot length at 75 days after pruning, followed by leaf-area duration were found most important characters contributing to the variation in duration of crop growth. The regression analysis showed that the leaves/shoot at 75 days after pruning contributed only 0.95% of the variation to duration of the crop growth, though it was significantly correlated. This may be due to the nullification of its positive direct effect on duration of crop growth by the negative in-

Table 1 Variability in physiological characters of grape genotypes

Genotype	Shoot length (cm) at 75 days*	Leaves/ shoot at 75 days*	Leaves/ shoot at flowering	Leaf area/ shoot at flowering (cm^2)	Leaf-area duration/ shoot	Leaf-expansion rate (cm/day)		Leaf chlorophyll (mg/g fresh weight)	Stomatal density (no./mm^2)	Total duration of crop growth (days)
						Length-wise	Width-wise			
'Julesky Muscat'	70.07	27.11	31.77	1 273.56	84 888.09	0.13	0.24	3.22	169.00	129.67
'Pearl of Csaba'	72.49	31.93	37.33	2 028.61	127 785.60	0.18	0.26	3.29	207.67	133.33
'Beauty Seedless'	65.00	21.22	50.55	2 188.70	163 953.60	0.18	0.27	3.36	190.00	146.67
'New Perlette'	31.03	9.00	40.13	3 640.31	231 837.70	0.25	0.33	3.11	183.67	153.33
'Madelein Angevine'	15.80	7.33	23.72	1 603.53	114 607.70	0.20	0.36	3.03	269.67	154.67
'Mendelein Angevine' x 'Rubired 76-2'	14.27	4.00	11.33	1 649.13	192 357.40	0.26	0.33	2.65	210.67	166.67
'Baunqui Abyad' x 'Beauty Seedless 71-50'	20.10	5.33	26.73	4 211.20	371 727.50	0.27	0.36	3.15	173.00	156.33
'Gold'	12.39	5.33	25.20	2 324.24	311 300.00	0.40	0.47	3.12	257.00	162.70
'Hur' x 'Beauty Seedless 70-56'	19.15	8.87	34.83	2 964.93	250 878.80	0.17	0.23	3.19	211.33	155.33
'Hur' x 'Beauty Seedless 76-64'	17.87	7.17	24.17	2 412.52	290 278.00	0.25	0.36	3.26	192.67	161.67
'Hur' x 'Cardinal 76-1'	15.30	8.83	36.00	2 241.31	228 077.20	0.18	0.19	3.15	187.33	155.67
'Pusa Seedless'	23.00	10.33	23.50	2 725.66	261 356.40	0.19	0.28	2.52	175.33	162.00
'Fakhri'	7.63	5.39	29.17	3 831.24	473 751.30	0.36	0.50	2.86	204.67	175.33
'Hur'	5.00	3.97	32.18	3 771.05	314 512.40	0.22	0.25	2.97	218.33	174.33
'Tas'	6.80	5.17	42.67	2 988.83	413 956.90	0.32	0.36	2.79	219.33	176.00
CD (P = 0.01)	*7.5*	*3.5*	*2.83*	*479.94*	*24 406.78*	*0.02*	*0.03*	*0.16*	*9.66*	*2.20*

*Days after pruning

Table 2 Correlation and regression analysis of physiological characters with duration of crop growth as dependent variable in grape

Character	Correlation coefficient (r)		Adjusted r^2	Contribution of character to r^2	Contribution to variation in duration of crop growth (%)
	Phenotypic	Genotypic			
Shoot length at 75 days*	—0.879	—0.913	0.7719	0.7719	77.19
Leaves/shoot at 75 days*	—0.858	—0.891	0.7816	0.0095	0.95
Leaf-area duration	0.792	0.802	0.8545	0.0729	7.29
Leaf-expansion rate (length-wise)	0.657	0.677	0.8553	0.0008	0.08
Leaf chlorophyll	—0.587	—0.643	0.8848	0.0295	2.95
Leaf area/shoot at flowering	0.507	0.537	0.8870	0.0022	0.22
Leaf-expansion rate (width-wise)	0.472	0.494	0.8910	0.0040	0.40
Stomatal density	0.302	0.307	0.9061	0.0151	1.51
Leaves/shoot at flowering	0.182	0.191			
Table value	0.393				

*Days after pruning

Table 3 Direct and indirect effects of physiological characters on duration of crop growth at genotypic level in grape genotypes

Character	Leaf area/shoot at flowering	Leaf-area duration	Leaves/shoot at 75 days*	Shoot length at 75 days*	Stomatal density	Leaf-expansion rate†	Leaf-expansion rate$^{\Psi}$	Leaf chlorophyll	Genotypic correlation with growth duration
Leaf area/shoot at flowering	0.686	—1.925	—2.619	3.398	0.302	0.562	0.181	—0.047	0.537
Leaf-area duration	0.542	—2.437	—3.493	4.936	—0.012	1.012	0.380	—0.127	0.802
Leaves/shoot at 75 days*	0.342	1.622	5.249	—6.964	0.457	—0.789	—0.307	0.182	—0.891
Shoot length at 75 days*	—0.327	1.690	5.134	—7.119	0.562	—0.776	—0.279	0.202	—0.913
Stomatal density	—0.144	—0.020	—1.672	2.787	—1.435	0.540	0.276	—0.026	0.307
Leaf-expansion rate†	0.294	—1.878	—3.152	4.206	—0.590	1.313	0.591	—0.105	0.677
Leaf-expansion rate$^{\Psi}$	0.189	—1.412	—2.453	3.002	—0.603	1.182	0.656	—0.088	0.494
Leaf chlorophyll	—0.090	0.859	2.654	—3.984	0.102	—0.384	—0.161	—0.360	—0.643
Residual mean			0.473						

*Days after pruning; †length-wise, $^{\Psi}$width-wise

Table 4 Coefficient of variation, heritability and genetic advance of characters correlated with crop-growth duration of grape

Character	Coefficient of variation		Heritability (broad sense)	Genetic advance (GA)	GA (% of mean)
	Phenotypic	Genotypic			
Shoot length at 75 days*	88.801	87.074	0.961	46.42	175.90
Leaf-area duration	43.791	43.398	0.982	57.70	0.01
Leaf chlorophyll	8.407	7.761	0.852	0.44	14.76
Crop-growth duration	8.081	8.639	0.990	27.90	17.70

*Days after pruning

direct effect through shoot length at 75 days after pruning (Table 3).

The leaf area/shoot at flowering stage showed strong direct positive effect on total duration of crop growth. Shoot length at 75 days after pruning had strong negative direct effect on total duration of crop growth; but it had indirect positive effect through leaves/shoot at 75 days after pruning. Leaf-area duration had a direct effect of—2.437 and it acted indirectly through leaf number at 75 days after pruning. The residual effect (0.473), associated with the value of standard partial regression coefficient, indicated the contribution of certain other characters.

Genotypic correlation coefficients were higher than phenotypic ones for all the characters (Table 2). There was association between various characters studied and the phenotypic expression of correlation was reduced under the influence of environment. The genotypic coefficient of variation was the highest for shoot length at 75 days after pruning, followed by leaf-area duration (Table 4). Genotypic coefficient of variation together with heritability estimates would give the estimates of genetic advance to be expected from the selection. In our study shoot length at 75 days after pruning and leaf-area duration showed high heritability, which are helpful in making selection of superior genotype on the basis of phenotypic expression of quantitative traits. The shoot length at 75 days after pruning showed high heritability which as well as high genetic advance (as % of mean) indicating that most of the variation in the character is additive in nature.

It was concluded that shoot length at 75 days after pruning was the most suitable character for selection of early-ripening genotypes.

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