



## Path analysis of yield and quality determinations in Thompson Seedless grape (*Vitis vinifera*) and its clones

S D SHIKHAMANY<sup>1</sup>, SWAPNIL V BORADE<sup>2</sup>, SANJAY K JEUGHALE<sup>3</sup> and SURYAKANT Y PATIL<sup>4</sup>

Maharashtra State Grape Growers Association, Manjri Farm Post, Pune 411 032

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### ABSTRACT

Attempts were made to delineate the correlation coefficients of the vine, cluster and berry parameters with yield and quality in to direct and indirect effects in Thompson Seedless grape (*Vitis vinifera* L.) and its clones, namely Tas-A-Ganesh and 2A clone by Path Coefficient Analysis. Yield was influenced most, directly by cluster weight in Thompson Seedless, while by canes/vine in Tas-A-Ganesh; indirectly by berry diameter via cluster weight in the former variety, while by canes/vine via berries/cluster in the latter. When the negative effects on yield were considered, the direct effect of berries/cluster was highest in Thompson Seedless, while it was of berries/cluster in Tas-A-Ganesh. Among the indirect negative effects, cluster weight through berry diameter was highest in Thompson seedless, but berries/cluster through canes/vine in Tas-A-Ganesh. All the parameters included in the study could determine the yield in 2A clone by only 1.0 per cent, as the residual effect was 0.99. The corresponding residual values were 0.506 for Thompson Seedless and 0.516 for Tas-A- Ganesh.

**Key words:** Grape, Path analysis , Quality, Yield

Mean cluster weight had direct positive effect on the total soluble solids content (TSS) of berries in Thompson Seedless as well as Tas-A-Ganesh, but cane diameter in 2A clone of grapes (*Vitis vinifera* L.). Cluster weight also had indirect positive effect on TSS content in the former two varieties but via different parameters, viz. berry diameter in Thompson Seedless but yield/vine in Tas-A-Ganesh. Indirect positive effect of berry diameter via cane diameter was highest in 2A clone. While yield/vine had direct negative effect on the TSS content in Thompson Seedless, clusters/cane and berry diameter respectively in Tas-A-Ganesh and 2A clone. Highest indirect negative effect on TSS was of clusters/cane via yield/vine. It was of berry diameter via clusters/cane in Tas-A-Ganesh and cluster weight via clusters/cane in 2A clone. Residual effect of the parameters included in the study was least in Thompson Seedless (0.314) and highest in Tas-A-Ganesh (0.883).

These results suggest the differential approach in managing the vine growth, cluster and berry characters for improving the yield/vine and TSS content of berries in different varieties through appropriate viticultural practices. Yield in grapevines is a function of the number of clusters/vine and the mean weight of cluster. While the former parameter is determined by the number of canes/vine

and the clusters/cane, the latter is determined by the cane diameter, berries/cluster and berry diameter (Chadha and Shikhamany 1999). Similarly, crop load/vine, berry size and the carbohydrate reserves (source) in the cane, apart from the temperature regime during berry ripening determine the quality as judged by the total soluble solids content of berries (Coombe 1992). In a correlation study, yield/vine was determined by a number of vine and cluster characters in Thompson Seedless grapes and its clones, namely Tas-A-Ganesh and 2A clone. The relative contribution of these characters to yield was different in different varieties (Shikhamany *et al.* 2015). These characters were also inter-related (Shikhamany 1983). Correlations, without any doubt, helped in determining the components of complex traits like yield and quality, but failed to provide a clear picture of the direct and indirect effects of each of the component characters towards the corresponding trait. Hence, path coefficient analysis, the standardized partial regression analysis was used to partition the correlation coefficients into direct and indirect effects. This technique was employed for identifying the crucial characters contributing to commercially important traits in a number of crops (Bhatt 1973, Singh *et al.* 1975, Shikhamany *et al.* 1978). The present study deals with path coefficient analysis to elucidate the variation in direct and indirect contribution of vine and cluster characters to yield and quality (total soluble solids content of berries) in Thompson Seedless, Tas-A-Ganesh and 2A clones of grapes. Information generated from this study will help to identify the crucial characters and evolve

<sup>1</sup>Chairman (e mail: sdshikhamany @gmail.com), Research Advisory Committee, MRDBS, Pune, Scientist (e mail: mrdbs@ gmail.com).

variety-wise viticulture practices to manage them.

**MATERIALS AND METHODS**

The present investigations were carried out in growers' vineyards around Nashik, Maharashtra on Thompson Seedless, Tas-A-Ganesh and 2A Clone during 2014-15 cropping season. Tas-A-Ganesh is a bud sport of Thompson Seedless identified by a progressive grower, Late Vasantrao Arve, in his vineyard at Borgaon in Sangli district, Maharashtra, while 2A clone was developed at Kearney Experimental Station, UC Davis, California, USA. Sixty vines were selected for each variety as detailed below.

All the selected vines were in the age group of 6-7 years, grafted on Dogridge rootstock and trained to extended Y training system. They were grown under similar

Variety	Village/location	No. of vines
Thompson Seedless	Mohadi	30
	Pimpalgaon	30
Tas-A-Ganesh	Palkhed	30
	Kothure	30
2A Clone	Khedgaon	60

agro-climatic conditions and subjected to similar cultural practices. Vines were pruned for fruiting in the second week of October 2014. Five clusters were collected from each vine on the 140<sup>th</sup> day after pruning for recording observations on the cluster and berry characters as well as TSS content of berries.

The following observations were recorded on five canes tagged in each selected vine.

*Canes/vine:* Recorded number of canes left on the vine after forward pruning and cane removal.

*Cane diameter:* Diameter at the middle length of each cane was measured and the average diameter was calculated.

*Yield/vine:* Yield of each selected vine was recorded in kg at harvest.

*Clusters/vine:* Number of clusters in each selected vine was counted and recorded at harvest.

*Clusters/cane:* Derived by dividing the number of clusters by the number of canes in each selected vine.

*Cluster weight:* Calculated mean weight of five clusters

selected at random from each vine.

*Berries/cluster:* Average number of berries over five selected clusters was recorded.

*Berry diameter (mm):* Average diameter of 25 berries measured at middle length of the berry using callipers.

*Total soluble solids content:* Per cent soluble solids contents was determined in the juice extracted by crushing the 25 selected berries using hand refractometer.

*Statistical analysis:* Path coefficients were determined by the computer based method, evolved by Akintude (2012) using the Microsoft Office Excel. The residual effects on account of the factors which are not included in the present study were also worked out.

**RESULTS AND DISCUSSION**

*Path Analysis of yield*

According to Akintude (2012), if the correlation between the casual factor (yield attribute) and the effect (yield/vine) is almost equal to its direct effect, then correlation explains the true relationship. Such situation was not found with the relationship of any yield attribute with yield/vine in Thompson Seedless (Table 1). It implies that the true relationship of any attribute was vitiated by the relationship of other attributes with yield.

Correlation of cane diameter with yield/vine was positive and its direct effect was also positive. But the coefficient of correlation was more than the direct effect. This indicates that the indirect positive effects are more than the indirect negative effects and the former have supplemented to the relationship of cane diameter with yield. The indirect positive effect of cane diameter through the number of clusters/cane was highest. On the other hand, clusters/cane had negative correlation with yield. Its direct effect was also negative. But the correlation coefficient was more than the direct effect. In this case, the indirect negative effects through other attributes have enhanced the negative relationship of clusters/cane with yield. The greatest indirect negative effect was through cane diameter followed by through the mean weight of cluster.

The highest positive direct effect on yield was of cluster weight followed by cane diameter in Thompson Seedless. While the indirect negative effect of cluster weight through

Table 1 Path coefficient analysis of yield/vine in Thompson Seedless

Independent variable	Direct effect (P)	Indirect effect via (P × r)						Correlation coefficient (r)
		Canes/vine	Cane diameter	Clusters/cane	Cluster weight	Berries/cluster	Berry diameter	
Canes/vine	0.1776	-	- 0.0344	0.0863	- 0.0666	- 0.1509	0.0019	0.0140
Cane diameter	0.3697	- 0.0165	-	0.1148	- 0.0350	- 0.0063	0.0525	0.4792
Clusters/cane	-0.2853	- 0.0537	- 0.1487	-	- 0.1063	- 0.0015	0.0626	-0.5330
Cluster weight	0.4726	- 0.0250	- 0.0274	0.0642	-	0.0266	- 0.2188	0.2922
Berries/cluster	-0.3752	0.0714	0.0062	- 0.0011	- 0.0336	-	0.1533	-0.1790
Berry diameter	-0.3404	- 0.0010	- 0.0571	0.0525	0.3038	0.1690	-	0.1269

Residual effect (Px) = 0.5062

berry diameter was the highest, the indirect positive effect of cane diameter through clusters/cane was also highest. The highest direct negative effect was of the number of berries/cluster. The indirect positive effect of berries/cluster through berry diameter was the highest. Berry diameter correlated positively with yield, but its direct effect was negative and more than the correlation coefficient. This was because of the indirect positive effect of berry diameter through cluster weight and berries/cluster. However, the residual effect in Thompson Seedless was 0.5062 (Table 1), indicating that the yield attributes included in the present study could account for only 49.38 per cent variation in yield and the rest was accounted for by the factors not included.

Correlation coefficient of the cluster weight with yield/vine was almost equal to its direct effect in Tas-A-Ganesh (Table 2). It indicates that the interference of the other attributes with its effect on yield was negligible in this variety. Correlation of canes/vine with yield/vine was positive and its direct effect was also positive. But the direct effect was less than the correlation coefficient. This was because of the indirect positive effects of canes/vine through cluster weight, berries/cluster and berry diameter, of which the effect through berries/cluster was highest. Similarly, correlation coefficient and the direct effect of berry diameter on yield /vine were positive in Tas-A-Ganesh, but the direct effect was less than the correlation coefficient. The indirect positive effects of berry diameter through berries/cluster and canes/vine enhanced the correlation of berry diameter with yield. On the other hand, berries/cluster had negative correlation with yield. Its direct effect was also

negative. But the correlation coefficient was more than the direct effect. In this case, the greatest indirect negative effect was through canes/vine followed by through berry diameter. The highest positive direct effect on yield was of canes/vine followed by berry diameter in Tas-A-Ganesh. Residual effect in TAG was 0.5159 (Table 2), indicating that all the yield attributes included in this study could account for only 48.41 per cent of the variation in yield.

Residual effect on yield/vine in 2A clone was very high (0.990). As a result, the direct or indirect effects whether positive or negative were very meagre (Table 3). Hence, in view of the limited relevance of path analysis of yield in this variety, the results are not discussed.

Among the direct positive effects, cluster weight ranked first followed by cane diameter in Thompson Seedless, whereas canes/vine and berry diameter ranked first and second in Tas-A-Ganesh. While indirect positive effect of berry diameter via cluster weight was the highest in Thompson Seedless, it was canes/vine via berries/cluster in Tas-A-Ganesh. When the negative effects on yield were considered, the direct effect of berries/cluster was highest followed by berry diameter in Thompson Seedless, while it was of berries/cluster followed by cluster weight in Tas-A-Ganesh. Among the indirect negative effects, it was cluster weight through berry diameter that was highest in Thompson seedless, but berries/cluster through canes/vine in Tas-A-Ganesh.

Strategies to improve yield based on the path analysis results include, the cultural practices that promote the yield attribute that has direct positive effect and that attribute

Table 2 Path coefficient analysis of yield/vine in Tas-A-Ganesh

Independent variable	Direct effect (P)	Indirect effect via (P × r)						Correlation coefficient (r)
		Canes/vine	Cane diameter	Clusters/cane	Cluster weight	Berries/cluster	Berry diameter	
Canes/vine	0.3301	-	-0.0062	-0.0018	0.0230	0.1412	0.0375	0.5239
Cane diameter	0.1517	-0.0134	-	-0.0061	-0.0097	-0.0134	0.0140	0.1232
Clusters/cane	-0.0520	0.0116	0.0179	-	-0.0092	0.0512	0.0869	0.1064
Cluster weight	-0.2057	-0.0370	0.0071	-0.0023	-	-0.0044	0.0340	-0.2083
Berries/cluster	-0.2902	-0.1607	0.0070	0.0092	-0.0031	-	-0.0654	-0.5031
Berry diameter	0.2952	0.0420	0.0072	-0.0153	-0.0237	0.0642	-	0.3696

Residual effect (Px) = 0.5159

Table 3 Path coefficient analysis of yield/vine in 2A Clone

Independent variable	Direct effect (P)	Indirect effect via (P × r)						Correlation coefficient (r)
		Canes/vine	Cane diameter	Clusters/cane	Cluster weight	Berries/cluster	Berry diameter	
Canes/vine	-0.0633	-	-0.0005	-0.0032	0.0002	-0.0008	-0.0027	-0.0703
Cane diameter	-0.0090	-0.0034	-	-0.0082	0.0016	-0.0012	0.0070	-0.0132
Clusters/cane	-0.0491	-0.0041	-0.0015	-	-0.0023	-0.0012	0.0004	-0.0579
Cluster weight	0.0165	-0.0008	-0.0009	0.0069	-	-0.0042	0.0069	0.0245
Berries/cluster	-0.016	-0.0031	-0.0007	-0.0038	0.0043	-	-0.0202	-0.0394
Berry diameter	0.033	0.0051	-0.0019	-0.0006	0.0035	0.0098	-	0.0488

Residual effect (Px) = 0.990

through which the indirect positive effect is highest and simultaneously suppress the parameter that has direct negative effect and that attribute through which the indirect negative effect is highest. Based on this strategy, viticulture practices to increase the cluster weight and number of berries/cluster with less emphasis on increasing the berry diameter and increase the cane diameter and the number of clusters/cane can be recommended to increase the yield in Thompson Seedless. If increased berry diameter is essential, number of berries/cluster needs to be reduced. Whereas, cultural practices that increase the number of canes/vine and produce smaller clusters with less number of bold berries seemed appropriate for increasing yield in Tas-A-Ganesh.

*Path analysis of quality*

According to Winkler (1932), the total soluble solids (TSS) content measured as degree Brix (<sup>o</sup>B) was used to denote the quality of table grapes, since it had the high degree of correlation with palatability of grapes. Correlation coefficient of yield/vine with TSS content was almost equal to its direct effect in Thompson Seedless (Table 4). It indicates the true relationship of yield/vine with TSS content of berries. Correlation coefficient was more than the direct effect in the relationship of clusters/cane and cane diameter with TSS content implying the supplementation by the indirect negative effects through other quality attributes. Although cluster weight had positive direct effect on the TSS content, its correlation was negative because of its indirect negative effects through yield/vine and clusters/cane. Highest negative direct effect on TSS content was of yield/vine. Clusters/cane and cane diameter although

had less direct negative effect, their negative correlations with TSS content were enhanced with the indirect negative effects through yield/vine. However, the residual effect in Thompson Seedless was 0.3137 (Table 4), indicating that the attributes of TSS included in the present study could account for 68.63 per cent variation in TSS content and the rest was accounted for by the factors not included.

In Tas-A-Ganesh variety, correlation of clusters/cane with TSS content was negative. Its direct effect was also negative. The direct effect was almost equal to the correlation coefficient, implying that the relationship between these two variables is true and none of the quality attributes studied have influenced it (Table 5). Correlation coefficient of yield/vine was more than its direct effect on TSS content. The indirect negative effect of yield/vine through the number of clusters/cane has supplemented to its direct effect. Although the direct effect of berry diameter on TSS content was positive, its correlation was negative and more. This was due to the indirect negative effect of berry diameter through clusters/cane.

The highest positive direct effect on TSS content was of cluster weight, supplemented by the indirect positive effect through yield/vine in Tas-A-Ganesh. However the combined effect was very meagre (Table 5). On the other hand, the highest direct negative effect was of clusters/cane. As stated earlier, none of the indirect effects, either positive or negative, through other attributes of TSS could influence it. Residual effect in Tas-A-Ganesh was 0.883 (Table 5), indicating that the attributes of TSS included in the present study could determine the TSS by 11.7 per cent only and the rest was determined by the factors not included.

Table 4 Path coefficient analysis of TSS content in Thompson Seedless

Independent variable	Direct effect (P)	Indirect effect via (P × r)					Correlation coefficient (r)
		Yield/vine	Clusters/cane	Cane diameter	Cluster weight	Berry diameter	
Yield/vine	-0.6544	-	-0.0935	-0.0714	0.0305	0.0093	-0.7794
Clusters/cane	-0.1217	-0.5026	-	-0.0758	-0.0153	-0.0141	-0.7295
Cane diameter	-0.1489	-0.3136	-0.0619	-	-0.0077	-0.0113	-0.5435
Cluster weight	0.1044	-0.1912	-0.1463	0.0110	-	0.0473	-0.1748
Berry diameter	0.0735	-0.0830	0.0234	0.0230	0.0671	-	0.1040

Residual effect (Px) = 0.3137

Table 5 Path coefficient analysis of TSS content in Tas-A-Ganesh

Independent variable	Direct effect (P)	Indirect effect via (P × r)					Correlation coefficient (r)
		Yield/vine	Clusters/cane	Cane diameter	Cluster weight	Berry diameter	
Yield/vine	-0.1867	-	-0.0253	-0.0067	-0.0196	0.0010	-0.2373
Clusters/cane	-0.2378	-0.0199	-	-0.0065	0.0042	0.0079	-0.2522
Cane diameter	-0.0546	-0.0230	-0.0281	-	0.0044	0.0013	-0.1000
Cluster weight	0.0940	0.0389	-0.0107	-0.0026	-	0.0031	0.1227
Berry diameter	0.0268	-0.0690	-0.0700	-0.0026	0.0108	-	-0.1041

Residual effect (Px) = 0.883

Table 6 Path coefficient analysis of TSS content in 2A clone

Independent variable	Direct effect (P)	Indirect effect via(P x r)					Correlation coefficient (r)
		Yield/vine	Clusters/cane	Cane diameter	Cluster weight	Berry diameter	
Yield/vine	-0.2012	-	-0.0080	-0.0026	0.0011	-0.0259	-0.2365
Clusters/cane	0.1374	0.0116	-	0.0329	-0.0065	-0.0069	0.1688
Cane diameter	0.1969	0.0027	0.0229	-	0.0045	-0.1121	0.1152
Cluster weight	0.0462	-0.0049	-0.1416	0.0190	-	-0.1109	-0.1922
Berry diameter	-0.5299	-0.0098	0.0018	0.0416	0.0097	-	-0.4864

Residual effect (Px) = 0.6520

Yield/vine correlated negatively with TSS content in 2A clone. Its direct effect on TSS content was also negative. But correlation coefficient was more than the direct effect. The indirect negative effect of yield/vine through berry diameter supplemented to its direct effect (Table 6). On the other hand, clusters/cane correlated positively with TSS content. Its direct effect was also positive. The indirect positive effect of clusters/cane through cane diameter enhanced the degree of correlation. The positive direct effect of cane diameter on TSS content was reduced by its indirect negative effect through berry diameter, resulting in the reduced correlation coefficient. Contrarily, the direct negative effect of berry diameter on TSS content was reduced by its indirect positive effect through cane diameter, resulting in the reduced correlation coefficient. While the direct effect of cluster weight on TSS was positive, its correlation was negative. It was mainly due to the indirect negative effect of cluster weight through clusters/cane. However, the residual effect in 2A clone was 0.652 (Table 6) indicating that the attributes of TSS included in the present study could account for only 34.8 per cent variation in the TSS and the rest was accounted for by the factors not included.

Based on the direct and indirect effects of its attributes on TSS content of berries, viticulture practices to limit the cane thickness, number of clusters/cane and yield/vine are suggested for obtaining grapes with high TSS content. Whereas limiting the yield through limiting the number of clusters/cane in Tas-A-Ganesh. Increasing the berry diameter, thereby the cluster weight will not hamper the TSS content in this variety. Cultural practices aimed at limiting the berry diameter and the number of clusters/cane, thereby the yield seem to be appropriate to increase TSS content in 2A clone. Number of clusters/cane can be increased, if cane diameter is more in this variety. Results of the study also suggested the need for determining the optimum number of clusters/cane with reference to cane diameter, berry diameter, cluster weight for a desired level of TSS content for table and raisin purposes, separately for these varieties.

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