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Variation in the Contribution of Cluster and Berry Characters to Quality in Thompson Seedless Grape and its Clones

S. D. Shikhamany*, Swapnil V. Borade, Sanjay K. Jeughale and Suryakant Y. Patil
R & D Division, Maharashtra State Grape Growers' Association, Manjri Farm Post, Pune-411 032, India
*Corresponding author email id: sdshikhamany@gmail.com

Abstract – **Investigations were carried out to elucidate the variation in the relationship of cluster and berry characters with berry quality, identify the crucial characters contributing to quality and determine their optimum levels and thereby suggest means to improve berry quality in Thompson seedless, Tas-A-Ganesh and 2A clone. Sixty single vines in each variety grafted on Dog Ridge rootstock and trained to extended Y trellis were the experimental units. The TSS/acid ratio, widely accepted as the indicator of palatability in grape varied positively with the number of berries/cluster in Thompson Seedless and 2A clone. While the ratio varied positively with the rachis length/cluster in 2A clone, varied negatively in Thompson Seedless. Berry diameter and its weight influenced the TSS/acid ratio negatively in 2A; but had no influence in Thompson Seedless. None of the cluster and berry characters studied did contribute to TSS/acid ratio in Tas-A-Ganesh. The established negative relationship between TSS and acids content could be seen in 2A clone only, but not in other varieties. Cluster weight, its compactness and the number of berries /cluster were the common crucial parameters, for Thompson Seedless and 2A clone in determining the TSS/acid ratio. While berry weight was an additional parameter in the determination of TSS/acid ratio in TS, Rachis length was in 2A. Cluster weight having negative relationship with TSS/acid ratio in TS and 2A, it is suggested to restrict it to its respective optimum levels of 408.3g and 380.0g in these varieties. Practices to reduce the cluster compactness to its optimum level of 30.9 would be pertinent in view of the negative relationship of cluster compactness with TSS/acid ratio in 2A clone. The positive relationship between cluster compactness and TSS/acid ratio suggested less emphasis in producing loose clusters in Thompson Seedless. Cluster compactness varying between 32 and 33 corresponding to a TSS/acid ratio ranging between 30 and 35 was found be an ideal balance. Limiting the berry number but increasing their size appeared to be the appropriate strategy in TS while, increasing the rachis length and retention of more berries/cluster in 2A to maintain cluster weight as well as the TSS/acid ratio.**

Keywords – **Quality Relationship, Grape, Thompson Seedless, Tas-A-Ganesh, 2a Clone.**

I. Introduction

Quality is of paramount importance in consumer preference and marketing of Table grapes. Total soluble solids (TSS) content has long been used to denote the quality of grapes, since Winkler (11) indicated its high degree correlation with palatability. Acid content of berries also contribute to palatability. Hence the ratio of TSS to acids contents is the widely accepted criterion to determine the palatability of grapes (12).While palatability is the primary consideration in the domestic market, visual appeal also considered in the overseas markets. Of the total production of 2.967 million MT (8), only 0.196 million MT was exported (1). Thus 93.4 per cent of grapes produced is consumed fresh or processed to raisins. It is estimated that approximately 24 per cent of the grapes produced is processed to raisins in India. TSS/acid ratio has more significance in raisin production. While quality is a varietal character, weather during berry ripening period has profound effect in determining both the TSS and acids contents in grapes (3, 12). These quality components were also shown to be influenced by the viticulture practices such as training, pruning, rootstock employed, nutrition, irrigation, berry thinning, girdling and use of growth regulators, through their effect on cluster and berry characteristics (2). Varieties differ in their response to viticulture practices with reference to cluster and berry characters. Abuse of growth regulators with over emphasis on increasing the berry and bunch size has resulted in poor quality grapes in recent years. Hence the present studies were conducted to elucidate the variation in the contribution of cluster and berry characters to berry quality, identify the crucial characters contributing to quality and determine the optimum levels of these characters in Thompson Seedless, Tas – A – Ganesh and 2A clone varieties grown predominantly. Results of these studies help modify the viticulture practices to achieve the optimum levels of the contributory characters to quality of grape.

II. 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 developed at Kearney Experimental Station, UC Davis, California, USA. Sixty vines were selected for each variety as detailed below.

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

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 agro-climatic conditions and subjected to similar cultural practices, including sub-cane development, use of ethrel for pre-pruning defoliation, hydrogen cyanamide for bud break, GA_3 sprays for cluster elongation, girdling and dipping in CPPU solution for berry sizing. Vines were pruned for fruiting in the second week of October 2014. Five clusters were collected from each vine on the 140th day after pruning for recording observations on the weight and compactness of cluster; total length of rachis and number of berries /cluster; diameter, weight and specific gravity of berries; and TSS and acid content of berries.

Cluster weight: Calculated mean weight of five clusters selected at random from each vine.

Cluster Compactness Index: It was derived by multiplying the average number of berries per cm of the total length of rachis by the mean berry diameter in a cluster.

Rachis length/cluster (cm): Total length of the main rachis and its branches was measured after removing the berries in five clusters selected and the total length recorded in cm. Mean of five clusters was taken as a unit.

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 calipers.

Berry weight: Average weight of 25 berries selected at random from five selected clusters, at the rate of five from each and recorded in g.

Specific gravity of berries: It was derived by dividing the total weight of 25 berries by their volume determined by water displacement method.

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

Acids content (g/100ml): Determined by titrating an aliquot of 10 ml juice against 0.1N NaOH using phenolphthalein indicator and expressed as gram equivalent tartaric acid in 100 ml juice.

TSS/acid ratio: Derived by dividing the TSS content with that of acids.

Statistical analysis: Significance of difference in a character between two varieties was tested by independent t-test. In a correlation matrix involving 10 characters, 45 pair-wise correlations were worked out for each variety. Quadratic functions to determine the regression of TSS content on eight independent variables, of acids content on seven and of TSS/acid ratio on nine were fitted resulting in 24 quadratic functions for each variety. T-test, correlations and the regression analysis - quadratic and multiple linear, were performed by the Microsoft Excel data analysis package. Values of X-optimum (X-opt.) and Y- maximum (Y-max.) were calculated for which ever relation, the quadratic function was a good fit. X-opt was calculated by the formula; X-opt = –b/2c, where 'b' is the coefficient of X and 'c' the coefficient of X^2 in the respective quadratic function $Y = a + bX + cX^2$. Y-max was derived by substituting the X values in the corresponding function. Multiple linear regression functions were fitted separately for TSS, acidity and TSS/acid ratio in each variety. Step-wise regression analysis was performed to identify the critical characters in the determination of the three quality parameters in each variety and their optimum values determined.

III. Results and Discussion

Variation as measured by the coefficient of variation in the characters studied was high (more than 15 per cent) in the total length of rachis and berries per cluster in all the varieties. It was high in berry specific gravity in Tas-A-Ganesh (TAG) and 2A clone (2A). Variation was also high in cluster and berry weights in Thompson Seedless (TS); berry diameter in TAG and acids content in 2A (Table1).

Variation in Total soluble solids content: TSS content was highest in 2A clone followed by TAG and TS in significantly decreasing order (Table-2). Variation in the leaf area available/cluster and the photosynthetic efficiency of the leaves in different varieties is the primary reason for varietal variation in TSS content. Variation in the endogenous auxin levels to attract metabolites and the activity of invertase enzyme (Hawker, 1969) in different varieties might have also contributed to this variation.TSS content was found to increase with increase in cluster compactness, berry weight and berry specific gravity, but reduced with increasing length of rachis in TS (Table-3). Cluster compactness correlated positively with TSS content in TS, but not in other varieties. Total rachis length, a positive contributor for cluster compactness, correlated negatively with TSS content in TS. It indicates that berry weight and its specific gravity increase as a result of accumulation of more sugars in TS. In attempts to produce loose to well-filled clusters in TS, less emphasis should be given to cluster elongation but more to reduce the number of berries and increase their size for maintaining TSS level and cluster weight. Optimum length of rachis was found to be 88.8 cm in this variety. Any practice that increases the rachis length more than this will reduce the TSS content.

Multiple regression analysis (Table-5) revealed that all the cluster and berry characters could determine the TSS content by 57.8 per cent in TS and 64.2 per cent in 2A, but only 9.3 per cent in TAG.

Table 5. Multiple regression of TSS on cluster and berry characters

Variety	Regression function	R^2
Thompson Seedless	$Y = -3.354 - 0.0008X_1 + 0.0426X_2 - 0.0114X_3 + 0.0097X_4 - 0.5482X_5 + 1.0265X_6 + 20.8545X_7$	0.578
Tas - A- Ganesh	$Y = 14.275 + 0.0007X_1 - 0.0528X_2 - 0.0159X_3 + 0.0898X_4 - 0.1027X_5 - 0.0326X_6 + 4.2936X_7$	0.093
2A Clone	$Y = 13.167 - 0.0157X_1 - 0.0419X_2 - 0.0358X_3 + 0.0898X_4 - 0.1502X_5 + 0.7862X_6 + 3.5759X_7$	0.642

Results of Step-wise regression analysis indicated that the cluster compactness, total length of rachis, berry weight and berry specific gravity are crucial in the determination of TSS content accounting for 55.3 per cent with their respective optimum values of 84.5, 88.8 cm, 5.58 g and 0.947 in TS (Table-4).

None of the cluster and berry characters studied had any relationship with TSS in TAG. Number of berries/cluster seems to be crucial in the determination of TSS content in this variety. Out of the combined determination of 9.3 per cent by all the cluster and berry characters, 6.7 per cent was accounted for by the number of berries/cluster with the optimum of 36.1(Table-4). Increasing the berry size seems to be a better option rather the number to increase the cluster weight in this variety.

Although cluster compactness had no bearing on the TSS content in 2A, its components, namely length of rachis and number of berries/cluster correlated positively with TSS content (Table-3). Therefore more emphasis on cluster elongation but less on berry thinning could be the strategy for producing loose to well-filled clusters without affecting the TSS content in this variety. But increasing the diameter and weight of berries would reduce its TSS content as indicated by the negative correlation of berry diameter and its weight with TSS content (Table-3). This negative relation could be attributed to limited source and dilution effect. Optimum berry diameter was found to be 18.5 mm, while berry weight 6.26 g in this variety (Table-4). Any attempts to increase these components beyond these limits would be at the expense of TSS content. It was observed in the multiple regression analysis that all the cluster and berry characters together could account for 64.2 per cent of the variation in the TSS content in 2A clone (Table-5). In the step-wise regression analysis, the weight and compactness of the cluster; and the length and number of berries per cluster were found to be pivotal in determining the TSS content in this variety accounting for 62.3 per cent variation, with their respective values of 500 g, 30.6, 80.9 cm and 137 as optimum (Table-4).

Variation in acids content: Acids content was lowest in 2A clone followed by Thompson Seedless and Tas-A-Ganesh in significantly increasing order (Table-2). Variation in the factors like translocation of acids from the leaves (5), formation of salts of potassium of corresponding acid (7), reduced ability of berries to synthesize organic acids during ripening (5) and conversion of acids to sugars (4) in the varieties could be the reason for the variation in acids content. Acids content was found to increase with the increasing length of rachis but to reduce with increasing number of berries/cluster in TS (Table-3).The negative relationship between rachis length and TSS content in this variety (Table-3) could have manifested in the positive relationship between rachis length and acids content. The negative relationship between the number of berries/cluster and acids content can be attributed to dilution effect. In the Multiple regression analysis it was observed that all the cluster and berry characters together could determine the acids content by 56.8 per cent in TS (Table-7).

Table-7: Multiple regression of Acids content on cluster and berry characters

Variety	Regression function	R^2
Thompson Seedless	$Y = 0.1415 + 0.0003X_1 + 0.0024X_2 + 0.0005X_3 - 0.0026X_4 - 0.007X_5 - 0.0267X_6 + 0.5866X_7$	0.568
Tas - A- Ganesh	$Y = 0.2853 - 0.00003X_1 - 0.0003X_2 - 0.0009X_3 + 0.0002X_4 + 0.0126X_5 + 0.0108X_6 + 0.0438X_7$	0.130
2A Clone	$Y = 0.547 + 0.0004X_1 + 0.0002X_2 - 0.001X_3 - 0.0023X_4 + 0.0434X_5 - 0.0213X_6 - 0.558X_7$	0.737

Step-wise regression analysis indicated that cluster weight, its compactness, number of berries/cluster, mean berry weight and its specific gravity were the crucial parameters in the determination of acids content in TS. They together accounted for 56.4 per cent of the variation in acids content with their respective optimum values of 342.9 g, 36.4, 89, 7.14g and 1.05 84.58.8 cm, 5.58 g (Table-6).

Mean berry weight correlated positively with acids content in TAG (Table-3). This relationship could neither be attributed to dilution effect nor the antagonism between TSS and acids content. It might be due to increased ability of the berries to synthesize acids and/or continued translocation of acids from the leaves even after veraison, when the berry attains the maximum size. The cluster and berry characters included in these studies had a very little role in determining the acids content in this variety. They all together could explain the variation in the acids content by only 13.0 per cent, of which 12.2 per cent was accounted for by berry diameter alone. Although berry weight was correlated better than its diameter, its contribution towards determining the acids content was negligible. The optimum value of berry diameter was 17.33 mm (Table-6).

Acids content was found to decrease with increasing length of rachis and number of berries per cluster; but increased with increasing diameter and weight of berry in 2A clone. Variation in TSS content in relation to these parameters was just reverse in this variety (Table-3). Thus the negative relationship observed between TSS and acids contents in this variety (table-3) seems primarily responsible for the relationship of the cluster and berry characters with acids content. In view of these correlations, it is suggested to adopt viticulture operations aimed at increasing the total rachis length and number of berries/cluster up to their optimum levels of 94.4 cm and 153.8; and refrain from any attempt to increase berry diameter or its weight beyond their optimum levels of 19.2 mm and 5.67 g respectively.

In the multiple regression analysis, it was observed that all the cluster and berry characters together determined the acids content by 73.7 per cent (Table-7). The step-wise regression analysis indicated that rachis length and the number of berries per cluster; and diameter, weight and specific gravity of berry were the critical parameters in the determination of acids content accounting jointly for 71.3 per cent variation with their respective optimum values of 94.4 cm, 153.8, 19.2 mm, 5.67 g and 0.121(Table-6).

Variation in TSS/acid ratio: This ratio is the ultimate measure of quality, particularly for raisin production. Variation in the relationship of cluster and berry characters with TSS/acid ratio in the varieties studied is presented graphically in fig.1. According to Winkler *et al*. (12), the ratio increases during berry ripening as a result of simultaneous increase in TSS but reduction in acids contents. While it was so in 2A clone, acids content increased with increasing TSS content up to 0.52 g/100 ml corresponding to 16.5^{O} B in Thompson Seedless but decreased in Tas-A-Ganesh (Fig.1). TSS/acid ratio was highest in 2A clone followed by Thompson Seedless and Tas-A-Ganesh in significantly decreasing order (Table-2). Higher TSS/acid ratio being one of the merits of 2A clone compared to Thompson Seedless, this clone has been identified and released by the Kearney Experimental Station, UC Davis. This ratio correlated positively with the number of berries/cluster and berry specific gravity, but negatively with Total rachis length/cluster in TS. Determination coefficient of rachis length on the TSS/acid ratio was higher (Table-4) compared to TSS content (Table-4) because of its positive relationship with acids content (Table-3). Although the positive relationship of number of berries with TSS content was not significant, it was significant with TSS/acid ratio because of its significant negative relationship with acids content. Positive relationship of berry specific gravity with TSS/acid ratio can be attributed to its similar relationship with TSS content in this variety (Table-3).

All the cluster and berry characters studied could account together for 63.6 per cent of the variation in the TSS/acid ratio in Thompson Seedless (Table-9).

Table 9. Multiple regression of TSS/acid ratio on cluster and berry characters

Variety	Regression function	R^2
Thompson Seedless	$Y = 16.79 - 0.0197X_1 - 0.0843X_2 - 0.0438X_3 + 0.1828X_4 - 0.6821X_5 + 3.8364X_6 + 4.4451X_7$	0.636
Tas - A- Ganesh	$Y = 39.011 + 0.0028X_1 - 0.0816X_2 + 0.0253X_3 + 0.0561X_4 - 0.8744X_5 - 0.7931X_6 + 7.4980X_7$	0.142
2A Clone	$Y = 10.12 - 0.0733X_1 - 0.0608X_2 - 0.0578X_3 + 0.428X_4 - 3.887X_5 + 3.1813X_6 + 67.435X_7$	0.819

The step-wise regression analysis revealed that cluster weight, its compactness, number of berries/cluster and berry weight were the crucial parameters in determining the TSS/acid ratio in this variety, together determining it by 62.3 per cent with their optimum values being 408.3 g, 45.3, 89.3 and 5.46 g (Table-8).

None of the cluster and berry characters studied had any relationship with TSS/acid ratio in TAG. All the characters together could determine the ratio by only 14.2 per cent.

While total rachis length and berries/cluster were associated positively with TSS/acid ratio, diameter and weight of berries were associated negatively in 2A clone. Similar was the relationship of TSS content with these parameters, but just reverse with acids content. Therefore the strength of their correlations with TSS/acid ratio was stronger than with either TSS or acids content (Table-3). It was observed in the multiple regression analysis that all the cluster and berry characters together could account for 81.9 per cent of the variation in the TSS/acid ratio in 2A clone (Table-9). In the step-wise regression analysis, the weight and compactness of the cluster; and rachis length and the number of berries per cluster were found to be crucial in determining the TSS/acid ratio in this variety accounting for 79.2 per cent variation, with their respective values of 380 g, 30.9, 103.1 cm and 142.6 as optimum (Table-8).

TSS and acids contents vary primarily with the stage of ripening with in a variety under similar agro-climatic conditions. TSS content increases with simultaneous decrease in the acids content as the stage advances after veraison in a given variety (9, 10). Further, Drawert and Steffan (4) demonstrated the conversion of acids to sugars during ripening. Hence the TSS and acids contents are correlated negatively. Negative correlation was observed only in 2A clone but not in other varieties. This could be due to deviation in the process of sugar accumulation or acid degradation and mainly dilution effect as result of increased berry size in these varieties (Table-2). TSS content correlated positively with TSS/acid ratio in all the varieties (Table-3). It is a mathematical relation. But the rate of increase in TSS/acid ratio per unit increase in the TSS content was more in 2A, followed by TS and TAG (Fig.1). On the other hand, the TSS/acid ratio was correlated negatively, as a rule, in all the varieties (Table-3). But the rate of reduction in the ratio per unit increase in the TSS content was more in 2A and TAG compared to TS (Fig.1). This could be attributed to varietal variation in the rate of accumulation sugars and degradation of acids due to various factors, as mentioned earlier, during ripening. Such variation was also reported by Shikhamany *et al.* (10) in two varieties.

TSS/acid ratio being the ultimate consideration in judging the palatability of grape berry, cultural

Management of the crucial variables in the determination of this ratio in different varieties has been the primary objective of this study. Cluster weight, its compactness and the number of berries /cluster were the common parameters crucial in the determination of TSS/acid ratio in TS and 2A. While berry weight was an additional parameter in the determination of TSS/acid ratio in TS, Rachis length was in 2A. Cluster weight having negative relationship with TSS/acid ratio in TS and 2A, attempts should not be made to increase the cluster weight beyond their optimum values of 408.3gand 380.0 g respectively. Similarly, cluster compactness influencing the TSS/acid ratio negatively in 2A, viticulture practices to reduce the cluster compactness to its optimum level of 30.9 would be pertinent. Since reduced cluster compactness was associated with reduced TSS/acid ratio in TS, over emphasis should not be given to producing loose clusters. A balance is needed between the cluster compactness and TSS/acid ratio in this variety. Cluster compactness could be between 32 and 33 against the TSS/acid ratio of 30-35 (derived from the function $Y = 15.60 + 0.816x - 0.009x^2$, where Y = TSS/acid ratio and x

= cluster compactness - Table-8). Since berries/cluster correlated positively with TSS/acid ratio in TS and 2A, less emphasis should be given to berry thinning than increasing the rachis length for reducing the cluster compactness. Limiting the berry number (to 89.3) but increasing their weight (to 5.46 g) appeared to be the appropriate strategy in TS while, increasing the rachis length (to 103.1) and retention of more berries/cluster (142.6) in 2A to maintain cluster weight as well as the TSS/acid ratio.

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AUTHORS' PROFILES

Dr S.D. Shikhamany.
Dr Shikhamany was Vice-Chancellor, Dr. YSR Horticultural University (2008 - 2011). ii) Director, Indian Institute of Horticultural Research (ICAR), Bangalore (2002-2007). iii) Director, National Research Centre for Grapes (ICAR), Pune (1997-2002). He has published 97 research articles and 35 popular articles

Swapnil V Borade
The author is post graduate in Bio-technology from Savitribai Phule Pune University and has a research experience of 4 years with 6 research papers to his name.

Sanjay K Jeughale
The author holds a Master's degree in Organic Chemistry with 4 years of research experience and has 7 research publications to his name.

Suryakant Y Patil
The author holds a master's degree in Agrochemicals and pest management from Shivaji university Kolhapur. He has 9 years of research experience and 5 research papers to his name.

Table 1. Variation in the cluster and berry characters in Thompson Seedless and its clones

Character	Thompson Seedless			Tas-A-Ganesh			2A Clone		
	Range	Mean	CV(%)	Range	Mean	CV(%)	Range	Mean	CV(%)
1. Cluster weight (g)	217.4 – 593.5	404.4	18.44	238.4 – 418.0	323.9	12.36	231.8 – 465.5	359.6	11.80
2. Cluster compactness	22.2 - 44.0	33.23	14.8	23.1 – 41.9	31.1	12.99	21.2 – 39.4	30.1	12.79
3. Rachis length (cm)	28.3 – 94.4	56.1	27.63	30.9 – 64.8	45.1	15.31	39.8 – 77.6	56.3	17.30
4. Berries / cluster	39.6 – 110.4	72.6	24.39	30.9 – 87.5	57.6	21.15	61.8 – 157.0	96.3	25.96
5. Berry diameter (mm)	15.5 – 20.6	18.4	6.89	16.1 – 19.0	17.6	28.62	15.6 – 19.0	16.8	4.24
6. Berry weight (g)	3.82 – 8.16	6.15	18.00	4.37 – 6.10	5.17	8.67	3.81 – 6.25	4.73	11.67
7. Berry sp. Gravity	0.94 – 1.11	1.05	3.11	0.96 – 1.09	1.06	20.02	1.00 – 1.11	1.06	20.17
8. T. S. S (^{O}B)	13.6 – 19.4	15.94	9.28	14.5 – 19.7	17.0	7.97	17.3 – 21.6	17.8	7.13
9. Acids content (g/100ml)	0.38 – 0.64	0.50	11.15	0.46 – 0.66	0.56	6.82	0.33 – 0.64	0.46	20.18
10. TSS/ acid ratio	23.5 – 40.4	32.6	13.64	24.6 – 38.4	30.5	10.88	44.0 – 60.3	52.0	6.49

Table 2. Comparison of cane and cluster characters in different varieties

Character	Means			Comparison		
	TS	TAG	2A	TS -TAG	TS - 2A	TAG - 2A
1. Cluster weight (g)	404.4	360.6	359.6	43.8	44.8*	1.0
2. Cluster compactness	33.23	31.1	30.1	2.13	3.13*	1.0*
3. Rachis length (cm)	56.1	45.1	56.3	11.0*	-0.2	-11.2*
4. Berries / cluster	72.6	57.6	96.3	15.0*	-23.7*	-38.7*
5. Berry diameter (mm)	18.4	17.6	16.8	0.8*	1.6*	0.8*
6. Berry weight (g)	6.15	5.17	4.73	0.98*	1.42*	0.44*
7. Berry sp. Gravity	1.05	1.06	1.06	-0.01	-0.01	0.0
8. T. S. S (^{O}B)	15.94	17.0	17.8	-1.06*	-1.86*	-0.8*
9. Acids content (g/100ml)	0.50	0.56	0.46	-0.06*	0.04*	1.0*
10. TSS/ acid ratio	32.6	30.5	52.0	2.1*	-19.4*	21.5*

TS = Thompson seedless; TAG= Tas-A-Ganesh; 2A= 2A Clone : *Significant @P=0.05

Table 3. Correlation coefficients (r) of the relationship of cluster and berry characters with quality attributes

Cluster/ berry characters	TSS (^{O}B)			Acidity (g/100ml)			TSS/Acid ratio		
	TS	TAG	2A	TS	TAG	2A	TS	TAG	2A
Cluster weight(g)	-0.011	0.123	-0.070	-0.117	-0.155	0.079	-0.094	0.195	-0.086
Cluster compactness	0.332**	-0.139	-0.039	-0.043	0.114	0.022	0.232	-0.182	-0.011
Total rachis length/cluster (cm)	-0.377**	0.030	0.645**	0.469**	-0.133	-0.735**	-0.599**	0.099	0.755**
Berries/cluster	0.144	0.247	0.734**	-0.491**	-0.007	-0.778**	0.462**	0.212	0.832**
Berry diameter (mm)	0.104	-0.104	-0.486**	-0.0001	0.230	0.683**	0.079	-0.214	-0.688**
Berry weight (g)	0.290*	-0.059	-0.407**	-0.018	0.289*	0.586**	0.214	-0.211	-0.570**
Berry specific gravity	0.640**	0.031	-0.014	0.184	-0.008	-0.023	0.269*	0.041	0.020
TSS (^{O}B)	1.000	1.000	1.000	0.023	0.017	-0.713**	0.630**	0.862**	0.883**
Acidity (g/100ml)	0.023	0.017	-0.713**	1.000	1.000	1.000	-0.757**	-0.487**	-0.950**

r- Significant @ 5% = 0.255; @1% = 0.331

Table 4. Variation in the relationship of cluster and berry characters with Total Soluble Solids content (° B) of berries in different varieties of grapes

	X	Variety	Quadratic equation	R^2	X-opt.	Y- max
1	Cluster weight (g)	TS	$Y= 14.358 + 0.008x – 0.00001x^2$	0.003	400	16.0
		TAG	$Y= 19.745 - 0.01x + 0.000004x^2$	0.045	1259	13.2
		2A	$Y= 20.42 - 0.011x + 0.000011x^2$	0.005	500	17.7
2	Cluster compactness	TS	$Y= 11.488 + 0.169x – 0.001x^2$	0.111	84.5	18.6
		TAG	$Y= 30.89 - 0.799x + 0.011x^2$	0.050	36.3	16.4
		2A	$Y= -6.303 + 1.607x – 0.0263x^2$	0.063	30.6	18.2
3	Rachis length (cm)	TS	$Y= 20.691 - 0.128x + 0.00072x^2$	0.152	88.8	15.0
		TAG	$Y= 21.997 - 0.231x + 0.003x^2$	0.008	38.5	17.6
		2A	$Y= 0.802 + 0.469x – 0.0029x^2$	0.430	80.9	19.8
4	Berries/cluster	TS	$Y= 9.612 + 0.174x – 0.00113x^2$	0.086	77.0	16.3
		TAG	$Y= 17.5 - 0.065x + 0.0009x^2$	0.067	36.1	16.3
		2A	$Y= 1.7558 + 0.274x – 0.001x^2$	0.609	137.0	20.5
5	Berry diameter (mm)	TS	$Y= 39.895 - 2.803x + 0.08123x^2$	0.017	17.3	15.7
		TAG	$Y= 164.5 - 16.49x + 0.459x^2$	0.025	18.0	16.4
		2A	$Y= 188.05 - 18.576x + 0.502x^2$	0.264	18.5	16.2
6	Berry weight (g)	TS	$Y= 28.819 - 4.846x + 0.434x^2$	0.205	5.58	15.3
		TAG	$Y= 23.006 - 2.109x + 0.176x^2$	0.004	5.99	16.7
		2A	$Y= 40.145 - 7.638x + 0.610x^2$	0.176	6.26	16.2
7	Berry specific gravity	TS	$Y= 164.429 - 317.535x +167.5674x^2$	0.450	0.947	14.0
		TAG	$Y= 440.71 - 818.1x +394.45x^2$	0.043	1.037	16.5
		2A	$Y= 709.66 - 1306x + 616.12x^2$	0.036	1.060	17.6
8	Acidity (g/100ml)	TS	$Y= -21.286 + 148.966x – 147.171x^2$	0.161	0.506	16.4
		TAG	$Y= 44.36 - 98.93x+88.51x^2$	0.009	0.559	16.7
		2A	$Y= 23.87 - 19.491x + 15.537x^2$	0.002	0.627	17.8

Table 6. Variation in the relationship of cluster and berry characters with Titratable Acids (g/100ml) content of berries in different varieties of grapes

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	X	Variety	Quadratic equation	R^2	X-opt.0	Y- max
1	Cluster weight (g)	TS	$Y= 0.572 - 0.00048x+ 0.0000007x^2$	0.024	342.9	0.490
		TAG	$Y= 0.523 + 0.00014x – 0.00000006x^2$	0.039	1166.6	0.686
		2A	$Y = - 0.2227 + 0.0038x – 0.000005x^2$	0.037	380.0	0.499
2	Cluster compactness	TS	$Y = 0.636 - 0.008x + 0.00011 x^2$	0.006	36.4	0.491
		TAG	$Y= 0.555 - 0.0005x + 0.00002x^2$	0.013	12.5	0.552
		2A	$Y= 2.040 - 0.104x+ 0.0017x^2$	0.131	30.59	0.449
3	Rachis length (cm)	TS	$Y= 0.507 - 0.0019x + 0.00003x^2$	0.238	31.7	0.477
		TAG	$Y= 0.459 + 0.005x – 0.000061x^2$	0.029	41.0	0.561
		2A	$Y= 1.136 - 0.017x + 0.00009x^2$	0.548	94.4	0.333
4	Berries/cluster	TS	$Y= 0.854 - 0.0089x + 0.00005x^2$	0.353	89.0	0.458
		TAG	$Y= 0.508 + 0.0018x – 0.000016x^2$	0.005	56.3	0.559
		2A	$Y= 0.988 - 0.008x + 0.000026x^2$	0.627	153.8	0.373
5	Berry diameter (mm)	TS	$Y= 1.492 - 0.1113x + 0.0031x^2$	0.006	18.0	0,493
		TAG	$Y= 6.437 - 0.684x + 0.0198x^2$	0.122	17.3	0.529
		2A	$Y= - 7.279 + 0.826x – 0.0215x^2$	0.492	19.2	0.654
6	Berry weight (g)	TS	$Y= 0.517 - 0.0064x + 0.00045x^2$	0.004	7.11	0.494
		TAG	$Y= 0.457 + 0.0152x – 0.0009x^2$	0.083	8.44	0.521
		2A	$Y= - 1.370 + 0.654x – 0.0577x^2$	0.384	5.67	0.483
7	Berry specific gravity	TS	$Y= -9.6799 + 19.3797x – 9.219x^2$	0.118	1.05	0.505
		TAG	$Y= -6.337 + 13.278x – 6.386x^2$	0.029	1.04	0.565
		2A	$Y= -54.976 + 104.86x – 49.57x^2$	0.121	1.06	0.479

Table 8. Variation in the relationship of cluster and berry characters with TSS/Acid ratio in berries in different varieties of grapes

	X	Variety	Quadratic equation	R^2	X-opt.	Y- max
1	Cluster weight (g)	TS	$Y= 23.81 + 0.049x – 0.00006x^2$	0.024	408.3	33.8
		TAG	$Y= 37.71 - 0.027x + 0.000011x^2$	0.084	1227.3	21.1
		2A	$Y =110.316 - 0.38x + 0.0005x^2$	0.026	380.0	38.1
2	Cluster compactness	TS	$Y = 15.60 + 0.816x – 0.009 x^2$	0.058	45.3	34.1
		TAG	$Y= 57.92 - 1.535x + 0.0204x^2$	0.057	37.6	29.0
		2A	$Y= -147.28 + 12.399x – 0.2009x^2$	0.115	30.9	44.0
3	Rachis length (cm)	TS	$Y= 40.82 - 0.125x – 0.0004x^2$	0.359	156.3	11.5
		TAG	$Y= 44.325 - 0.666x + 0.0077x^2$	0.025	43.2	29.9
		2A	$Y= -42.446 + 2.062x – 0.01x^2$	0.576	103.1	63.9
4	Berries/cluster	TS	$Y= - 2.002 + 0.893x – 0.005x^2$	0.381	89.3	37.9
		TAG	$Y= 33.6 - 0.194x + 0.0023x^2$	0.053	42.2	29.5
		2A	$Y= - 41.954 + 1.340x – 0.0047x^2$	0.737	142.6	53.6
5	Berry diameter (mm)	TS	$Y= 4.915 + 2.8x – 0.07x^2$	0.007	20.0	32.2
		TAG	$Y= 1.70 + 4.695x – 0.1746x^2$	0.046	13.4	33.3
		2A	$Y= 1167.31 - 121.4343x + 3.234x^2$	0.482	18.8	27.4
6	Berry weight (g)	TS	$Y= 53.56 – 8.153x + 0.747x^2$	0.085	5.46	31.3
		TAG	$Y= 54.534 -7.389x + 0.517x^2$	0.045	7.17	28.1
		2A	$Y= 247.16 - 72.66x + 6.06x^2$	0.356	6.0	29.4
7	Berry specific gravity	TS	$Y= 942.997 – 1800.84x + 888.45x^2$	0.195	1.01	30.5
		TAG	$Y= 1203.0 -2263.75x +1091.6x^2$	0.073	1.04	29.4
		2A	$Y= 6616.7 - 12437.7x + 5878.9x^2$	0.106	1.06	38.3
8	TSS (^{O} B)	TS	$Y= 118.81 - 12.35x + 0.432x^2$	0.448	14.3	30.5
		TAG	$Y= 3.319 + 1.253x + 0.02x^2$	0.746	31.3	62.1
		2A	$Y= -44.343 +4.613x – 0.0093x^2$	0.780	256.3	527.1
9	Acidity (g/100ml)	TS	$Y= 11.761 + 143.206x – 201.835x^2$	0.610	0.354	37.2
		TAG	$Y= 144.46 - 354.34x + 267.227x^2$	0.256	0.663	27.0
		2A	$Y= 152.98 - 369.49x + 263.66x^2$	0.921	0.701	23.5

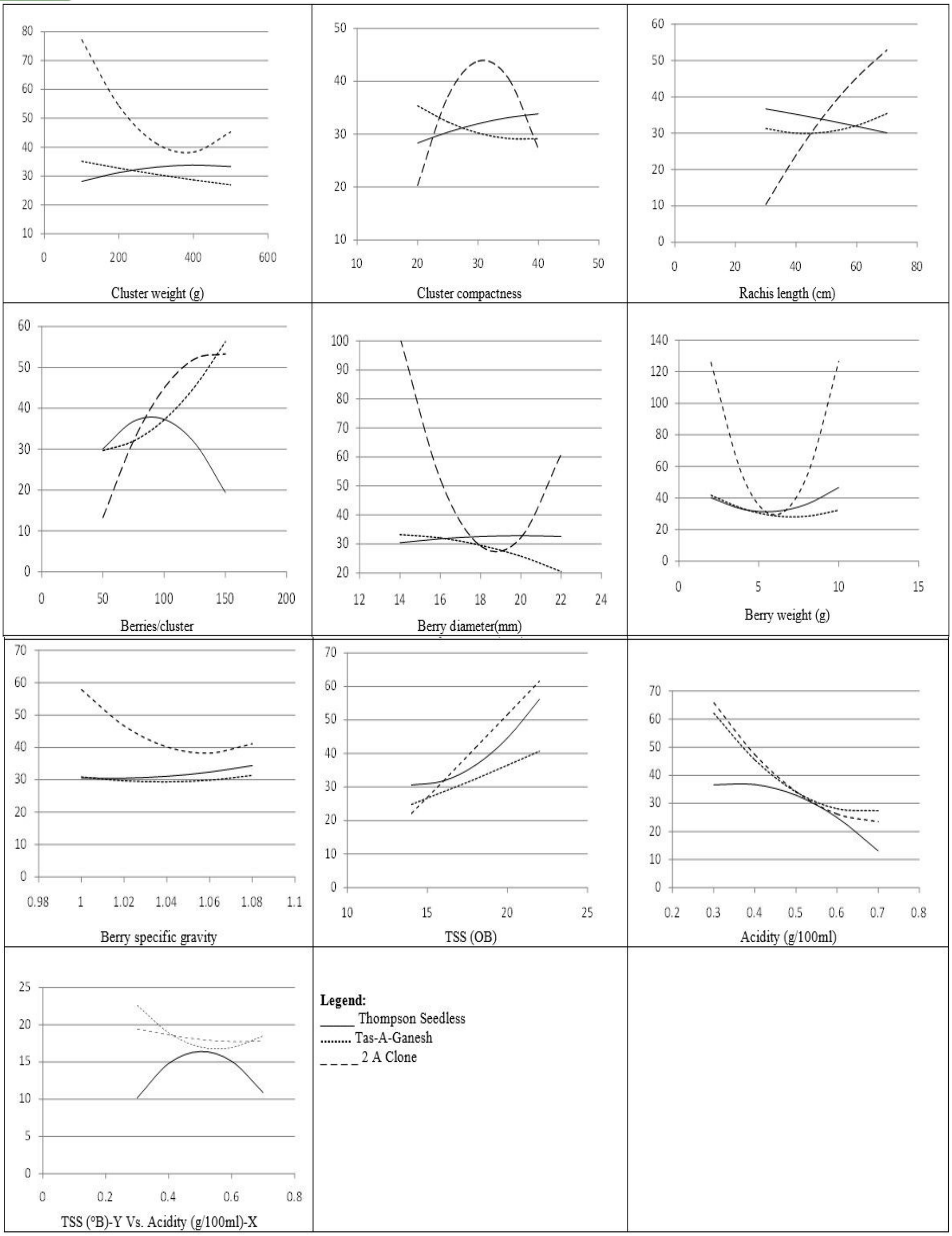

Fig. 1. Relationship of cluster and berry characters (X) with TSS/Acid ratio (Y) in grape varieties