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Influence of shoot density on leaf area, yield and quality of Tas-A-Ganesh grapes (*Vitis vinifera* L.) grafted on Dog Ridge rootstock

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Abstract

Seven year old vines of Tas-A-Ganesh grapes (*Vitis vinifera* L.) grafted on Dog Ridge rootstock (*Vitis champani*) were shoot thinned for three years continuously with different shoot retention treatments viz., 30, 45, 60 and 75 shoots per vine. The forward pruning of vines was carried out during the month of October. The shoot length, cane diameter and inter nodal length was measured to study the relation with bunch characters. The vines having 30 shoots had the highest shoot length, cane diameter, internode length and leaf area per shoot as compared to the other treatments. The increase in number of shoots per vine from 30 to 75 resulted into increase in yield per vine but reduced the berry diameter. The data recorded on various parameters suggests that to achieve the exportable quality bunches, the number of bunches per vine needs to be standardized. The relationship between LAI and brix yield suggested the importance of LAI studies in canopy management for yield and quality improvement.

Keywords: Berry diameter, Leaf area index, pruned biomass, shoot density, yield.

INTRODUCTION

Grape (*Vitis vinifera*) is cultivated in an area of about 1, 06,000 ha area under cultivation and production of 974000 MT (Indian Horticulture Database, 2010). Earlier the vines grown on their own roots were performing well since the soil and water condition was good. Due to increasing problems of soil salinity, bad quality water and drought condition, the severe decline in the productivity of vines raised on their own roots in semi arid regions of Maharashtra and Northern Karnataka have been reported. Owing to the conditions of salinity and drought as a major reason, establishment of grape vineyards on rootstock were became mandatory.

The use of rootstock is increasing in grape growing of the country. The primary use of rootstocks is for pest resistance (Hardie and Cirami, 1988; Howell, 1987; Pongracz, 1983). Reynolds and Wardle (2001) outlined seven major criteria for choosing rootstocks in the order of importance. Numerous reports have also proved that rootstock affect vine growth, yield and fruit quality. These effects take place due to interaction between environmental factors and the physiology of scion and rootstock cultivars. The difference in performance of vines grafted on rootstock and own rooted vines is experienced by the grape growers. Canopy management plays an important role in producing the quality grapes. In the tropical parts of the country where the grapes are being grown for table as well as wine purpose, it is important to manage the canopy in terms of shoot density per vine for the production of quality grapes and also to minimize the disease incidence. It is also said to increase the photosynthetic efficiency of the vine. To maintain the crop load on the vine, the canopy needs to be maintained properly. When studying the crop load per vine, it is common place to prune the vines to different number of buds per vine at dormant pruning (Reynolds et al., 1994). While dormant pruning level affects yield by establishing the potential cluster number per vine, it also determine the shoot number and also strongly affects the leaf area per shoot (Winkler et al., 1974). The recommended ratio of external leaf area to fruit weight is estimated to be 1.0 to 1.5 m^2 kg^{-1} (Smart and Robinson, 1991). However,

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weight of dormant cane pruning is a more common measure of vegetative growth than leaf area because it is more easily obtained (Myers et al., 2008). The pruned biomass also indicates the availability of stored food material required for the growth of developing bunch after the fruit pruning. The quality crop yield also depends on the pruning weight that accumulates the reserve food material in the form of carbohydrate, starch, protein, etc. and phenols which can make the vine to resist from disease infection. Shaulis (1982) stated that the dormant pruning weight is better expressed per meter of canopy than per vine in order to understand the density of shoot growth and hence estimate the density of the leaves. Smart and Robinson (1991) recommended density of shoot growth between 0.3 and 0.6kg^{-1} of canopy whereas Dokoozlian and Kliewer (1995) found that the light environment of Cabernet Sauvignon with vertical-oriented shoot growth, was optimal at or below 1.0 kg^{-1}. This differs from soil type, training system used and vigor of the vines. Hence, these values may provide only general guidelines of a balance between vines vegetative and reproductive growth. When shoot spacing is optimized, the vine is more efficient at radiation interception (Smart, 1988). Appropriate shoot spacing can improve fruit composition in *vinifera* (Reynolds et. Al., 1994; Smart 1988; Reynolds et. al., 2005).

The objectives of this study were to determine the effect of shoot density on shoot vigor, leaf area and yield and quality of Tas-A-Ganesh grapes grafted on Dog Ridge rootstock under tropical condition of Pune.

MATERIALS AND METHODS

The trial was conducted at the research farm of National Research Centre for Grapes, Pune from 2006- 2009. The experimental site is situated in Mid-West Maharashtra state at an altitude of 559 m above sea level; it lies on 18.32° N latitude and 73.51° E longitudes. The climate in this region is mild to slightly dry. The soil of this region is black having pH 7.75 and EC 0.46 dS/m. The grape rootstock Dog Ridge was planted during March, 1999 and the grafting of table grape variety Tas-A-Ganesh was performed during October 1999. The vines were trained to flat roof gable system of training with four cordons (H shape) developed horizontally.

The vines were trained as four cordons on a horizontally divided canopy trellis with vertical shoot positioning. The height of cordon from the ground surface was 1.20 m and was separated by 0.60 m wide cross arms. The distance from the fruiting wire to the top of foliage support wire was 0.60 m. The vines were planted at the spacing of 3.0 m between the rows and 1.83 m between the vines, totaling the density of 1800 vines per hectare.

Since the region falls under tropical condition, double pruning and single cropping is followed. Hence, the vines were pruned twice in a year (once after the harvest of crop i.e. back pruning and second for fruits i.e. forward pruning). During the back pruning time, the sprouting on the cordons takes place and more than 100 shoots per vines appears. Based on the treatments, the shoots on each vine were thinned to different shoot density. The early growth stage of 4-5 leaf after back pruning was chosen for shoot thinning. The shoot thinning treatments were applied to retain 30, 45, 60 and 75 or more shoots per vine. The care was taken that the retained shoots were divided equally on all the cordons so as to distribute food material equally on each cordon.

The trial was laid out in a randomized block design with four treatments and five replications. There were eight vines in each replication. Five vines having uniform shoots on each cordon and fruitful canes were tagged and labeled for data recording in each replication. The shoots retained on each vine were pruned at 7th bud for fruits during the month of October. The shoot length was measured when the shoot growth was stopped after the berry setting stage. On each shoots, main and side shoots were measured with the help of measuring tape. Simultaneously, inter nodal length was measured with measuring scale and the cane diameter was measured with Verneer caliper. The leaf excised from main and lateral shoots were used to measure leaf area with the help of portable leaf area meter (CID Inc.). The leaf area index was recorded with the help of Sunscan Canopy Analyzer (Delta T Devise, England). Total leaf area per vine was calculated by multiplying leaf area per shoot and total number of shoots per vine. The weight of pruned biomass was recorded during back pruning as well as fruit pruning.

The data recorded from five replicates for three consecutive production seasons were pooled together after passing normality test. Standard deviation was used as measure of variability. The overall significance of the treatments was determined by one-way-ANOVA test followed by Fisher's LSD comparison as a post-hoc test. Correlation and regression studies were based on total 60 records per parameter. The data analysis and graphical presentations were carried out by using Sigma Stat 3.5 and Microsoft Excel 2003.

RESULTS AND DISCUSSION

The results of the present investigation on the effect of shoot density on various growth and yield parameters are presented in Table 1. The desired shoot number (canes) per vine was maintained at the time of fruit pruning during all the three years of study. It was observed that with the increase in number of shoots per vine, there was significant reduction in average shoot length and also the cane diameter. The highest shoot length (94.71 cm) was

Table 1. Effects of number of shoots maintained on grapevines on different growth and yield parameters#

Parameter	Number of shoots per vine				Sig.
	30	45	60	75	
Shoot length (cm)	94.71±4.26 a	91.16±3.40 b	89.04±3.36 b	76.70 ±3.89 c	**
Cane diameter (mm)	9.63±0.44 a	9.14±0.32 b	8.63±0.38 c	6.94±0.41 d	**
Internode length (cm)	5.58±0.18 a	5.39±0.21 b	4.97±0.34 c	4.83±0.12 c	**
Leaf area/ shoot (sq.mt)	0.22±0.03 a	0.19±0.01 b	0.16±0.02 c	0.14±0.02 d	**
Leaf area/ vine (sqmt)	6.60±0.86 d	8.71±0.65 c	9.61±1.04 b	10.64±1.35 a	**
Leaf area index	2.44±0.14 d	2.61±0.08 c	2.79±0.08 b	2.94±0.13 a	**
Pruning weight (kg/vine)	1.23±0.11 ab	1.20±0.10 b	1.25±0.10 ab	1.30±0.10 a	ns
Berry diameter (mm)	20.72±0.66 a	19.97±0.36 b	18.84±0.40 c	16.69±0.47 d	**
Bunch weight (g)	460.26±27.87 a	415.22±21.69 b	388.10±20.16 c	299.83±14.95 d	**
Yield/ vine (kg)	18.59±1.38 d	20.52±1.05 b	23.39±0.96 b	24.37±0.95 a	**
TSS (˚Brix)	20.39±0.38 a	19.64±0.26 c	19.21±0.28 c	18.00±0.40 d	**
Brix yield (kg/vine)	3.79±0.31 c	4.03±0.23 b	4.49±0.21 a	4.39±0.18 a	**
LA : fruit ratio (sq mt/ Kg)	1.75±0.24 c	2.17±0.21 b	2.15±0.30 b	2.43±0.34 a	**

#Data are pooled means for three consecutive production seasons ±standard deviation. '**' indicate treatment significance by one-way-ANOVA at $p<0.01$. [a]Values in the rows followed by different letters differ significantly by DMRT at $p=0.05$.

recorded when the number of shoots per vine were minimum (30 shoots per vine). The reduction in shoot length was 19.02% from minimum shoots (30) to maximum shoots per vine (75). Similarly, 27.93% reduction in cane diameter was recorded from minimum shoot numbers to the maximum. This was mainly due to the competition of the shoot for nutrients and water that might have resulted in to dilution effect, which is generally observed in the vineyard. Significant differences were recorded for inter nodal length. It was observed that with the increase in number of shoots there was significant shortening of the internodes. There was considerable difference between the leaf area per shoot and per vine among the different shoot retention treatments. The leaf area per shoot was 0.22, 0.19, 0.16 and 0.14 sq. m. while the leaf area per vine was 6.60, 8.71, 9.61 and 10.64 sq. m for 30, 45, 60 and 75 shoot per vine treatments respectively. The shoot thinning treatments increased the leaf area per shoot while the reduction in shoots per vine resulted into reduction in leaf area per vine. This might be due to the lack of transport of assimilate by the individual shoots. These results are in conformity with the results obtained by Naor and Gal (2002) who reported that shoot thinning increased leaf area per shoot to an extent that the effect on whole vine leaf was area was small and insignificant, probably due to compensation effect. These results indicated that the increase in number of shoots per vine has positive impact for leaf area. Study conducted by Miller et al. (1996) on potted plants reported that decreasing shoot number decreased the leaf area per plant and Dokoozlian (1990) in his study on matured field grown vines suggesting that the response may not be linear across the wide range growing conditions.

Significant differences were recorded for leaf area index (LAI) among the different shoot retention treatments. Higher LAI of 2.94 was recorded in 75 shoots treatments as compared to the minimum leaf area index in 30 shoots treatment (2.44). The relationship between leaf area per vine and leaf area index (LAI) is illustrated in Figure 1. There is highly significant correlation between these factors. This relationship could be interpreted by a regression equation $Y= 0.08X + 1.96$, $R^2=0.46$. Leaf area being an important attribute in its contribution in yield and quality, the alternative interpretation through LAI can be a useful tool for the further research. The extent and constancy of crop constraint in the field study strongly suggest that early leaf removal may be an excellent tool for limiting yield by replacing time-consuming cluster thinning and avoiding its negative side effects (Poni et al, 2006). The changes in quality due to reduction in leaf might be due to the source- sink balance.

The pruning weight per vine was also recorded during the period of study. The pruning weight was not significantly influenced by the different shoot retention treatments. The pruning weight per vine ranged from 1.13 kg in 30 shoots treatments to 1.32 kg per vine in 75 shoots treatment. The studies conducted by several workers have reported that the retained shoot number per vine has no effect on pruning weight. Myers et al. (2008) reported that the shoot thinning treatment did not affect dormant pruning weight per vine. Naor and Gal (2002) also reported that the vine can increase the vigor of the individual shoot to compensate for reduction in shoot number imposed by shoot thinning. Miller and Howell (1996) in Concord and Freeman et al. (1979) in Shiraz had also reported that the increasing nodes retained at pruning from 20 to 160 nodes per vine either

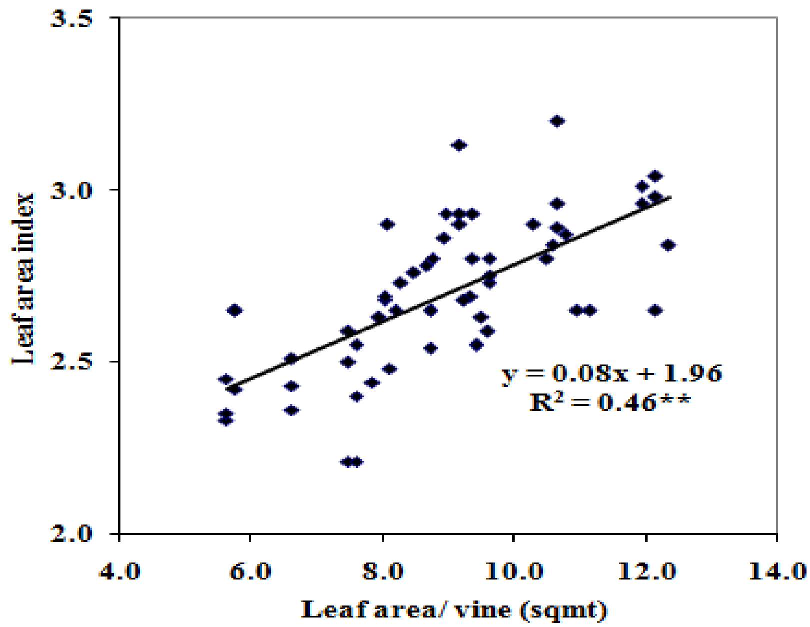

Figure 1. Relationship between leaf area per vine and leaf area index of respective grapevines

in Concord or Shiraz had no effect on pruning weight per vine. Even after reduction of shoot density per vine to 50%, the pruning weight in Pinot Noir was not changed (Reynolds et al., 1994).

Berry diameter plays an important role in quality parameters for table grapes. Berry diameter significantly differed among the different shoot retention treatments. When the number of shoots per vine was maintained at 30, the berry diameter was 20.72 mm and with the increase in number of shoots then after, the berry diameter reduced to 16.69 mm in 75 shoots per vine treatment. The reduction in berry diameter was 3.61% from 30 - 45 shoots, 5.65% from 45-60 shoots and 11.41% from 60-75 shoots per vine respectively. The decrease in shoot diameter was mainly due to the dilution effect through increased number of shoots per vine. There was significant reduction in berry weight (19.44) from 30 to 75 shoots per vine. The impact of increase or decrease in berry weight is generally visible directly on bunch weight. With the retention of minimum shoots per vine (30) resulted in to higher bunch weight of 460.26g as compared to the minimum bunch weight (299.83g) obtained in retention of maximum shoots (75) per vine. The yield per vine ranged from 18.59 kg per vine in 30 shoots to 24.37 kg in 75 shoots per vine. It was observed that the yield per vine ranged more than two fold from 30 shoots treatment to 75 shoots treatment. The increase in yield per vine was 23.71% from 30 to 75 shoots per vine. These results supports the findings of Sun et al., (2011) who reported that with shoot thinning, yields were reduced by 3.1 to 7.2 kg per vine and clusters were reduced by up to 59 clusters per vine, while berry weight increased by 0.03 to 0.09 g in Marechal Foch grapevine. However, in our study the berry diameter was reduced to 19.44% in the same treatment indicating the negative correlation with each other parameters. The yield per vine was ranged two folds from 12 shoots to 28 shoots treatment (Myers et al., 2008). A total soluble solid in berries was significantly varied due to different shoot retention treatments. Increased in shoot number per vine resulted in to reduction in total soluble solids (TSS). The TSS ranged from 20.39° Brix to 18.00° Brix in 75 shoots treatment. The increased in shoot number per vines indicates that the bunch number also increased that has helped to increase the total weight and thus reduced the TSS. The delay in total soluble solids accumulation in berries was significant with the increase in bunch number and yield per vine. These results are in accordance with the results obtained by Myers et al. (2008).

The relationship between Leaf area index and brix yield per vine is expressed in Figure 2. The regression could be expressed as Y= 1.18x-1.01, R^2= 0.50. LAI being an interpretation of photosynthetic potential of the grapevine, these results prove importance in the data interpretation. The correlation co-efficient among different parameters studied during the present investigation are presented in Table 2. It could be seen from the results that most of the parameters had highly significant (either positive or negative) impact on each other. This interprets the dependency of these factors on each other.

There was increase in brix yield per vine from 30 shoots (3.79), 45 shoots (4.03), 60 shoots (4.49) and 75 shoots (4.39) respectively. Since the number of shoots and bunches per vine increased, there was increase in

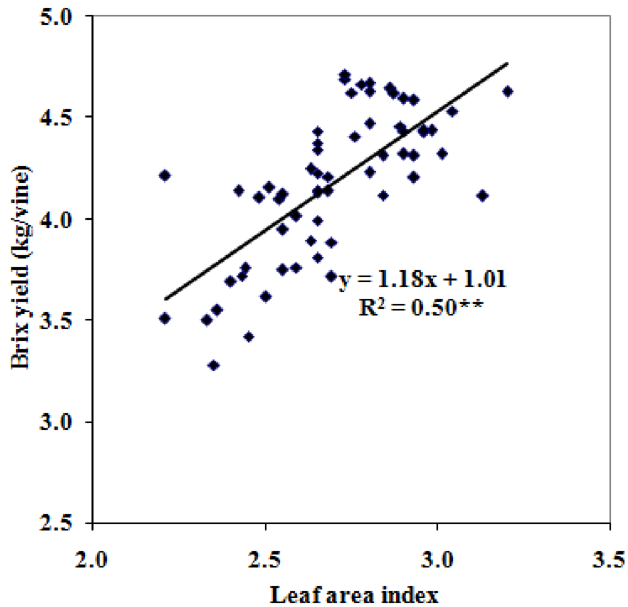

Figure 2. Relationship between leaf area index and brix yield of grapevines

Table 2. Correlation coefficients# between different growth and yield parameters as influenced by number of canes maintained per grapevine.

Sr. No.	Parameters	Cane Diameter	Leaf area/ Vine	Leaf area index	Pruning Wt (Oct)	Berry Diameter	Bunch Wt.	Yield/ Vine	TSS	Brix yield	LA : Fruit Ratio
1	Shoot length	0.84**	-0.67**	-0.69**	-0.38**	0.84**	0.86**	-0.62**	0.83**	-0.36 *	-0.44**
2	Cane Diameter		-0.69**	-0.79**	-0.48**	0.90**	0.90**	-0.73**	0.89**	-0.47**	-0.39 *
5	Leaf area/ Vine			0.68**	0.46**	-0.76**	-0.72**	0.72**	-0.75**	0.56**	0.83**
6	Leaf area index				0.59**	-0.79**	-0.75**	0.85**	-0.79**	0.71**	0.27 ^{ns}
7	Pruning Wt (Oct)					-0.48**	-0.34 *	0.75**	-0.43**	0.77**	0.05 ^{ns}
8	Berry Diameter						0.90**	-0.78**	0.91**	-0.53**	-0.44**
9	Bunch Wt.							-0.70**	0.91**	-0.43**	-0.46**
10	Yield/ Vine								-0.77**	0.93**	0.22 ^{ns}
11	TSS									-0.47**	-0.43**
12	Brix yield										0.06 ^{ns}

#Correlation coefficients drawn over pooled data for three production seasons. '*', '**' and 'ns' represent significance at p=0.05, 0.01 and non-significance of correlation coefficient, respectively.

brix yield. Variation in the ratio of leaf area to fruit weight was recorded in the different treatments of shoots per vine. More number of shoots per vine has imparted more leaf area and thus the ratio was also significantly higher with the increase in number of shoots per vine. Considering the leaf area to fruit ratio of 30 shoots per vine seems to be better in relation to TSS and berry diameter. However, the values obtained in 75 shoots per vine treatment are higher resulting in to the heavy crowding of the canopy in a vine. This favors the development of various fungal diseases in the canopy. As the shoot numbers increased from minimum 30 shoots per vine, the resultant berry weight was decreased. The berry diameter considered as quality parameter is possible to obtain by retaining 30 and 45 bunches per vine. These data supports the results obtained by Myers et al. (2008). However, the retention of different number of shoots per vine for different purpose can help to obtain more total yield that may not be of exportable quality. These results support the conclusion made by Freeman et al. (1979) and Reynolds et al. (1994) attempting to set different crop yield level by pruning do more than adjust the crop. Bernizzoni et al. (2011) reported that a load of 15 shoots/m maximised canopy efficiency by inducing the fastest recovery of whole-vine photosynthesis and markedly improved sugar, colour and phenolics in Barbera variety of grapes. Retaining 10 shoots/m improved overall grape compositions as compared to Control.

CONCLUSIONS

In a grape variety Tas-A-Ganesh, the vegetative growth parameters like shoot length, cane diameter, inter nodal length, leaf area per shoot and per vine were significantly influenced with the increase in the number of shoots per vine. The data recorded on various yield and quality parameters suggest that the increase in number of bunches per vine reduces the berry diameter that is considered as important quality parameters in table grapes meant for export. The yield per vine increases with the increase in number of shoots per vine but, the total soluble solids were found to be decreased indicating that the yield per vine can be maintained by maintaining the proper number of shoots per vine. The quality changes reported in the study suggest that leaf area per shoot or per vine and also the cane diameter can contribute. The source-sink balance evolves in shoot thinning towards a higher supply of assimilates per unit of crop than that available in non-thinned canopies during the veraison-to-harvest period.

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