J. Hortl. Sci.
Vol. 9(1):18-22, 2014

Effect of canopy management practices during forward pruning on berry development and photosynthesis in Tas-A-Ganesh grapes

R.G. Somkuwar, S.D. Ramteke, J. Satisha, Mahadev Bhange and Prerna Itroutwar
National Research Centre for Grapes
Pune - 412307, India
E-mail: rgsomkuwar@yahoo.co.in

ABSTRACT

Effect of canopy manipulation during forward pruning on berry development and photosynthetic parameters was studied in Tas-A-Ganesh grape grafted onto Dogridge rootstock. Canopy manipulation including shoot thinning, leaf removal, shoot thinning with leaf removal, and shoot pinching, was done after forward pruning. Significant differences were observed in yield and quality. Shoot thinning to about 40 shoots per vine, with removal of three basal leaves, resulted in significantly higher yield, followed by that in shoot thinning alone. Lowest yield was recorded in the Control. Leaf removal drastically reduced bunch development affecting berry weight, diameter and length compared to other treatments. Among different canopy manipulation treatments, higher average bunch weight was recorded in shoot thinning plus leaf removal, whereas, lowest bunch weight was recorded with leaf removal alone. At harvest, the amount of total soluble solids in berries was low in leaf removal at pre-bloom stage, but increased in the treatment of shoot thinning with leaf removal, at the same stage. Different canopy manipulation treatments had significant impact on photosynthesis and transpiration rates. Overall results indicated that canopy manipulation practices such as shoot thinning, to retain 40 shoots per vine with or without leaf removal, followed by pinching, can be recommended to grape growers.

Key words: Grape, canopy managements practices, photosynthesis, quality, yield

INTRODUCTION

Grape is one of the major fruit crops of the country. Earlier, grapevines grown on their own roots performed well, since, most grape growing regions were free from soil-and water-salinity and water scarcity. However, with introduction of the rootstock in grape cultivation, changes in management practices became necessary. Since cost of production in grape is higher compared to that in all other horticultural crops, quality production is given due importance. Grapevine canopy management is aimed at optimizing carbon allocation to the fruit sink without disturbing growth or development in the other parts of grapevine, e.g., perennial structures such as roots. Given the complexity a grapevine canopy may have (microclimate, photosynthetic activity, yield and fruit quality) (Smart *et al*, 1985; Hunter *et al*, 1995), canopy management should be practiced with great care. Thorough consideration should be given to partitioning of assimilates between the site of production, accumulation and utilization, to reach this goal. In addition to primary effects like changed translocation patterns when seasonal practices (such as topping and different levels of defoliation) are applied (Hunter and Visser 1988a; Koblet *et al*, 1993), secondary effects like compensatory growth, take place (Hunter and Visser 1990). Leaves at different ages play a major role in import and export of food material from the source to the sink as growth progresses (Ruffiner *et al*, 1990; Hunter *et al*, 1994). This variation in canopy due to management practices like shoot-thinning and leaf-removal is known to directly affect assimilation dynamics. Berry growth and chemical composition can be regulated by manipulating source-sink relationship (Kliewer and Dokoozlian, 2005). Assimilate supply from a source may be increased by increasing leaf:fruit ratio, thus, generally leading to larger fruit size in grape (Petrie *et al*, 2000). However, abiotic stress (such as drought) can reduce leaf area and photosynthesis in the grapevine (Matthews and Anderson, 1988), thus limiting leaf function, and changing the source-sink balance. Functional relationship between source availability around bloom period and yield (Petrie *et al*, 2003) inherently implies that defoliation around flowering can reduce fruit-set, leading to loose clusters. With this in view, an effort was made to study the effect of seasonal canopy management practices on growth compensation, photosynthetic activity, yield and quality parameters in Tas-A-Ganesh grape grafted onto Dogridge rootstock.

MATERIAL AND METHODS

Vines and vineyard

A field experiment was conducted at the farm of National Research Centre for Grapes, Pune, during fruiting season of 2007-08. Pune is situated in mid-west Maharashtra at an altitude of 559m above mean sea level, at latitude of 18.32°N and longitude of 73.51°E. Seven-year old vines of Tas-A-Ganesh grape grafted onto Dogridge rootstock were selected for the study. The vines were on flat roof gable system of training, with North-South cordon orientation, spaced at 2.4m between rows and 1.2m between vines (thus, accommodating 1815 vines per hectare). Under tropical conditions, the vines were pruned twice a year once after harvest of the crop (foundation pruning) and another for fruits to develop (fruit pruning). All the recommended cultural practices were followed. The experiment was conducted in Randomized Block Design, with five treatments replicated four times. Twenty well-developed vines were selected under each canopy management treatment. Five different canopy management practices were imposed during the fruit pruning season, i.e., shoot thinning to 15 shoots per meter (retaining approximately 40 shoots per vine), removal of basal three leaves at pre-bloom stage, a combination of shoot thinning with leaf removal, and, shoot pinching at 10 leaves above the bunch, and a Control. Canopy management practices followed during the period of study are elaborated below.

Shoot thinning

Shoot thinning was done at 4 to 5 leaf stage, which was approximately about 16-17 days after pruning. All the secondary and tertiary shoots were hand-removed, and the remaining shoots were thinned evenly when necessary, to 15 shoots/m per vine.

Leaf removal

The fruit bunch appears at the 5th leaf on a newly emerged shoot. Basal three leaves on the shoot were removed during the pre-bloom to berry-setting stage (approximately 40-45 days after pruning).

Shoot pinching

For development of a bunch, approximately 10 leaves above the bunch are deemed sufficient. Hence, shoot pinching was done at the 10th leaf after bunch, and growth was stopped here.

Gas exchange parameters: Parameters such as stomatal conductance, photosynthetic rate and transpiration rate were recorded during the full-bloom stage. Recently matured leaves (5th - 6th leaf from tip) were used for measuring various parameters using Infra-Red Gas Analyzer (IRGA model Li 6400, LI-COR Biosciences, Nebraska, USA). Observations were recorded during bright sunlight during 11.0am to 12.30pm.

Yield and quality parameters

Bunch and berry traits: Fully mature and ripe bunches were harvested and weighed. Fifty berries from each bunch were randomly collected and weighed for calculating the average berry weight. Bunch and berry diameter was measured using a graduated scale.

Total soluble solids (°Brix): Fresh samples (berries) were pressed using a hand press and juice filtered through a muslin cloth. Extracted juice was used for recording total soluble solids (°Brix) using a hand refractometer.

Titratable acidity: Titratable acidity of fresh, filtered juice of 50 berry samples was determined using 0.1N NaOH and titrated till reaching the end-point (change from colourless to pink) with phenolphthalein indicator.

Statistical analysis

Analysis of variance was performed for each variable using SAS statistical package Version 9.3 (SAS Institute, Cary, NC). Least significant differences among treatments were calculated using the same software.

RESULTS AND DISCUSSION

Effect of canopy management practices on vegetative growth and photosynthesis

Results on vegetative growth parameters in relation to canopy management practices are presented in Table 1. Among the different treatments studied, differences for shoot length were non-significant. However, shoot thinning with leaf removal, shoot thinning, and shoot pinching, considerably increased shoot diameter. Shoot diameter in treatments was higher than in the Control. Though differences in inter-nodal length were significant, impact of canopy management practices on increasing internodal length was not experienced so much. When the shoot length had no effect, internodal length could not be improved in any of the treatments. Canopy management practices had no effect on total number of bunches per vine and LAI in Tas-A-Ganesh grape. It is evident that considerable growth was induced by shoot thinning and leaf removal. Increase in shoot diameter may be due to consolidation of food material in shoots supported by photosynthetically active leaves. In a similar study, Hunter *et al* (1995) concluded that an additional compensatory growth and energy demand brought about by lateral removal could have a direct impact on metabolic processes in the grapevine, particularly, availability and distribution of carbohydrates for bunch development.

Highest photosynthesis rate (11.30µmol/m^2/s) was recorded in shoot-thinning (6-7 leaf stage), followed by shoot pinching at 10 leaves above the bunch (10.77µmol/m^2/s) compared to the Control (8.05µmol/m^2/s). Results in the present investigation are in conformity with those of Koblet (1975) and Hunter and Visser (1988b) who concluded that changes in canopy microclimate increase photosynthetic activity and export photoassimalates. However, in this study, a noticeable enhancement of photosynthetic activity due to improved light intensity, and possibly, delayed senescence and abscission of the remaining leaves due to lateral-shoot thinning, were found to have a positive effect on yield. Canopy manipulation practices had no marked stimulating effect on stomatal conductance. Rate of transpiration varied from 2.34 to 3.05 µmol H_2O/ m^2/s and was comparable with findings of Hunter and Visser (1989) for defoliation per cent values for all leaf positions. Maximum rate of transpiration (3.05 µmol/m^2/s) was recorded with shoot-pinching at 10 leaves above the bunch, while, a drastic reduction in the rate of transpiration (2.00 µmol H_2O/ m^2/s, 2.34 µmol/m^2/s, respectively) was recorded with leaf removal (pre-bloom stage and shoot thinning at 6-7 leaf stage). Rate of transpiration was higher in shoot-pinching treatment compared to other treatments. Results of the present investigation are in line with Falis *et al* (1982) who reported a general decline in transpiration rate with removal of the shoot and leaves during the growth season. Shoot thinning had a positive effect on transpiration rate in grapevine.

Effect of canopy management practices on yield and berry composition

Data recorded on yield and berry composition figure in Table 2. Application of different canopy management

Table 1. Effect of canopy manipulation on vegetative growth and photosynthesis in grape cv. Tas-A-Ganesh

Treatment	Shoot length (cm)	Shoot dia. (mm)	Internodal length (cm)	No. of bunches/ vine	Leaf area index (LAI)	Photosynthesis (µmol/m^2/s)	Stomatal conductance (µmol/m^2/s)	Transpiration rate (µmol/m^2/s)
Shoot thinning (6-7 Leaf stage)	93.64 [ab]	9.13 [ab]	5.80 [a]	38.60 [a]	1.10 [a]	11.30 [a]	0.07 [ab]	2.34 [c]
Leaf removal (Pre-bloom stage)	99.07 [a]	8.56 [bc]	5.80 [a]	31.80 [a]	1.02 [a]	9.65 [c]	0.08 [ab]	2.00 [c]
Shoot thinning + Leaf removal	102.61[a]	9.57 [a]	5.30 [ab]	38.40 [a]	1.10 [a]	9.05 [d]	0.09 [a]	2.93 [ab]
Shoot pinching (10 leaves above the bunch)	88.27[ab]	8.87 [ab]	4.82 [bc]	38.60 [a]	0.98 [a]	10.77 [b]	0.09 [a]	3.05 [a]
Control	80.00 [b]	8.14 [c]	4.70 [c]	34.20 [a]	1.00 [a]	8.05 [e]	0.06 [b]	2.46 [bc]
CV %	15.28	5.97	7.92	14.32	9.42	1.11	20.12	15.27
CD *(P=0.05)*	-	0.709	0.561	-	-	0.146	-	0.523
Significance at $p \leq 0.05$	NS	*	*	NS	NS	**	NS	*

*Values followed by the same alphabet are statistically not significant at $p \leq 0.05$; NS: Not significant

Table 2. Effect of canopy management on yield and berry composition in grapes cv. Tas-A-Ganesh

Treatment	Bunch wt(g)	50-berry wt(g)	Berry length (mm)	Berry dia. (mm)	TSS (°Brix)	Juice pH	Acidity (%)	Yield/ vine (kg)
Shoot thinning (6-7 Leaf stage)	375.60 [a]	184.20 [a]	20.20 [b]	18.40[a]	20.20 [b]	3.59 [b]	0.52 [b]	12.75[a]
Leaf removal (Pre-bloom stage)	258.00 d	165.35 [d]	18.00 [d]	17.40[c]	18.60 [d]	3.65 [a]	0.43 [c]	10.80 [b]
Shoot thinning & Leaf removal	290.60 c	178.50 [b]	21.00 [a]	17.78[b]	21.00 [a]	3.58 [b]	0.55 [b]	11.14 [b]
Shoot pinching (10 leaves above bunch)	307.80 [b]	172.35 [c]	19.44 [c]	18.40 [a]	17.66 [c]	3.65 [a]	0.53 [b]	12.25 [a]
Control	235.60 [e]	133.00 [e]	19.56 [bc]	17.00 [d]	19.80 [bc]	3.58 [b]	0.62 [a]	10.09 [b]
CV %	1.38	1.60	2.51	1.48	2.51	0.95	7.99	6.84
CD *(P=0.05)*	5.440	3.579	0.663	0.354	0.663	0.046	0.056	1.047
Significance	**	**	**	**	**	*	**	*

*Values followed by the same alphabet are statistically not significant at $p \leq 0.05$

Table 3. Correlation coefficient between various growth, yield and photosynthesis parameters as influenced by canopy management practices

Parameters	Shoot length (cm)	Yield per vine (kg)	Photosynthesis (μmol/cm²/s)	Transpiration rate (μmol $H_2O/m^2/s$)	Bunch wt (g)	50-berry wt (g)	TSS (°Brix)
Shoot length (cm)	1	0.228	-0.076	0.027	0.173	0.416*	-0.014
Yield per vine (kg)		1	0.622*	0.213	0.784**	0.662*	-0.150
Photosynthesis (μmol/cm²/s)			1	0.115	0.604*	0.446*	-0.038
Transpiration rate (μmol $H_2O/m^2/s$)				1	0.132	0.180	-0.019
Bunch wt (g)					1	0.818**	0.124
50-berry wt (g)						1	0.077
TSS (°Brix)					1.000		

*Significant at $p \leq 0.05$; **Significant at $p \leq 0.01$

practices resulted in variation in berry quality. Yield per vine ranged from 10.09kg in the Control to 12.75kg in shoot thinning treatment at 6-7 leaf stage. Significant differences were recorded for yield among treatments. Highest yield was recorded when shoot-thinning was performed at 6-7 leaf stage (12.75kg/vine), followed by shoot-pinching at 10th leaf above the bunch (12.25kg/vine) over the Control (10.09kg/vine). Shoot thinning may have helped the vine improve its photosynthetic activity, thereby increasing source-strength required for bunch development (Fig 1). Similar studies were reported by Hunter *et al* (1995) in Cabernet Sauvignon. Grapevines tend to have reduced cluster weight with leaf-removal. We presume that this is in response to a lower shoot vigor of the grapevine at leaf removal compared with rest of the treatments, when more vigorously growing shoots during fruit-set may compete with clusters at anthesis for available carbohydrates (Vasconcelos *et al*, 2009).

Berry quality parameters varied due to canopy manipulation practices. Berry diameter increased with canopy manipulation treatments. Maximum berry diameter (17.78mm) was recorded in shoot-thinning with leaf-removal. Results of the present investigation are in accordance with Keller (2009) who reported that berry growth after flowering was highly dependent on assimilate supply. Kemp (2010) reported that removal of leaves early in the first stage of berry growth may disrupt cell division and growth due to reduced assimilates. Keller (2009) explained that environmental factors, especially heat stress, seemed to restrict berry size when imposed before the lag phase of growth. Spayd *et al* (2002) reported that sun exposed berries get heated by the incoming radiation, and that a rise in temperature due to early leaf-removal can potentially limit berry size.

Significant variation in total soluble solids (TSS) and titratable acidity was recorded among different canopy management treatments. Higher total soluble solids and acidity were recorded with a combination of shoot-thinning and leaf-removal (21.00°Brix and 0.55%, respectively), whereas, lowest total soluble solids (18.60°Brix) and acidity (0.43%) were recorded in leaf-removal treatment. Increase in total soluble solids may have been due to a reduction in the canopy area which resulted in exposure of the bunches to sunlight. These results are in accordance with Price *et al* (1995) who reported exposed Pinot Noir berries as having the highest TSS and lowest acidity; however, there was no difference in pH when compared with moderately-exposed and naturally-shaded fruit. Leaf removal at four weeks post-bloom decreased TSS but did not affect titrable acidity or pH compared to the shaded fruit (Vasconcelos and Castagnoli, 2000). Changes in total soluble solids in a berry may have been due to canopy management practices that resulted in stress to the vine. Early-season carbon supply limitation, whether imposed by environmental stress or by cultural practices (such as leaf-removal) may restrict berry size and/or number, but these do not usually impair berry ripening (Keller 2009). This is clearly demonstrated in his study. Poni *et al* (2006) emphasized that defoliation at or close to flowering should be avoided in low-vigour vines as it affects yield and berry size adversely. However, results from leaf-removal depend upon climate, variety, clone and trellis system, all of which affect sunlight and temperature within a grapevine canopy.

A positive correlation between photosynthesis and yield per vine and average bunch weight is also reported in the present investigation (Table 3) indicating the importance of canopy management practices during forward pruning to achieve quality grape production.

REFERENCES

Fails, B.S., Lewis, A.J. and Barden, J.A. 1982. Net photosynthesis and transpiration of sun- and shade – grown *Ficus benjamina* leaves. *J. Amer. Soc. Hort. Sci.*, **107**:758-761

Hunter, J.J. and Visser, J.H. 1988a. Distribution of ^{14}C-

photosynthate in the shoot of *Vitis vinifera* L. cv. Cabernet Sauvignon. I. The effect of leaf position and development stage of the vine. *S. Afr. J. Enol. Vitic.,* **9**:3-9

Hunter, J.J. and Visser, J.H. 1988b. Distribution of ^{14}C-photosynthate in the shoot of *Vitis vinifera* L. cv. Cabernet Sauvignon. II. The effect of partial defoliation. *S. Afr. J. Enol. Vitic.*, **9**:10-15

Hunter, J.J., and Visser, J.H. 1989. The effect of partial defoliation, leaf position and developmental stage of the vine on leaf chlorophy concentration in relation to the photosynthetic activity and light intensity in the canopy of *Vitis vinifera* L. cv. Cabernet Sauvignon. *S. Afr. J. Enol. Vitic.,* **10**:67-73

Hunter, J.J. and Visser, J.H. 1990. The effect of partial defoliation on growth characteristics of *Vitis vinifera* L. cv. Cabernet Sauvignon. I. Vegetative growth. *S. Afr. J. Enol. Vitic.,* **11**:18-25

Hunter, J.J., Skrivan, R. and Ruffener, H.P. 1994. Diurnal and seasonal physiological changes in leaves of *Vitis vinifera* L. CO_2 assimilation rates, sugar levels and sucrolytic enzymes activity. *Vitis,* **33**:189-195

Hunter, J.J., Ruffner, H.P., Volschenk, C.G. and LE Roux, D.J. 1995. Partial defoliation of *Vitis vinifera* L. cv. Cabernet Sauvignon/99 Richter: Effect on root growth, canopy efficacy, grape composition and wine quality. *Amer. J. Enol. Vitic.,* **46**:306-314

Keller, M. 2009. Managing grapevines to optimize fruit development in a challenging environment: a climate change primer for viticulturists. *Aust. J. Grape Wine Res.,* **16**:56-69

Kemp, B. 2010. The effect of the timing of leaf removal on berry ripening, flavour and aroma compounds in Pinot Noir wines. Ph.D. thesis submitted to Lincoln University, New Zealand, pp. 236

Kliewer, W.M. and Dokoozlian, N.K. 2005. Leaf area/crop weight ratios of grapevines: influence on fruit composition and wine quality. *Amer. J. Enol. Vitic.,* **56**:170-181

Koblet, W. 1975. Wanderung von Assimilaten uas verschiedenen Rebenblattern wahrend der reifephase der Trauben. *Wein-Wiss*., **30**:241-249

Koblet, W., Candolfi-Vasconcelos, M.C., Aeschimann, E. and Howell, G.S. 1993. Influence of defoliation, rootstock and training system on Pinot Noir grapevines. I. Mobilization and accumulation of assimilates in woody tissue. *Vitic. Enol. Sci.,* **48**:104-108

Matthews, M.A. and Anderson, M.M. 1988. Fruit ripening in *Vitis vinifera* L.: Responses to seasonal water deficits. *Amer. J. Enol. Vitic.,* **39**:313-320

Petrie, P., Trought, M. and Howell, G. 2000. Fruit composition and ripening of Pinot Noir (*Vitis vinifera* L.) in relation to leaf area. *Aust. J. Grape Wine Res.,* **6**:46-51

Petrie, P.R., Dunn, G.M., Martin, S.R., Krstic, M.P. and Clin-geleffer, P.R. 2003. Crop stabilization. In: Grape growing at the edge. Australian Society of Viticulture and Oenology Seminar. S.M. Bell *et al* (Eds.), pp. 11-16, ASVO, Adelaide

Poni, S., Casalini, L., Bernizzoini, F.S., Civardi and Intrieri, C. 2006. Effects of early defoliation on shoot photosynthesis, yield components and grape composition. *Amer. J. Enol. Vitic.,* **57**:397-407

Price, S.F., Breen, P.J., Valalladao, M. and Watson, B.Y. 1995. Cluster sun exposure and quercetin in grapes and wine. *Amer. J. Enol. Vitic.,* **46**:187-194

Ruffner, H.P., Adler, S. And Rast, D.M. 1990. Soluble and wall associated forms of invertase in *vitis vinifera*. *Phytochem.,* **29**:2083-2086

Smart, R.E., Robinson, J.B., Due, G.R. and Brien, C.J. 1985. Canopy microclimate modification for the cultivar Shiraz II. Effects on must and wine composition. *Vitis,* **24**:119-128

Spayd, S.E., Tarara, J.M., Mee, D.L. and Ferguson, J.C. 2002. Separation of sunlight & temperature effects on compostion of *Vitis Vinifera* cv. Merlot berries. *Amer. J. Eno. Vitic.,* **53**:171-182

Vasconcelos, M.C., Greven, M., Winefield, C.S., Trought, M.C.T. and Raw, V. 2009. The flowering process of *Vitis vinifera*: A review. *Amer. J. Enol. Vitic.,* **60**:411–433

Vasconcelos, S.C. and Castagnoli, S. 2000. Leaf canopy structure and vine performance. *Amer. J. Enol. Vitic.,* **51**:390–396

(MS Received 30 May 2013, Revised 03 December 2013, Accepted 28 February 2014)