

Effect of Pruning Severity on Vegetative, Physiological, Yield and Quality Attributes in Grape (*Vitis vinifera* L.): A Review

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<http://dx.doi.org/10.12944/CARJ.3.1.06>

(Received: March 11, 2015; Accepted: May 2, 2015)

ABSTRACT

Grape is one among the most delicious, refreshing and nourishing fruits of the world. It is one of the earliest fruits grown by man. The berries are a good source of sugars and minerals like Ca, Mg, Fe, and vitamins like B1, B2, and C. Grape has so many uses and is so unique that no fruit can challenge their superiority. Crop load is the most important factor affecting yield and cluster quality as well as vine vigor of both seeded and seedless varieties. Hence, an optimum canopy size and bunch number per vine are to be maintained for achieving better fruit Quality which warrants proper balancing between vigour and capacity. The pruning requirement of different varieties differs as per their growth behaviour. Therefore, variety-specific standardization of pruning is essential for any grape cultivars for harnessing potential yield and quality. In this view, it is essential to get scientific information on the pruning requirement of grapes. Pruning all the matured canes to fruit bud level, as adopted by local grape growers results in more exploitation of reserved food material leading to loss of vigour, quality and early setting of senility in vines. Heavy bearing of vines results in poor quality fruits with low TSS and high fruit acidity.

Key words: Canopy size, crop load, grape, pruning level, vigour.

INTRODUCTION

Pruning is the most important cultural practice in the management of grapevine to sustain production and productivity. Pruning methods have been developed to balance fruit productivity, vegetative growth and attain maximum yield without reducing vine vigour. An increase in the severity of pruning will increase the vigour of individual shoot at the expense of total growth and crop (Weaver, 1976 and Celik *et al.*, 1998).

Pruning the vines for optimum cropping according to the vigour is the most reliable method to maintain balance between growth and production. The vine should carry moderate number of canes in order to maintain the uniform vigour throughout its life span. So, canopy, vigour and productivity can be balanced through pruning levels. Eynard and Gay

(1992) suggested that equilibrium of crop load versus vegetative development is important for production of quality fruits. Hence, it was felt necessary to study the effect of different pruning severities of any grape cultivars for their performance in newer climatic conditions.

Effect of pruning levels on vegetative characters

Weight of the pruned material

In 'Niagra' grapes decreased pruning severity (Morris *et al.*, 1985) allowing increased number of nodes per cane (3 to 9) resulted in reduced pruning weight per vine (1.53 to 1.12 kg). Mortensen and Harris (1989) found that vigorous muscadine cultivars and selections such as 'Hunt', 'Dixie' and 'N.C. 77-21' produced over 4.5 kg (9.9 lb) of pruned wood while less vigorous muscadines such as 'Cowart', 'Magoon', Ga. 10-6-1 and Ga. 24-16

produced less than 1.8 kg (4.0 lb) of pruned wood. According to Robinson and Smart (1991), pruning weight is proportional to leaf area carried on the shoots in the previous growing season. Calculation of mean cane weight gives a useful indication of shoot vigour. The ratio of yield to pruning weight gives a good indication of balance between fruit and vegetative growth. An optimal level for moderately vigorous vine is a yield/pruning weight ratio of 5:10 g. Smith (1996) evaluated eleven 'Chardonnay' clones and concluded that high yielding clones had large pruning weights, yield and pruning weight ratio. Kilby (1999) observed that in 'Merlot', spur pruning with 2 buds produced more pruning weight (246 g/vine) than spur pruning with four buds (218 g/vine).

In cv. Cabernet Sauvignon, hedge pruning (Lopes *et al.*, 2000) resulted in less pruning weight (0.73 kg/vine) as compared to spur pruning (0.96 kg/vine). Velu (2001) observed that in 'Muscat', severe pruning *viz.*, pruning 67 % of the canes to 5 bud level and 33 % to 2 bud level recorded the maximum pruned weight (1.19 kg/vine) in both the seasons (summer and winter). Kadu (2004) compared fifteen wine grape varieties for vine vigour by means of pruning weight per vine and number of canes per vine. Pina and Bautista (2006) reported that vigour of the vine can be expressed by relating it to the pruning waste weight. Among different grape cultivars, cv. 'Sultanina' showed the highest pruning weight (2.39 kg/vine) whereas cv. 'Moscatel de Alejandria' recorded lowest pruning weight of 0.62 kg/vine. According to Poling (2007), pruning *V. vinifera* grapevines weighed between 0.7 and 1.5 kg (1.5 and 3.3 lb) was considered as well balanced. Chalak (2008) observed that maximum pruning weight (887.42 g) was recorded in 4 buds/cane while it was minimum (525.43 g) in 12 buds/cane. Geller and Kurtural (2013) studied the mechanical canopy and crop-load management of Pinot Gris grapes in a warm climate and identified a mechanical hedging and shoot thinning method. In that, a 100 mm spur height was retained during the dormant season and 35 shoots/m of row was retained at Eichhorn-Lorenz (E-L) scale stage, which was found better to optimize crop load without adversely affecting pruning weight in a warm climate.

Bud sprouting

The bud load on a vine has a definite effect on bud sprouting. Daniel and Rao (1969) observed a slight delay of bud sprouting by 3 to 4 days in the least severe pruning (7 node level) in comparison to the most severe pruning (1 node level) in cv. Anabe-Shahi grapes. Godara *et al.* (1977) reported that severely pruned vines took lesser number of days for bud sprouting and flowering compared to lightly pruned ones in 'Beauty Seedless' grapes. Kumar and Tomer (1978) reported apical dominance in 'Himrod' grape due to pruning. It was observed by them that in 6 buds/cane pruning level, sixth and fifth bud gave 100 % and 97.50 % sprouting, respectively. However, in fourth and third bud, it was only 35 % and 7.5 % respectively. Christensen (1986) observed apical dominance in bud emergence in cv. Thompson Seedless and examined buds from position one to twelve. He stated that apical buds (12th bud) sprouted better as compared to basal buds. Palma *et al.* (2000) reported that higher bud load per vine delayed the bud sprouting compared to lower bud load treatment in cv. Victoria. Velu (2001) reported that in 'Muscat', where the pruning level was severe (pruning 67 % of the canes to 5 bud level and 33 % to 2 bud level), taken lesser number of days (40.06 days) for bud sprouting. Chalak (2008) observed that the bud sprouting percentage decreased with less pruning intensity. The maximum bud sprouting (38.79%) was recorded in 4 buds per cane and it was minimum (23.20%) in 12 buds/cane. With increase in buds per vine (24 to 27), there was a decrease in sprouted buds (100 to 47%) in cv. Cabernet Sauvignon (Schalkwyk and Archer, 2008). Kohale *et al.* (2013) stated that in cv. Sharad Seedless, pruning at 4 buds per cane had the maximum bud sprouting percentage. The production of panicles on the cane was found to be more by maintaining 6 buds per cane. Further, in 8 buds/cane level, the number of days for bud sprouting (11.56 days) was extended as compared to 6 buds/cane level (10.37 days) and 4 buds per cane (9.00 days).

Leaf area

Studied the influence of pruning on leaf area of three grape varieties *viz.*, Bangalore Blue, Khandari and Muscat (Mohanakumaran, 1963) found that upto a certain point, there was increase in

berry weight and quality. In another study observed positive and significant correlation between leaf area of vine and weight of bunches in vine while no correlation between the leaf area and number of bunches was observed. Buttrose (1966) reported that minimal leaf area for growth of aerial organs was estimated to be 1500 cm² (12 leaves) but in the field where bunches have more berries, a greater leaf area would be required. Edson *et al.* (1993) stated that the increased crop load per vine reduced the total leaf area in 'Seyval' grape vines. Koblet *et al.* (1994) reported that the total yield and yield of fruits were reduced as leaf area decreased and recorded that each 1 g of grapes produced a required leaf area of 16-26 cm². Zamboni *et al.* (1997) stated that vines with high number of nodes developed a larger total leaf area compared to those having lower node number but had the same 'total leaf area/fruit yield ratio'. Gicheol and Chool (1999) reported that the leaf area tended to be lesser on less severely pruned canes in *Vitis labrusca* B. cv. Kyoho. Lopes *et al.* (2000) observed that higher crop load per vine results in reduction in leaf area in 'Cabernet Sauvignon' grape vines. Velu (2001) in 'Muscat' observed the maximum leaf area (114.14 cm²) at the 10th leaf stage in pruning levels *viz.*, pruning 67 % of the canes to 5 bud level and 33 % to 2 bud level. Chougule (2004) reported that in 'Thompson Seedless', the maximum leaf area (241.75 cm²) was obtained in cane density of 30 per vine while the minimum leaf area (136.17 cm²) was noticed with 40 cane density per vine. According to Kliewer and Dokoozlian (2005), optimal leaf area (m²) per m canopy length and leaf area density (m²/m³) for single-canopy (SC) type trellis-training systems ranged from 2 to 5 m²/m, and 3 to 7 m²/m³, respectively. Grapevines with ratios that fell within the ranges for each of those parameters were considered well balanced and capable of producing high-quality fruit and wines. Cangi and Kilic (2011) reported that the mean leaf area decreased with increased bud loading levels. Brandon *et al.* (2012) reported that decrease in severity of pruning, increased leaf area per vine and leaf layer number in a linear manner.

Shoot growth

Examined when shoot length and diameter were 40-50% greater in 'Seperavi' and 'Rkatsiteli', the yields were 10 and 15% greater, respectively (Lomkatsi, 1971). Owing to the phenomenon of

apical dominance in grape vines, irrespective of the number of nodes left on a cane, only one to two nodes put forth effective shoot growth. The bud load on a vine has a definite effect on shoot growth. Dass and Melanta (1972) observed that the maximum productive shoots were produced in vines of cv. Anab-e-Shahi pruned to five buds per cane as compared to seven buds per cane. Severely pruned vines had more vegetative growth compared to lightly pruned vines in cv. Bangalore Purple grapes (Shinde and Rane, 1979). Edson *et al.* (1993) observed that increased crop load per vine decreased shoot growth in 'Seyval' grape vines. Salem *et al.* (1997) reported that the increased bud load per vine decreased the shoot growth in cv. Kings Ruby and cv. Thompson Seedless. Lopes *et al.* (2000) observed that the higher crop load per vine reduced the shoot growth in cv. Cabernet Sauvignon. However, Reddy (1982) noticed the maximum shoot growth in 8 bud level followed by 6 bud level in cv. Anab-e-Shahi. Velu (2001) revealed that in 'Muscat', severe the pruning level (pruning 67 % of the canes to 5 bud level and 33 % to 2 bud level), more was the shoot growth (63.22 cm) obtained. Benismail *et al.* (2007) studied the effect of bud load and canopy management on growth components in grape cv. Cardinal and found that the shoot growth was reduced with increased bud load per plant. He also opined that the vine production may be improved by the adopting appropriate plant management practices with the aim of establishing a balance between vegetative growth and fruit development. Kohale *et al.* (2013) observed that the effect of time and intensity of pruning had a significant effect on cane length in cv. Sharad Seedless.

Cane diameter

In 'Pusa Seedless' (Ghugare and Mukherjee, 1967) observed a positive correlation between the cane Diameter, number of bunches produced per cane and bunch weight. Hulamani *et al.* (1967) observed that the bunch weight, berry thickness and net yield directly influenced with the thickness of cane. More productivity was recorded in canes with more than 10 mm diameter. Further, they recorded increased fruitfulness with increased cane thickness in cv. Bhokri. Bindra (1977) revealed in 'Perlette' grape, the canes with thickness ranging from 9 to 11 mm were most productive. Rangareddy (1996) reported that there was a positive correlation

between thickness of cane and productivity in grape cv. Anab-e-Shahi. Chougule (2004) observed that the maximum cane diameter (10.52 mm) was recorded in vines with cane density of 30 per vine in cv. Thompson Seedless, while the minimum cane diameter (6.65 mm) was noticed with density of 40 canes per vine. Somkuwar and Ramteke (2006) noticed that higher the bunch number per vine resulted in reduction in shoot diameter. Chalak (2008) stated that cane diameter was decreased as the pruning intensity decreased in cv. Tas-A-Ganesh. It was the maximum (7.99 mm) in 4 buds per cane and the minimum (5.10 mm) in 12 buds per cane.

Internodal length

According to Shikhamany (1983), vigour of the grape vine had been an important growth attribute for distinguishing different grape varieties. It can be judged on the basis of pruning weight, length of the cane, length of the internode before this node, cane diameter and number of canes per vine. Sommer *et al.* (1995) observed that minimal pruning had a stunting effect on growth resulted in shorter shoots with shorter internodes and smaller leaves. Chalak (2008) reported that the maximum internodal length (3.48 cm) was recorded in 12 buds/cane while it was minimum (3.22 cm) in 4 buds/cane, which was at par with 6 buds/cane (3.24 cm). Brandon *et al.* (2012) reported that as pruning severity increased from 40+10 to 20+10, shoots per hectare decreased and the internodal distance between the shoots increased.

Plant nutrient status

Considering the seasonal variations in leaf concentrations of N, P and K, it appears that the most suitable organ to analyze is petiole tissue and the most suitable time for sampling is during the bloom period (Conradie, 1981). Ahlawat and Yamdagni (1991) observed a significant decrease in levels of petiole N,P,K contents with the advancement of berry developmental stages. Jeet Ram *et al.* (1993) reported that higher bud load per vine (100 canes per vine) reduced the petiole nutrient contents compared to lower bud load (50 canes per vine). They observed that petiole N,P and K contents were lower in the vines with higher bud load in 'Perlette' grapes. Keller *et al.* (1998) reported that yield was determined primarily by N availability at bloom stage. The low N supply during bloom reduced fruit set in grape cultivar

Cabernet Sauvignon. Mc. Artney and Ferree (1999) observed that petiole N was negatively related to the number of shoots per vine. According to Velu (2001), the maximum petiole N (2.038%), P (0.742%) and K (2.859%) were observed in pruning level viz., pruning 67 % of the canes to 5 bud level and 33 % to 2 bud level. Chougule (2004) reported that the maximum petiole N content (2.24%), P content (1.04%) and K content (3.00%) were registered with a cane density of 35 per vine in cv. Thompson Seedless, while the minimum petiole N content (0.69%), P (0.36%) and K content (1.34%) were recorded with a cane density of 30 per vine. Sharma and Shikhamany (2008) assessed the petiole nutrient content for the grape cultivar Thompson Seedless grafted on Dogridge rootstock at full bloom stage and reported that the critical nutrient ranges for N, P and K were respectively 1.44 - 1.80, 0.28 - 0.36 and 1.61 - 2.95 %, that tends to affect vine vigour and productivity.

Effect of pruning severity on physiological parameters

Chlorophyll content

Slavtcheva (1996) noticed positive correlations between yield per vine and photosynthetic rate and leaf area per vine. Velu (2001) observed that the maximum chlorophyll content (2.699 mg/g) was registered at a pruning level of 67 % of canes to 5 bud level and 33 % of the canes to 2 bud level. Kumar (1999) reported that in cv. Bangalore Blue, the total chlorophyll content during summer was found to be significantly higher than during winter season. Satisha *et al.* (2000) revealed a positive correlation between yield per vine and photosynthetic rate and leaf area per vine. The berry diameter was more when fifteen leaves were left per cane.

Effect of pruning severity on yield parameters

Bunch traits

Kumar and Tomer (1978) retained 60 buds on each vine in 'Himrod' grape and revealed that 5 buds with 12 canes pruning gave the maximum bunch weight (237.69 g) as compared to 6 buds with 10 canes (204.50 g). Joon and Singh (1983) observed a reduction in bunch weight due to pruning levels in 'Delight' grape. It was recorded that 2 buds spur gave more bunch weight (368.33 g) as compared to 6 buds spur (352.0 g). According to Gray *et al.* (1996), pruning the muscadine cultivar 'Alachua' to five nodes (a medium pruning severity

level) yielded more bunches than when the vine was pruned two to three nodes and numerically more than vines pruned to ten nodes without the steady weakening of the vine. Avenant (1998) revealed that in cv. Festival Seedless, the average number of bunches/vine increased linearly from 8.92 to 22.50 as cane density increased from 4 to 12 canes with 14 buds on each cane. Lopes *et al.* (2000) recorded that in cv. Cabernet Sauvignon, mechanical pruning produced more number of bunches/vine (60.30) as compared to hand pruning (28.93). Striegler *et al.* (2000) studied the effect of certain pruning method on yield of 'Sunbelt' grapes and revealed that minimally pruned vines had highest clusters/vine, lowest cluster weight, and lowest berry weight among the treatments. Velu (2001) observed that in cv. Muscat, the maximum number of bunches/vine (25.38) was obtained in pruning all the canes to 5 bud level. Savic and Petranovic (2004) reported an increase in number of bunches/vine from 15.58 to 21.46 with increase in bud load from 12 to 24 buds/vine in 'Grenache' grape. The average number of bunches/vine of both "Flame Seedless" and "Crimson Seedless", grapevine was gradually enhanced with increasing bud load/vine (Khamis *et al.*, 2008).

According to Main and Morris (2008), mechanically pruned vines of 'Cynthiana' grapes had produced 38 % more clusters as compared to hand pruning. Kohale *et al.* (2013) reported in 'Sharad Seedless' that eight buds/cane level recorded the maximum number of bunches (30.68) per vine, whereas in six buds/cane and 4 buds/cane, the number of bunches were 29.04 and 27.03, respectively. Somkuwar and Ramteke (2006) reported that to produce the quality grapes, it requires careful control of crop size to balance the amount of fruit to vegetative growth, fruit quality and adequate vine growth for consistent productivity. Excess fruit production lead to poor fruit quality and reduced vegetative growth resulting in poor yield in the later years. Havinal (2007) studied the bunch shape in wine grape varieties where shapes of bunches recorded in 'Viognier' and 'Ugni Blanc' were found to be long cylindrical, 'Pinot Meunier' and 'Pinot Noir' to be globular and 'Cabernet Sauvignon', 'Merlot' and 'Syrah' to be cylindrical. Chalak (2008) observed that in 6 buds/cane pruning, the maximum bunch length (13.20 cm) was recorded in the variety Cabernet Franc. In 'Muscat' Velu (2001) recorded the

maximum bunch weight (212.30 g) by pruning 67 % of the canes to 5 bud level and 33 % of canes to 2 bud level. According to Palanichamy *et al.* (2004), among the three pruning treatments *viz.*, 4, 6 and 8 buds per cane retaining uniformly 12 canes per vine on the 'head' system, the maximum number of bunches (36.2/vine) were obtained with pruning at 6 bud level. However, the maximum bunch weight (234 g) was recorded at 4 bud pruning level in grape cv. Pusa Navrang. Ahmad (2008) reported the maximum bunch weight of 138.12 g and 152.24 g with pruning severity of 5 buds/cane and 12 canes/vine, respectively. Chalak (2008) observed in cv. Cabernet Sauvignon, the maximum number of bunches (57.00) in 12 buds/cane pruning level which was at par with 8 buds/cane (41.81) and 10 buds/cane (40.97). The minimum number of bunches (15.11) was recorded in 4 buds/cane pruning level which was at par with 6 buds/cane level (24.88). It was also observed in the variety Cabernet Sauvignon the maximum bunch weight (199.93 g) in 4 buds/cane level and it was at par with 6 buds/cane level (118.72 g) and 10 buds/canes (117.66 g). Bunch weight was generally higher on vines with a bud load of 16 buds per vine than those with higher bud load of 32 buds per vine. The results also revealed that bunch weight is often higher under lower bud loads (Popescu, 2012).

Yield

According to Chadha and Kumar (1970), pruning 4 bud level gave a significantly higher yield than 6 bud pruning. The highest yield was found in case of 4 bud pruning with 50 canes per vine. Byrne and Howell (1978) tested different pruning levels and found that as severity of pruning increased from 50+10 to 10+10 (No. of buds retained/vine for first pound of pruning + No. of buds retained/vine for each additional pound of pruning), yield decreased from 7.0 kg/vine to 3.6 kg/vine. Joon and Singh (1983) maintained 40 buds per vine in cv. Delight grapes and observed that the average yield per vine increased with decreased intensity of pruning. Vines pruned with 6 buds gave significantly higher yields (27.85 kg/vine) as compared to 2 bud spur (16.25 g/vine) and 4 bud spur pruning (21.93 kg/vine). Jackson *et al.* (1984) reported that there was an increase in yields in direct proportion to the higher node number. Thatai *et al.* (1987) reported that, in 'Perlette' grape, 12 canes with 4 buds/cane gave maximum yield per vine (3.66 kg) as compared to 10 canes with 3 buds/

cane (2.56 kg) and 14 canes with 5 buds/cane (3.38 kg). Reynolds *et al.* (1994) revealed that yield, cluster per vine, and crop load increased with increasing shoot density but cluster weight, berries per cluster and berry weight reduced significantly. Avenant (1998) concluded that in cv. Festival Seedless, the yield per vine increased linearly (3.93 to 11.87 kg/vine) as pruning intensity decreased from 12 to 4 canes with 14 buds/cane. Miller and Howell (1998) revealed that in cv. Concord, yield increased from 4.0 to 23.0 kg per vine as bud load increased from 20 to 160 buds per vine. Sehwat *et al.* (1998) observed that the severity of pruning lowered the leaf per bunch ratio and bunch weight while yield increased with increasing number of buds per cane.

Chougule (2004) observed that in cv. Thompson Seedless, the highest yield per vine (15.96 kg) was recorded with a cane density of 35 per vine. However, the low yield per vine (8.43 kg) was registered in cane density of 30 per vine. It was observed in 'Merlot' that when the vines were pruned at 2 to 9 buds per cane; the maximum yield was recorded in fifth bud position followed by sixth bud position. However, in cv. Sauvignon Blanc, it was in fourth and sixth bud position (Anon, 2006). Heazlewood *et al.* (2006) studied the effect of four pruning treatments comprising of 10, 20, 30 and 40 nodes per vine in 8-year-old vines of cv. Pinot Noir on yield and cane carbohydrate concentration from 2002 to 2004. For each of the yield components measured, there was a significant year effect but no interaction between year and pruning treatment. Chalak (2008) observed that 4 buds per cane level recorded the maximum yield per vine in *viz.*, 'Pinot Noir' (3.80 kg/vine), 'Ugni Blanc' (5.05 kg/vine) and 'Sauvignon Blanc' (5.18 kg/vine). The 6 buds per cane level recorded the maximum yield per vine in 'Syrah' (8.21 kg) and 'Grenache' (7.89 kg/vine). Ahmad (2008) observed that in Himrod cultivar, the vines pruned at 5 buds per cane registered the highest yield (11.53 kg/vine). However, 6 buds per cane gave minimum yield (10.59 kg/vine). Terence (2008) examined the effect of pruning level and canopy division on yield characteristics in Concord grapes. Number of nodes retained per vine ranged from 56 to 383 on five single-wire trained treatments and 90 to 260 nodes on three Geneva double-curtain trained treatments. Increasing retained nodes above 260 nodes on single-wire training system did not

increase yield but additionally delayed juice soluble solids accumulation and harvest. Kohale *et al.* (2013) reported that in cv. Sharad Seedless, the maximum yield (18.92 t/ha.) was recorded in 8 buds per cane whereas in 6 buds per cane, it was 18.26 t/ha and with 4 buds per cane it was 17.25 t/ha. According to Lydia and Kurtural (2013), the interaction effect of three pruning systems and two canopy management practices on yield of syrah grapes revealed that cane pruned vines with 32 shoots per 30 cm of row yielded 22 t/ha and paved the way for rejuvenation of grape vines that declined in productivity. Miele and Antenor (2013) studied the effect of the pruning and thinning intensity on the variables related to yield components in grapevine Cabernet Sauvignon and reported that pruning and thinning had highly significant effect on the vineyard yield which varied from 10,971 kg/ha (short pruning-75% cluster thinning) to 32,819 kg/ha (long pruning+0% cluster thinning) as average of four years.

Berry attributes

Dass and Melanta (1972) reported that the crop load affects berry weight and quality of berries. Fitzgerald and Patterson (1994) stated that the berry weight was increased by thinning, but was not affected by leaf removal. Kumar (1999) observed in cv. Bangalore Blue that the number of berries recorded in a bunch at harvest was 41.8 and 40.4 during the winter and summer seasons of growth, respectively. It was also reported that the length of the berry significantly increased during the winter season (19.42 mm) compared to summer season (19.29 mm). Velu (2001) observed in cv. Muscat that severely pruned canes (pruning 67 % of the canes to 5 bud level and 33 % of canes to 2 bud level) produced more number of berries/bunch (56.6). Chougule (2004) observed in cv. Thompson Seedless that the number of berries/bunch was affected due to cane density when 35 canes/vine had the maximum berries/bunch (121.40) compared to 30 canes/vine (106.20) and 40 canes/vine (113.60). The highest average berry weight (1.5 g) recorded in cv. Pusa Navrang at 4 bud level of pruning that differed significantly with each other among all the three pruning treatments *viz.*, 4, 6 and 8 buds per cane retaining uniformly 12 canes per vine on the 'head' system. As the severity of pruning reduced, the berry weight decreased, which means they are inversely proportionate to each other (Palanichamy

et al., 2004). Havinal (2007) evaluated twelve wine grape varieties for growth, yield and quality. It was recorded the maximum hundred berry weight (169.88 g) in the variety 'Ugni Blanc' and it was (105.0 g) in the variety Merlot. Somkuwar and Ramteke (2007) recorded the effect of number of bunches on 25 berry weight. It was observed that increase in number of bunches/vine (30 to 50) resulted into decrease in 25 berry weight (21.75 to 19.82 g) in cv. Sharad Seedless. Chalak (2008) observed that the maximum number of berries per bunch (93.22) was recorded in 10 buds/cane level and it was the minimum (87.33) in 4 buds/cane level. It was also noticed that the maximum hundred berry weight (110.67 g) was obtained in 4 buds/cane level and it was at par with 6 buds/cane (109.30 g) and 8 buds/cane level (108.80 g) in cv. Cabernet Sauvignon.

Effect of pruning severity on quality parameters

TSS

Chadha and Kumar (1970) stated that the total soluble solids and reducing sugar content increased with the severity of pruning. Abramov (1973) recorded better fruit quality and better wine obtained from Mal'bek vines on which 12-14 buds were left after pruning than in those left with 8-10 buds per shoot. Singhrot *et al.* (1977) revealed that, TSS was negatively correlated with number of buds/cane. The maximum TSS (23.50°Brix) was observed in 6 buds per cane pruning level. Kumar and Tomer (1978) observed in cv. Himrod grape that the TSS decreased from 18.5°Brix to 16.85°Brix with the corresponding pruning level increased from 2 buds per spur to 6 buds per spur. Sims *et al.* (1990) recorded in 'Muscadine' grape, a reduction in Total Soluble Solids as a result of light pruning. The highest TSS (16.50°Brix) was recorded in 400 nodes per vine and the lowest TSS (16.00°Brix) in 800 nodes per vine. Sehwat *et al.* (1998) stated that TSS increased with increased pruning severity in cv. Thompson Seedless. Kilby (1999) reported in cv. Cabernet Sauvignon a TSS of 20.3°Brix in 2 buds per spur while in 4 buds per spur, it was 19.5°Brix. Velu (2001) reported that the maximum TSS (16.44°Brix) was recorded with pruning 67 % of the canes to 5 bud level and 33 % to 2 bud level. Chougule (2004) in Thompson Seedless observed that the highest TSS (22.42°Brix) was registered by a cane density of 35 per vine and the lowest TSS (16.83°Brix) was

recorded in the cane density of 40 per vine. The highest TSS (17.8 %) was found in 4 bud pruning and the significantly lower TSS (16.0 %) was recorded at 8-bud pruning treatments in cv. Pusa Navrang (Palanichamy *et al.*, 2004). Bates (2008) observed that, in 'New York Concord' grape increased nodes per vine (56 to 383) resulted increase in yield but decreased the rate of soluble solids accumulation. Karibasappa and Adsule (2008) recorded more TSS in red wine varieties as compared to white wine varieties. Among the red wine varieties, the highest TSS (24.80°Brix) was recorded in 'Pinot Noir' followed by 'Merlot' (23.10°Brix). Among the white wine varieties, Chenin Blanc, Ugni Blanc and Garganega recorded 18.50, 19.80 and 19.60°Brix TSS, respectively. Chalak (2008) observed that, as the intensity of pruning decreased, TSS and TSS to acid ratio decreased. The maximum TSS (21.5°Brix) and TSS to acid ratio (32.70) were recorded in 4 buds per cane level. The minimum TSS (18.89°Brix) and TSS to acid ratio (21.88) were observed in 12 buds per cane level. Kohale *et al.* (2013) observed in cv. Sharad Seedless that the maximum TSS (21.17 and 22.06°Brix, respectively) was recorded in 4 buds per cane in both seasons.

Acidity

Winkler (1962) reported that increase in leaf area beyond a particular point resulted in low sugar and high acid content. Kumar and Tomer (1978) recorded that, in cv. Himrod grape the acidity increased from 0.56 per cent to 0.61 per cent with a decrease in pruning intensity from 3 to 6 buds/spur. Joon and Singh (1983) revealed that in 'Delight' grape, the vines pruned with 6 buds per cane showed the highest acidity (0.88%) while it was less (0.73%) in vines pruned up to 2 buds/spur. Morris *et al.* (1985) observed that in 'Concord', the heavy fruit load resulted in the production of light coloured fruits with reduced percentage of soluble solids and pH and increased acidity. Avenant (1998) reported that in cv. Festival Seedless, sugar concentration, pH and sugar-acid ratio decreased and acid concentration increased as pruning intensity decreased. Kilby (1999) reported increased acidity in 'Merlot' grape due to pruning level. Two buds per spur recorded 0.82 % acidity while it was 0.97 % in 4 buds per spur. Velu (2001) reported that in cv. Muscat, the pruning level (pruning 67 % of the canes to 5 bud level and 33 % to 2 bud level) registered the least

acidity content (0.47%) and a highest Sugar-acid ratio (30.8). Chougule (2004) observed that in cv. Thompson Seedless, the lowest acidity (0.49%) was in 35 cane density per vine, while the highest acidity (0.80%) was recorded in cane density 40 per vine. Somkuwar and Ramteke (2007) recorded increased acidity with an increase in bunches per vine in cv. Sharad Seedless. The treatment 30 bunches/vine recorded 0.39 per cent acidity and it was 0.44 per cent in 40 bunches/vine. Havinal (2007) screened 12 wine grape varieties and recorded the highest acidity (0.94%) in 'Chenin Blanc' which was on par with 'Chardonnay' (0.91%). The low acidity (0.76%) was observed in cv. Viognier. Chalak (2008) recorded the maximum acidity (0.88%) in 12 buds per cane level in cv. Cabernet Sauvignon which was at par with 10 buds per cane level (0.86%) and 8 buds per cane (0.82%). The minimum acidity (0.70%) was recorded in 4 buds per cane which was at par with 6 buds per cane (0.75%). Kohale *et al.* (2013) observed in cv. Sharad Seedless that, the maximum acidity was recorded when canes were pruned Up to 8 buds in both seasons.

TSS: acid ratio

Joon and Singh (1983) observed that, in cv. Delight grape, TSS: acid ratio decreased significantly with a decrease in pruning intensity. It was recorded that, the vines pruned Up to 2 buds per spur showed the highest TSS: acid ratio (24.70) as compared to a vine pruned Up to 6 buds per cane (18.18). Thatai *et al.* (1987) observed that in cv. Perlette grape, the maximum TSS: acid ratio (26.00) was in 4 buds/cane pruning, while it was 21.40 in 5 buds per cane. Chougule (2004) reported that in cv. Thompson Seedless, the maximum TSS: acid ratio (32.98) was recorded in 35 canes per vine. It was followed by 30 canes/vine (30.42) and 40 canes per vine (27.75). Havinal (2007) reported that, the highest TSS: acid ratio was observed in 'Cabernet Sauvignon' (28.03) followed by 'Grenache' (27.72), 'Pinot Noir' (27.00) and 'Viognier' (26.79), whereas, the lowest TSS: acid ratio (23.13) was recorded by 'Chenin Blanc', which was on par with 'Chardonnay' (23.80), 'Sauvignon Blanc' (24.60), 'Ugni Blanc' (24.70) and 'Pinot Meunier' (25.37). Chalak (2008) observed the maximum TSS: acid ratio (33.50) in cv. Cabernet Franc in 4 bud per cane pruning level and it was at par with 6 buds per cane pruning level

(31.10). The minimum TSS: acid ratio (23.30) was recorded in 12 buds per cane (25.00).

Sugars

Balakrishnan and Rao (1963) observed that the total soluble solids and reducing sugar content increased with the severity of pruning. Mohanakumaran *et al.* (1964) found a positive and highly significant correlation between leaf area of the cane and per cent total soluble solids, reducing sugars and Sugar-acid ratio. Hulamani *et al.* (1967) showed that the sugar content of berry was found to be in direct relation with spur thickness, while the acidity varied inversely. Chadha *et al.* (1969) reported that in cv. Perlette, TSS and reducing sugars reduced when the number of canes raised from 100 to 140 per vine. Chadha and Kumar (1970) in cv. Perlette grapes, the highest TSS and sugars recorded with 200 canes/vine at 3 bud level. Sharma *et al.* (1977) stated that the highest TSS and reducing sugars with 2 bud pruning were obtained in cv. Perlette grapes. Pavlov (1998) in 'Naslada' stated that the bud load exceeding 32/vine decreased the sugar content. Velu (2001) observed that severely pruned vines (pruning 67 per cent of the canes to 5 bud level and 33 per cent to 2 bud level) registered the maximum total sugars (14.36%), reducing sugars (12.72%) and non-reducing sugars (1.64%) in cv. Muscat. Kohale *et al.* (2013) reported in cv. Sharad Seedless that the highest total sugars (18.69 and 18.67%) were recorded in 4 buds per cane, and was at par with 6 buds per cane (18.10 and 18.17 %, respectively) in both seasons.

Physical parameters of cluster

Kumar (1999) reported that the increase in length of bunches at different intervals of their growth was found to be non-significant between winter and summer seasons. However, the increase during the summer season was more compared to winter season. Kumar (1999) reported that the bunch weight during the period of growth was found to be significantly influenced by seasons. It followed a double sigmoid growth curve pattern. Anzanello *et al.* (2010) reported that the execution of dry summer pruning allows to obtaining two crops per season in grapes 'White Niagara' 'Niagara Rosada' and 'Concord', with the largest production in the second crop.

Quality parameters

Kumar (1999) observed in cv. Bangalore Blue that titrable acidity of berries was significantly more during winter season (0.89%) than during the summer season (0.68%). It was also reported that the change in total, reducing and non-reducing sugar content in berries was significantly more during the summer season than winter. Terence (2008) examined the effect of pruning level and canopy division on yield, vegetative growth and fruit characteristics in Concord grapes and found that the

season had a greater effect on titratable acidity and declined from veraison to harvest.

CONCLUSION

Pruning is one of the important cultural operations in grape and standardization of pruning levels for any grape cultivar is of utmost importance for obtaining optimum yield and quality. High net return in grapes with increased productivity could be ensured by adopting judicious pruning practices.

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