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Effect of Severity of Pruning on Yield and Quality Characters of Grapes (*Vitis vinifera* L.): A Review

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A B S T R A C T

Viticulture in India is considered to be one of the most remunerative farming enterprises due to high monetary returns. Grape culture is laborious one and sensitive to climate. Pruning is the most important operation in grape and its standardization is of utmost important in determining fruitfulness, yield and quality. Pruning practices adopted in the vineyard is largely dependent on vine growing environment, variety and season. Further, pruning largely not only influences the productivity in terms of fruitfulness of a particular variety but also the quality of grape *viz.*, berry size, Total soluble solids and sugar.

Introduction

Grape (*Vitis vinifera* L.) is considered as one of the most important commercial fruit crops of temperate regions. However, it is also grown successfully in tropical and sub-tropical regions of the world as a commercial fruit crop. The vines of this cultivar are moderate in vigour but tend to produce more number of bunches with variable sizes. Hence, optimum canopy size and bunch number per vine are to be maintained for achieving better fruit quality which calls for a proper balancing between vigour and capacity. Among the different cultural practices, pruning is of immense importance as it helps to control the growth, crop load and also the quality of bunches (Reddy and Prakash, 1990). Further, in Tamil Nadu, grapes are pruned twice in a year to get a summer crop and rainy season crop for which the adaptability of this new introduction is not known.

Cultivation of grapes in India has been commercially taken up under a wide range of soil and climatic conditions in the states of Maharashtra, Karnataka, Telaugana, Andhra Pradesh and Tamil Nadu. It is one of the most remunerative farming enterprises that has created interest among Indian growers. At present in India, grape is grown in an area of about 1,18,700 ha with an annual production of 25.85 lakh MT and a productivity of 21.80 tonnes ha^{-1} (Anon., 2015). The major grape growing states of India are Maharashtra,

Karnataka, Telaugana, Andhra Pradesh and Tamil Nadu.

Pruning i.e., removal of unwanted growth is vital for viticulture. Otherwise, the vegetative growth tends to be uncontrolled leading to very poor fruiting. Fruitfulness of any variety is of considerable importance in viticulture as it has direct impact on productivity of vines. An increase in the severity of pruning will increase the vigour of individual shoot at the expense of total growth and crop (Winkler *et al.*, 1974).

Pruning the vines for optimum cropping according to the vigour is the most reliable method to maintain the balance between growth and production. The vine should carry a moderate number of canes, in order to maintain the uniform vigour throughout its life span. 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 quality fruit. In this chapter, the effect of pruning severity, season and intensity on yield and quality characters, are reviewed under appropriate heads and sub heads.

Effect of pruning severity on yield parameters

Effect of pruning levels on bunch traits

Balakrishnan and Rao (1963) reported that, when the vines were pruned to 4, 6, 8 and 10 buds cane^{-1} keeping 14 canes per vine in grape var. Muscat Hamburg, the maximum highest number of bunches (227.0) recorded were 12 buds per cane level and minimum number of bunches (158.0) were observed 4 buds per cane. Bhujbal (1972) found that in grape cv. Thompson Seedless, when the vines were pruned to 4, 6, 8 and 10 buds per cane keeping 16 canes per vine, the maximum bunch weight (326.0 g) recorded were 8 buds per cane level and minimum bunch weight (206.0 g) were observed 16 buds per cane.

Singhrot *et al.*, (1977) observed that in grape cv. Thompson Seedless, when the vines were pruned to 4, 6, 8 and 10 buds per cane keeping 16 canes per vine, the maximum number of bunches (30.67) were recorded in 10 buds per cane level while the minimum number of bunches (16.33) were noticed in 4 buds per cane. Kumar and Tomer (1978) retained 60 buds on each vine in grape cv. Himrod and revealed that 5 buds with 12 canes pruning resulted the maximum bunch weight (237.69 g) as compared to 6 buds with 10 canes (204.50 g).

Purohit *et al.*, (1979) reported that cv. Anab-E-Shahi grapes, effect of 3, 6, 9, 12 and 15 leaves per bunch was studied on growth and quality of berries. The maximum volume of berry was recorded in 15 leaf level (9.30 ml). Joon and Singh (1983) observed a reduction in bunch weight due to pruning levels in grape cv. Delight. It was recorded that 2 buds spur resulted more bunch weight (368.33 g) as compared to 6 buds spur (352.0 g).

Gray *et al.*, (1996) reported that medium pruning severity level of five nodes adopted in Muscadine cultivar Alachua resulted in more bunches than vines pruned to two to three nodes. Further vines pruned at ten nodes resulted in poor vine vigour. Avenant (1998) revealed that in cv. Festival Seedless, the average number of bunches vine^{-1} 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 grape cv. Cabernet Sauvignon, mechanical pruning produced more number of bunches per 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 per vine, lowest cluster weight, and lowest berry weight among the treatments. Velu (2001) observed that in cv. Muscat Hamburg, the maximum number of bunches per vine (25.38) was obtained in pruning all the canes to 5 bud level and maximum bunch weight (212.30 g) by pruning 67 per cent of the canes to 5 bud level and 33 per cent of canes to 2 bud level.

Chougule (2004) observed that in grape cv. Thompson Seedless, the highest number of bunches per vine (48.00) was recorded with a cane density of 40 per vine and the lowest number of bunches per vine (28.75) were noticed with a cane density of 30 per vine. 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 (36.20 vine^{-1}) 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.

Savic and Petranovic (2004) claimed that an increase in number of bunches per vine from 15.58 to 21.46 with increase in bud load from 12 to 24 buds per vine in Grenache grape. 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.

Chalak (2008) observed in cv. Cabernet Sauvignon, the maximum number of bunches (57.00) in 12 buds per cane pruning level which was at par with 8 buds per cane (41.81) and 10 buds per cane (40.97). The minimum number of bunches (15.11) was recorded in 4 buds per cane pruning level which was at par with 6 buds per cane level (24.88). It was also observed in the variety Cabernet Sauvignon that the maximum bunch weight (199.93 g) in 4 buds per cane level and it was at par with 6 buds per cane level (118.72 g) and 10 buds per cane level (117.66 g).

According to Main and Morris (2008), mechanically pruned vines of Cynthiana grapes had produced 38 per cent more clusters as compared to hand pruning. 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).

Abdel mohsen (2013) in grape variety Crimson Seedless maintained cane length (2, 4, 6, 8, 10 and 12 nodes) and observed that the cluster per vine (22.67 and 31.00) and cluster weight (292.0 and 303.2 g) was more in 10 nodes in both seasons. Kohale *et al.,* (2013) studied that in grape cv. Sharad Seedless that eight buds per cane level recorded the maximum number of bunches (30.68) per vine, whereas in six buds per cane and 4 buds per cane, the number of bunches were 29.04 and 27.03 respectively.

Porika (2013) found that that in grape cv. Red Globe, the berry traits *viz*., number of berries per bunch, berry weight, berry diameter and berry volume were significantly superior in pruning of 50 per cent of the canes for vegetative growth and 50 per cent of the canes for crop yield during June and January, the treatment as compared to other treatments in both rainy and summer seasons. Among two seasons, summer season crop showed superior bunch characters.

Senthil kumar (2014) reported that in grape cv. Italia, the maximum bunch weight was recorded with treatment pruning of 50 per

cent canes to 5-6 bud level for fruiting and remaining 50 cent canes to two bud level for vegetative growth in both summer and winter (720.21 g and 674.28 g) and it was significantly.

Effect of pruning severity on yield

Ballal (1961) found cane pruning to 9 buds was advantageous for Thompson Seedless and medium spur for Khandhari, Bangalore Purple, Phadki and Karachi varieties. In grapes, 4 bud pruning 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 (Chadha and Kumar, 1970).

Bhujbal (1972) reported that in grape cv. Thompson Seedless, when the vines were pruned to 4, 6, 8 and 10 buds per cane keeping 16 canes per vine, the maximum yield (18.00 kg vine^{-1}) recorded were 4 buds per cane level and minimum yield (3.24 kg vine^{-1}) were observed 12 buds per cane.

Chadha *et al.,* (1973) pruned Black Prince grape to 40, 50, 80, 100 or 120 buds per vine and found increased bunch number and yield per vine with increased pruning severity. Size and time of ripening were not affected. Increased production in Chardonnay and Gamay Beujolis grapes was observed as the pruning severity decreased (Lider *et al.,* 1973). Bhujbal (1974) noticed that the yield was higher when the Angur Kalan grapevines were pruned to 6 bud severity of pruning. To increased bunch numbers and yields with less severe pruning on Khandhari grapes (Chadha *et al.,* 1974).

May *et al.,* (1976) showed for Crouchen that yield responses to increasing node number, tended to be asymptotic, as reported above for Sultana, as increasing the node number from 32 to 48 nodes per vine produced a 15 per cent increase in yield but a further increase in yield was not achieved with 64 nodes per vine.

Balasubramaniam and Khandha (1977) reported that the yield increase with long cane pruning (10 buds) in grape cv. Thompson Seedless. The grapevines are pruned 2, 3 and 4 node treatments, due to a sharp decline in bud burst with the less severe treatments, which is agreement with commercial and experimental studies with mechanical hedging, where yield was similar to hand pruning (May and Clingeleffer, 1977).

Singhrot *et al.,* (1977) recorded that, in Thompson Seedless yield per vine increased with decreased intensity of pruning. The maximum yield per vine (8.20 kg) was recorded in 8 buds per cane (7.77 kg) and the minimum yield per vine (2.87 kg) was recorded in 4 buds per cane level. Spayd and Morris (1978) found that a less severe pruning level (60+10) delayed fruit maturity in one year as opposed to the industry standard, but pruning severity level (60+10 or 30+10) did not affect yield per node, berry weight, berries per cluster, or vine size. Bud load is the most important factor affecting yield and cluster quality as well as vine vigor of Thompson Seedless grapevines (Morris and Cawthon, 1980).

Singh and Kumar (1980) explained that Anab-E-Shahi grape pruned to the severity with 40 canes per vine and 3 buds per cane produced the highest number of bunches per vine but the highest yield was obtained from vines with 24 canes and 5 bud per cane. Light pruning will generally increase yield but only to a certain point where the vine becomes too large and fruitfulness eventually decreases (Smart *et al.,* 1982).

Tolmer and Bnar (1982) stated that in general, there was a progressive increase in yield with increasing the number of buds in a cane but

yield difference only between 3 bud and 6 buds pruning treatment was significant. The 9 bud pruning gave higher yield in Thompson Seedless and Beauty Seedless, where 6 bud and 3 bud pruning gave better result in Perlette and Himord respectively.

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 resulted significantly higher yields (27.85 kg vine^{-1}) as compared to 2 bud spur (16.25 kg vine^{-1}) and 4 buds spur pruning (21.93 kg vine^{-1}).

Boskov and Hristov (1984) reported that the highest yield with quality for wine making in Rkatsiteli grape variety when pruned to 5 bud per cane. Jackson *et al.,* (1984) revealed that, there was an increase in yields in direct proportion to the higher node number. Morris *et al.,* (1985) observed that in grape cv. Concord, both yield and juice qualities were considered the 50+10 pruning result superior. The highest yielding treatments were the shoot positioned with 3 and 6 nodes per bearing unit on the Geneva Double Curtain training system. However, the 3 node spurs produced fruit with inferior percentage soluble solids and colour.

Kovachev *et al.,* (1987) found out the increasing the bud load and yield owing to greater number of bunches produced, but reduced the grape sugar content and the best results (yield + quality) were produced with 44 buds per vine. Thatai *et al.,* (1987) experimental grape cv. Perlette revealed that pruning of 12 canes with 4 buds per cane resulted in maximum yield per vine (3.66 kg) as compared to 10 canes with 3 buds per cane (2.56 kg) and 14 canes with 5 buds per cane (3.38 kg). Individual cluster weight is most often increased through severe pruning but the effect of overall yield loss through fewer clusters per vine can't be made up for completely by a greater yield per cluster (Bowed and Kliewer, 1990).

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. Savic (1997) opined that spur pruning to 25 buds per vine produced the highest yield and best quality table grapes and high bud load treatment gave the poorest results in the variety Cardinal. Avenant (1998) concluded that in grape cv. Festival Seedless the yield per vine increase linearly (3.93 to 11.87 kg vine^{-1}) as pruning intensity decreased from 12 to 4 canes with 14 buds per cane. The grapevine cv. Concord yield increased from 4.0 to 23.0 kg per vine as bud load increased from 20 to 160 buds per vine (Miller and Howell, 1998).

Reddy (1998) recommended that in grape cv. Pusa Seedless should be pruned to 8 bud level in 2nd week of January to get better yield. The severity of pruning lowered the leaf per bunch ratio and bunch weight while yield increased with increasing number of buds per cane (Sehrawat *et al.,* 1998). Shahein *et al.,* (1998) studied that in grape cv. Flame Seedless and Ruby Seedless cultivars on yield increased with increasing bud load per vine (16/2 bud spurs).

Minimal pruning with and without skirting of Chancellor grapevines resulted in higher yields than hand pruning, but with lower cluster weights, fewer berries per cluster, lower berry weight, and lower grape soluble solids (Reynolds and Wardle, 2001). Chougule (2004) indicated that in grape 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. Palanichamy *et al.,* (2004)

reported that the Pusa Navrang a teinturier grape hybrid was pruned at three different levels *viz*., 4, 6 and 8 buds per cane retaining uniformly 12 canes per vine on the head system. Among the three pruning treatments, the highest yield (8.16 kg vine^{-1}) was obtained with pruning at 6 bud level.

It was observed in grape var. 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). The minimum yield per vine (3.30 kg) was recorded in the variety Chardonnay (Anon., 2007).

Ahmad (2008) claimed that in grape cv. Himrod, the vines pruned at 5 buds per cane registered the highest yield (11.53 kg vine^{-1}). However, 6 buds per cane gave minimum yield (10.59 kg vine^{-1}). Chalak (2008) observed that 4 buds per cane level recorded the maximum yield per vine in *viz*., Pinot Noir (3.80 kg vine^{-1}), Ugni Blanc (5.05 kg vine^{-1}) and Sauvignon Blanc (5.18 kg vine^{-1}). The 6 buds per cane level recorded the maximum yield per vine in Syrah (8.21 kg vine^{-1}) and Grenachae (7.89 kg vine^{-1}).

Abdel mohsen (2013) in grape variety Crimson Seedless maintained cane length (2, 4, 6, 8, 10 and 12 nodes) and observed that the yield per vine was more (6.61 and 8.21 kg in both season) in 10 nodes. Kohale *et al.*, (2013) found that in cv. Sharad Seedless, the maximum yield (18.92 t ha^{-1}) was recorded in 8 buds per cane whereas in 6 buds per cane, it was 18.26 t ha^{-1} and with 4 buds per cane 17.25 t ha^{-1}.

Porika (2013) reported that in grape cv. Red Globe, pruning all the canes to 5-6 bud levels for rainy season crop resulted low yield (18.85 kg vine^{-1}) and similarly pruning practices for summer crop, that registered the maximum yield per vine (24.86 kg vine^{-1}). However, the maximum cumulative yield per vine was recorded in pruning of 50 per cent of the canes for vegetative growth and 50 per cent of the canes for crop yield during June and January treatment (38.20 kg vine^{-1}).

Regarding yield per vine, the pruning of 50 per cent canes to 5-6 bud level for fruiting and remaining 50 per cent canes to two bud level for vegetative growth in both summer and winter registered the maximum value (17.52 kg vine^{-1} and 14.50 kg vine^{-1}). The same pruning treatment had registered the maximum annual yield per vine (32.02 kg vine^{-1}) in grape cv. Italia (Senthil kumar, 2014).

Effect of pruning severity on berry attributes

Kliewer and Weaver (1971) studied the adjusted crop levels in grape cv. Tokay by pruning and cluster thinning and found that 1 to 1.4 m^2 of leaf area was required to attain maximum berry mass, maturity and colour. Purohit *et al.*, (1979) revealed that in grape cv. Anab-E-Shahi grapes, effect of 3, 6, 9, 12 and 15 leaves per bunch was studied on growth and quality of berries. The maximum bunch weight was recorded in 15 leaf level (822 g). The berry weight was increased by thinning, but was not affected by leaf removal (Fitzgerald and Patterson, 1994).

Kumar (1999) reported that in grape 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). Mikhailov (1998) reported that increasing the bud load reduced the mean bunch weight and

sugar content and medium bud load with 12 buds per vine produced the best grapes for fresh consumption. Velu (2001) observed in grape cv. Muscat Hamburg that severely pruned of 67 per cent of the canes to 5 bud level and 33 per cent of canes to 2 bud level produced more number of berries per bunch (56.60).

Chougule (2004) found out in grape cv. Thompson Seedless that the number of berries per bunch was affected due to cane density when 35 canes per vine had the maximum berries per bunch (121.40) compared to 30 canes/vine (106.20) and 40 canes per vine (113.60). Palanichamy *et al.,* (2004) reported that the Pusa Navrang a teinturier grape hybrid was pruned at three different levels *viz*., 4, 6 and 8 buds per cane retaining uniformly 12 canes per vine on the head system. Among the three pruning treatments, the maximum number of bunches (36.2 vine^{-1}) were obtained with pruning at 6 bud level. The maximum bunch weight (234 g) along with its size (20.5 x 15.3 cm) was recorded at 4 bud level.

Ahamad *et al.*, (2004) opined that in grape cv. Perlette the spurs pruned at three different nodes 4, 6 and 8. The maximum percentage of bud burst, fruitful buds, bunch weight and TSS were observed in spurs pruned to six nodes. Maximum bunch weight of 138.12 g and 152.24 g were recorded with pruning severity of 5 buds per cane and 12 canes per vine, respectively (Ahmad, 2008). Somkuwar and Ramteke (2007) recorded the effect of number of bunches on 25 berry weight. It was observed that increase in number of bunches per vine (30 to 50) resulted into decrease in 25 berry weight (21.75 to 19.82 g) in grape cv. Sharad Seedless.

Chalak (2008) noticed that the maximum number of berries per bunch (93.22) was recorded in 10 buds per cane level and it was the minimum (87.33) in 4 buds per cane level. It was also noticed that the maximum hundred berry weight (110.67 g) obtained in 4 buds per cane level and it was at par with 6 buds per cane (109.30 g) and 8 buds per cane level (108.80 g) in grape cv. Cabernet Sauvignon.

Arora and Gill (2009) studied the pruning of vines was done at four levels *viz.*, 3, 4, 5 and 6 buds. The highest percentage of fruitful buds was observed in the treatment in which 4 buds per cane were retained. The number of bunches (64.10 vine^{-1}), yield (25.80 kg vine^{-1}) were significantly higher, when 4 buds were retained on each cane after pruning. Whereas, the minimum number of bunches (47.50 vine^{-1}), yield (18.20 kg vine^{-1}), when 6 buds per cane were left after pruning. The bunch weight and fruit quality parameters were also improved in the treatment in which 4 buds per cane was retained after pruning.

Fawzi *et al.*, (2010) reported that for pruned to six different levels of bud load, namely 78, 91, 104, 117, 130 and 143 buds per vine on Crimson Seedless. Vines pruned to 117 buds per vine results the greatest cluster weight, length, rachis weight, berry weight, berry firmness, adherence, TSS and total sugars. Increasing bud load on the vine significantly increased total carbohydrates and protein contents of the canes during the dormant season. In this respect, vines pruned to 143 buds per vine showed higher per cent of both total carbohydrate and protein content than the other levels of bud load.

Abdel mohsen (2013) in grape variety Crimson Seedless maintained cane length (2, 4, 6, 8, 10 and 12 nodes) and observed that the berry weight was more (4.88 g) in 10 nodes. Porika (2013) reported that in grape cv. Red Globe, the average bunch weight (749.92 g and 809.81 g) was recorded in pruning of 50 per cent of the canes for vegetative growth and 50 per cent of the

canes for fruiting. Senthil kumar (2014) worked out in grape cv. Italia, the number of bunches was found to the highest (30.70) when the vines are pruned at 5-6 bud level in all the canes during summer followed by winter (26.60) respectively.

Effect of pruning severity on berry dimensions

Dass and Melanta (1972) reported that the crop load affects berry weight and quality of berries. In grape cv. Thompson Seedless as the number of buds on a bearing unit increased berry dimensions *viz*., length and diameter (Lawande, 1973). Kumar (1999) found in grape cv. Bangalore Blue that, the change in diameter of berries during the winter season was significantly more than during the summer season. The maximum diameter of the berry was 17.16 and 17.11 mm, respectively during winter and summer season. It was stated that 100 berry weight was significantly influenced by seasons as well as a period of growth and development. It was also observed that the change in volume of berries was significantly higher during summer than winter season.

Chougule (2004) observed that in cv. Thompson Seedless, the maximum berry diameter (19.78 mm) and highest berry weight (3.51 g) was noted in cane density of 30 per vine. Somkuwar and Ramteke (2007) recorded the effect of number of bunches on berry diameter in grape cv. Sharad Seedless. It was observed that an increase in the number of bunches per vine (30 to 50) resulted in a decrease berry diameter (16.67 to 15.92 mm).

Chalak (2008) reported in cv. Viognier that the maximum berry diameter (13.20 mm) was recorded in 4 buds/cane and it was at par with 6 buds per cane (12.90 mm). The minimum berry diameter (11.08 mm) was recorded at 12 buds per cane level. Abdel mohsen (2013) in grape variety Crimson Seedless maintained cane length (2, 4, 6, 8, 10 and 12 nodes) and observed that the berry size was more (35.66 and 33.67 cm^2 in both season) in 10 nodes.

Effect of pruning severity on quality parameters

Effect of pruning severity on total soluble solids

Shaulis and Robinson (1953) opined that in grape cv. Concord grapes that had been pruned moderately (30+10) or severely (20+10) were earlier to mature and accumulated standard TSS of 16°Brix than grapes from vines. Further the lightly pruned acidity of the juice tended to be higher as pruning severity increased. Balakrishnan and Rao (1963) reported that in grape variety Muscat Hamburg, when the vines were pruned to 4, 6, 8 and 10 buds per cane keeping 14 canes per vine in two season (April and September), the maximum total soluble solids (15.8 and 13.2^{o}Brix) recorded were 4 buds per cane level and minimum total soluble solids (14.0 and 10.5^{o}Brix) were observed 14 buds per cane in both season.

Chadha and Kumar (1970) stated that in grape cv. Perlette, the highest total soluble solids recorded with 200 canes per vine at 3 bud level. Bhujbal (1972) noticed that in grape cv. Thompson Seedless, when the vines were pruned to 4, 6, 8 and 10 buds per cane keeping 16 canes per vine, the highest total soluble solids (22.60^{o}Brix) recorded were 8 buds per cane level and minimum yield (20.60^{o}Brix) were observed 16 buds per cane.

Singhrot *et al.,* (1977) revealed that, TSS was negatively correlated with number of buds per cane. The maximum TSS (23.50^{o}Brix) was observed in 6 buds per cane pruning level. Sharma *et al.,* (1977) stated that the highest TSS with 2 bud pruning was obtained in

grape cv. Perlette. In cultivar 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 (Kumar and Tomer, 1978).

Purohit *et al.,* (1979) studied the effect of 3, 6, 9, 12 and 15 leaves per bunch was studied on growth and quality of berries in cv. Anab-E-Shahi grapes. The maximum TSS was recorded in 15 leaf level (14.12°Brix). In general lighter pruning increases the yield but it may also be associated with negative effects on fruit quality such as lower total soluble solids and modified pH and titrable acidity (Jackson *et al.,* 1984). 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.

Schrawat *et al.,* (1998) reported that more the severity of pruning, the lower is the percentage of berry drop and fruit TSS increased and acidity decreased when pruning severity increased in Thompson Seedless cultivar. The grape cultivar Cabernet Sauvignon a TSS of 20.3°Brix in 2 buds per spur while in 4 buds per spur, it was 19.5°Brix (Kilby, 1999).

Velu (2001) reported that the maximum TSS (16.44°Brix) was recorded in the pruning of 67 per cent of the canes to 5 bud level and 33 per cent to 2 bud level. Chougule (2004) in grapes cv. 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.

Palanichamy *et al.,* (2004) reported that the Pusa Navrang a teinturier grape hybrid was pruned at three different levels *viz*., 4, 6 and 8 buds per cane retaining uniformly 12 canes per vine on the head system. Among the three pruning treatments TSS (17.80%) and juice recovery (74.50 %) were the highest in the 4 bud level. Bates (2008) explained that, in New York state grape cv. Concord increased nodes per vine (56 to 383) resulted increase in yield but decreased the rate of soluble solids accumulation.

Chalak (2008) observed that, as the intensity of pruning decreased, TSS and TSS to acid ratio decreased. The maximum TSS (21.50°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.

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 18.5, 19.8 and 19.60°Brix TSS, respectively. Abdel mohsen (2013) indicated that in grape variety Crimson Seedless maintained cane length (2, 4, 6, 8, 10 and 12 nodes) and observed that the total soluble solids content was highest (17.88 and 19.17 % in both season) in 10 nodes.

Kohale *et al.,* (2013) observed in grape cv. Sharad Seedless that the maximum TSS (21.17 and 22.06°Brix, respectively) was recorded in 4 buds per cane in both summer and winter seasons. The pruning of vines in all the canes to 2 bud level for vegetative growth in rainy season and 2 bud level for vegetative growth in summer season, registered the high total soluble solids (Porika, 2013). Senthil kumar (2014) revealed that, the pruning of 100 per cent canes to two bud level for vegetative growth in summer and winter season crop recorded the maximum TSS (14.82°Brix and 13.75°Brix).

Effect of pruning severity on titrable acidity

Winkler (1962) reported that increase in leaf area beyond a particular point resulted in low sugar and high acid content. Balakrishnan and Rao (1963) studied that in grape variety Muscat Hamburg, when the vines were pruned to 4, 6, 8 and 10 buds per cane keeping 14 canes per vine in two season (April and September), the lowest acidity (0.44%) recorded were 6 buds per cane level and highest acidity (0.57%) were observed on 14 buds per cane in April season.

Bhujbal (1972) found that in grape cv. Thompson Seedless, when the vines were pruned to 4, 6, 8 and 10 buds per cane keeping 16 canes per vine, the lowest acidity (0.54%) recorded were 8 buds per cane level and highest acidity (0.58%) were observed 12 and 16 buds per cane.

In grape cultivar Himrod, the acidity increased from 0.56 per cent to 0.61 per cent with a decrease in pruning intensity from 3 to 6 buds per spur (Kumar and Tomer, 1978). Purohit *et al.*, (1979) reported that in grape cv. Anab-E-Shahi grapes, effect of 3, 6, 9, 12 and 15 leaves per bunch was studied on growth and quality of berries. The lowest acdity was recorded in 15 leaf level (0.465 g 100 ml^{-1}).

Joon and Singh (1983) revealed that in grape var. Delight, 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 per spur. Shatat (1991) cited no significant effect on average cluster weight, total acidity, while its effect on TSS was either negligible (cv. Darawishi), inconsistent (cvs. Salti and Zeini) when the bud load level was increased. Avenant (1998) reported that in grapes cv. Festival Seedless, sugar concentration, pH and sugar-acid ratio decreased and acid concentration increased as pruning intensity decreased. Kilby (1999) opined that the increased acidity in Merlot grape due to pruning level. The 2 buds per spur recorded 0.82 per cent acidity while it was 0.97 per cent in 4 buds per spur.

Velu (2001) revealed that in grapes cv. Muscat Hamburg, the pruning of 67 per cent of the canes to 5 bud level and 33 per cent to 2 bud level registered the least acidity content (0.47 %) and a highest sugar-acid ratio (30.80%). In grape cv. Thompson Seedless, the lowest acidity (0.49%) was in moderately lower of 35 cane density per vine, while the highest acidity (0.80%) was recorded in high cane density of 40 per vine (Chougule, 2004). Somkuwar and Ramteke (2007) recorded increased acidity with an increase in bunches per vine in grape cv. Sharad Seedless. The treatment involving 30 canes per vine recorded (0.39%) acidity whereas the acidity was highest (0.44%) in 40 canes per vine.

The maximum acidity (0.88%) was registered in berries with 12 buds per cane level from vine in grape cv. Cabernet Sauvignon which was at on 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%) (Chalak, 2008). Abdel mohsen (2013) in grape variety Crimson Seedless maintained cane length (2, 4, 6, 8, 10 and 12 nodes) and observed that the lowest acidity (0.54 and 0.52% in both 2010 and 2101 season) in 10 nodes.

Kohale *et al.*, (2013) observed in grape cv. Sharad Seedless that the maximum acidity was recorded when canes were pruned up to 8 buds in both seasons. The pruning of vines in all the canes to 2 bud levels for vegetative growth in rainy season and 2 bud level for vegetative growth in summer season registered the lower titrable acidity (Porika,

2013). Senthil kumar (2014) reported that, the pruning level of 100 per cent canes to two bud level for vegetative growth in summer and winter season crop recorded the lower titrable acidity (0.59 and 0.63%).

Effect of pruning severity on TSS/acid ratio

Balakrishnan and Rao (1963) reported that in grapes variety Muscat Hamburg, when the vines were pruned to 4, 6, 8 and 10 buds/cane keeping 14 canes/vine in two season (April and September), the maximum TSS/acid ratio (35.0 and 30.5%) recorded were 6 buds cane^{-1} level and minimum TSS/acid ratio (24.6 and 26.3%) were observed 14 buds cane^{-1} in both season. Purohit *et al.,* (1979) found in cv. Anab-E-Shahi grapes that among 3, 6, 9, 12 and 15 leaves per bunch studied on growth and quality of berries. The maximum TSS/acid ratio was recorded under 15 leaves per bunch (30.85).

Joon and Singh (1983) observed that in grapes cv. Delight the 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) state that in grapes cv. Perlette grape, the maximum TSS/acid ratio (26.00) was registered pruning practiced at in 4 buds per cane, while it was 21.40 in 5 bud level pruning. Chougule (2004) explained that in cv. Thompson Seedless, the maximum TSS/acid ratio (32.98) was recorded under the treatment involves the higher cane number of 35 per vine followed by 30 canes/vine (30.42) and 40 canes per vine (27.75) respectively.

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). Maximum TSS/acid ratio (33.50) in grapes cv. Cabernet Franc in 4 buds per cane pruning level and it was at par with 6 buds per cane pruning level (31.10) and minimum TSS/acid ratio (23.30) was recorded in 12 buds per cane (25.00) reported by Chalak (2008).

The pruning in all the canes to 2 bud levels for vegetative growth in rainy season and 2 bud levels for vegetative growth in summer season, registered the highest TSS: acid ratio (Porika, 2013). Senthil kumar (2014) reported that the pruning of 100 per cent canes to two bud level for vegetative growth in summer and winter season crop recorded the maximum TSS: acid ratio (25.12 and 21.83) in grapes cv. Italia.

Effect of pruning severity on sugars

Balakrishnan and Rao (1963) reported that in grapes variety Muscat Hamburg, when the vines were pruned to 4, 6, 8 and 10 buds/cane keeping 14 canes/vine in two season (April and September), the maximum reducing sugar content (13.51 %) recorded were 6 buds cane^{-1} level and minimum TSS/acid ratio (24.6 and 12.25 %) were observed 14 buds cane^{-1} in April season. 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. The sugar content of berry was found to be in direct relation with spur thickness, while the acidity varied inversely (Hulamani *et al.,* 1967).

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 sugars content recorded with 200 canes vine^{-1} at 3 bud level. Boichov (1972) reported that the quality expressed in sugar content, total and percentage of ripe grapes at the first picking was the highest with 28th bud level while higher bud reduced the quality and vine shoot growth in Italia grape. Sharma *et al.,* (1977) stated that the highest reducing sugars with 2 bud pruning were obtained in cv. Perlette grapes.

Purohit *et al.,* (1979) reported that cv. Anab-E-Shahi grapes, effect of 3, 6, 9, 12 and 15 leaves per bunch was studied on growth and quality of berries. The highest sugar content was recorded in 15 leaf level (110.03). Less severs pruning was reflected in the storage of greater amounts of total carbohydrate in the vine, acceleration of early shoot growth, increased percentage of reducing sugar in the mature flowers, and an accompanying increase in pollen germinability (Kasimatis, 1980).

Velu (2001) observed that in severely pruned vines registered the highest total sugars (14.36%), reducing sugars (12.72%) and non reducing sugars (1.64%) in grapes cv. Muscat Hamburg. Kohale *et al.,* (2013) reported in grapes cv. Sharad Seedless that the highest total sugar (18.69%) was in severity pruned under at 4 buds per cane, and it was on par with 6 buds per cane (18.17%). Porika (2013) claimed that pruned of 50 per cent of the canes pruned for vegetative growth and 50 per cent of the canes for crop yield during June and January recorded the highest reducing sugar, total sugar (15.26% in rainy season and 17.24% in summer season) and sugar/acid ratio.

Effect of pruning severity on anthocyanin

Red grapes contain flavonoid type compounds of which anthocyanin and tannins are the most prominent. Because tannin content of grape skins is already high at veraison when anthocyanin appear (Ribereau gayon and Glories, 1982). Increasing the total amount of buds retained at winter pruning increased quality in terms of colour density and anthocyanin and was most likely due to decreased cluster and berry size (Freeman, 1983).

Anthocyanin concentration generally peaks around 1 to 2 weeks before harvest and then slightly decreases by the time most berries reach their optimum ripeness based on sugar concentration (Roggero *et al.,* 1986). Even though grapes start to accumulate colour during phase III of berry growth, it is necessary for fruit to be exposed to light during phases I and II for the biosynthesis to initiate (Dokoozlian and Kliewer, 1996).

Multiple studies have found that total anthocyanins increase or decrease with increasing canopy shade without consistency. However, when broken down into individual anthocyanin concentration, a distinction is evident. Cyanidin and peonidin based anthocyanins belong to a di-oxygenated group who's percentage of total anthocyanins significantly increased with shade (Downey *et al.,* 2004 and Ristic *et al.,* 2007). Anthocyanins are generally located in the hypodermis portion of the skin of red grape cultivars, with the exception of teinturier varieties whose anthocyanin are located throughout the berry (Cheynier *et al.,* 2006).

Mori *et al.,* (2005) reported that high night time temperatures tend to decrease anthocyanin accumulation as opposed to low night time temperatures which have the tendency to increase anthocyanin accumulation. Day time temperature of 30^{o} C combined with 30^{o} C night time temperature versus 30^{o} C day time temperature combined with 15^{o} C night time temperature caused anthocyanin to decrease from 5.5 mg g^{-1} to

4.0 mg g^{-1} flesh weight of skin. There was not an effect of night time temperatures on other flavonol accumulation in skins or on soluble solids of berry. Generally, with higher temperatures berry growth speeds up and the biosynthesis of anthocyanin decreases.

Clingeleffer (2009) study the four pruning systems (hand spur, tight and loose mechanical hedging and minimal) produced distinctly different canopy architectures. Spur pruning decreased berry anthocyanin compared with the other treatments (*i.e.* 0.55, 0.67, 0.84 and 0.68 mg/g for the spur, 0.4 and 0.6 m hedging treatments and minimal pruning, respectively). The lighter hedging (0.6 m) had significantly higher levels of anthocyanin than the 0.4 m wide treatment. Despite the lower maturity, colour levels in the fruit of minimal pruned vines were similar to the 0.4 m hedge treatment and higher than the spur pruned vines.

Effect of seasons on 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. 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 obtaining two crops per season in grapes varieties White Niagara, Niagara Rosada and Concord, with the largest production in the second crop.

Effect of season on 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 %). Further similar trend 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 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.

In conclusion pruning is one of the important cultural operations in grape production and standardized the pruning severity for any grape varieties 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. Pruning the vines for optimum cropping according to the vigour is the most reliable method to maintain the balance between growth and production. The vine should carry a moderate number of canes, in order to maintain the uniform vigour throughout its life span. Canopy, vigour and productivity can be balanced through pruning levels.

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