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Influence of source to sink manipulation on growth and yield attributes in grape cultivars under mild tropics of India

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In grape, manipulation of the source-to-sink ratio through various canopy management practices plays pivotal role, particularly balancing the growth and yield of grape cultivars under mild tropical climatic condition is a major task where, double pruning single cropping system is followed. So it is very much necessary to standardize as well as identify the proportion of biomass to crop load especially in the commercial cultivars like Red Globe (seeded and less vigorous cultivar) and Crimson Seedless (seedless and more vigorous cultivar) and hence the same cultivars were selected for this study. The study includes three cane regulation (20, 30, 40 canes per vine) and three leaf regulation (8, 12, 16 leaves per canes) treatments. Among the different treatment combinations, growth parameters like inter nodal length and girth of the cane (vegetative and fruiting cane) were found to be maximum under lowest cane and leaf density (20 cane with 8 leaves) treatments. Similarly, days taken to bud sprouting and panicle initiation were found to be earliest in case of lowest cane and leaf density treatments. The maximum leaf area per vine was observed in Red Globe, moderate cane and leaf density (12 leaves with 30 canes per vine) whereas, in crimson seedless, increased leaf and cane density increased leaf area. But, movement of assimilates into the sink (bunch) showed different trend with increased berry weight, bunch weight, bunch volume, yield per vine in moderate to high leaf or cane density in Red globe and less to moderate leaf density in Crimson Seedless. Whereas, leaf area required for production of per gram berry was found very less in lowest cane and highest leaf density (20 cane with 16 leaves) in both cultivars. This showed that, even though both the cultivars were differed in their vigour but with respect to assimilates accumulation were found to be in lowest cane density with highest leaf density.

Keywords: Source-sink, regulation, pruning, grape, leaf area

Introduction

Grape is one among the most delicious, refreshing and nourishing fruits of the world which 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 B_1, B_2, and C. Grape has so many uses and is so unique that no fruit can challenge their superiority. Source to sink relationship is the most important factor affecting yield and quality as well as vine vigor of both seeded and seedless varieties which is influenced by regulation of crop load and biomass. 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.

Source sink relationships can be defined as the ability of a plant to undergo photosynthesis, thereby fixing CO_2 in the source organs, and to transport this fixed carbon to various sink tissues or organs. It also defines the ability of the sink organs to assimilate or store the fixed carbon structures such as glucose and fructose. The source sink concept typically refers to the ratio between the leaves and the fruit. In literature about the grapevine, it is common to state that to ripen 1 g of grapes, a leaf area of 8 to 10 cm^2 is necessary (Conde *et al*., 2007[1]). The concept of source sink relationships needs to be reassessed and approached from a different angle using unique ideas and various scientific procedures. Areas which may be looked into can include signalling between organs, using biological tracers to follow the movement of various compounds (sugar, amino acids, hormones), through the vine, or plant signals involving compounds such as carbohydrates, jasmonic acid or calcium to understand the communication between organs.

The current way of looking at source-sink relationships is over-simplified and there are numerous limitations involved in this approach. The vine is far more complex and various aspects must be taken into consideration before any claims can be made concerning source-sink relationships. The concept of source-sink modulation is achieved by cane and leaf regulations and in grape production it is considered as one of the technical viticultural practices suitable to modify grapevine physiology and crop production. While pruning for fruiting, more number of canes are retained on vigorous vines, less are retained on less vigorous ones. Hence, cane thinning is considered as a technique which could lead to improvement in grape quality (Lancono *et al*., 1991[2]).

Taking into account, the fruit production habit wherein the vines produce cluster in the last growth branches that originate in the development of previous season, cane regulation is used to limit the number of canes and creating the balance between the vigour and production of the vines, while leaf regulation is to enhance the berry yield and quality which is also one of the significant practice in viticulture (Matti and Ferrini, 2005) [3].

Thus in this study much emphasis have been given towards source to sink relation in order to standardize number of leaves and canes to regulate growth of grapevines. Keeping these points in view, the present investigation were undertaken to evaluate the influence of source to sink modification/manipulation on reserve restoration in the vines (canes, leaves) and the consequences on growth parameters over two successive years of treatment with the objective to study the effect of source (cane and leaf regulation) to sink (bunches) on growth parameters in different grape varieties.

Methodology

The experiment was conducted at research farm (Block 1), ICAR-Indian Institute of Horticultural Research, Hessaraghatta, Bengaluru which has a mild tropical climate and it is situated at an elevation of 890 m above the mean sea level. 8 to 9 year old vines of Red Globe and Crimson Seedless grapes grafted on Dogridge rootstock and trained to Y trellies were used to conduct this experiment. Standard cultural operation viz., manuring, irrigation, plant protection were uniformly followed throughout the experimental period. Double pruning and single cropping method was being followed where in vines were pruned for vegetative growth (by developing canes) during summer popularly called as foundation pruning and on developed canes second pruning was done during winter, popularly called as fruit pruning. The cane regulation was done after foundation pruning and the leaf regulation was done on the canes pruned after fruit pruning. The experimental design was laid in Factorial Randomized Blocks Design (FRBD) with two factors i.e., Regulation of Canes (20, 30, 40 canes per vine) and Regulation of Leaves (8, 12, 16 leaves per cane) comprising total of 9 treatment combinations replicated thrice. The growth and yield attributes observation were took as per the below mentioned methodology.

Inter nodal length of the cane (cm): The distance between fourth and fifth node from the base of the four canes in each vine was measured with a scale and average was recorded at 90 days after back pruning and expressed in centimetres.

Girth of the cane (mm): The girth of the cane was recorded between fourth and fifth node from the base of the four cane in each vine was measured by using vernier calipers and average was recorded after 90 days of back pruning and expressed in millimetres.

Inter nodal length of the fruiting shoot (cm): The distance between fourth and fifth node from the base of the four shoots in each vine was measured with a scale and average was recorded at 90 days after forward pruning and expressed in centimetres.

Girth of the fruiting shoot (mm): The girth of the fruiting shoot was recorded between fourth and fifth node from the base of the four cane in each vine was measured by using vernier callipers and average was recorded after 90 days after forward pruning and expressed in millimetres.

Number of days for bud sprouting from pruning: The number of days from forward pruning to visible bud sprouting in each treatment was counted and recorded in days.

Number of days taken for panicle initiation: The data of panicle initiation on each vine was recorded and the average number of days taken from forward pruning to panicle initiation was recorded.

Leaf area per cane: It was measured in leaves collected from randomly selected five canes in each vines at Veraison stage. The leaf area was calculated by placing the individual leaf lamina in a leaf area meter (*Biovis PSM*) and expressed in square centimeter.

Bunch volume (cm^3): The volume of randomly selected bunches per replication under treatment was determined by water displacement method and expressed in cubic centimeter.

Bunch weight (g): The weight of five bunches was recorded from tagged canes on an electric balance and average weight of bunch was expressed in gram.

Leaf area per gram berry weight (cm^2 per g): To determine the relationship between leaf area (cm^2) per gram crop weight. The total leaf area per vine (cm^2) is divided by total crop weight per vine (g) and expressed in cm^2 per gram as mentioned by Kliewer and Dokoozlian, (2005) [4].

Results and Discussion

In the present investigation, two grape varieties (Red Globe and Crimson Seedless) were assessed by regulating different levels of canes and leaves per vine in order to explore the influence of source-sink modulation on growth characteristics. During the experimental period the growth or vigor rate and yield attributes were recorded in both the cultivars by regulating the different number of canes per vine during back pruning (April) and number of leaves per cane during forward pruning (October) in both the cultivars for various growth attributes and further results were discussed below.

Effect of source sink manipulation on the growth attributes of grape varieties

Internodal length and girth of vegetative and fruiting cane: The increased cane load resulted in decreased internodal length of canes in both cultivars with maximum internodal length in vegetative cane (5.18 cm and 4.84 cm) and fruiting cane (7.12 cm and 5.75 cm) in Red Globe and Crimson Seedless, respectively. Similar trend were also observed among leaf regulation treatments with maximum intermodal length in vegetative and fruiting canes i.e. 4.75 cm and 4.58 cm in Red Globe and 6.61 cm & 5.60 cm in Crimson Seedless, respectively (Table 1). Whereas, the interaction between the treatments shown statistically non-significant difference. These results clearly infer that as the source/canopy load increases the sink capacity decreases due to movement of metabolites. This might be because in severely thinned canes the lesser competition for metabolites, among the limited number of canes per vine, availability of more photosynthates consequent to better vigour and physiological activities induced to increase the inter-nodal length of cane. These results are in conformity with the reports of Chalak *et al.* (2012)[5] in Thompson Seedless grapes and Ashwini *et al*. (2017) [6] in wine varieties.

The Girth of vegetative and fruiting cane has often been used as an index of the yield potential. Here the Girth of the cane between fourth and fifth node was significantly influenced by the different levels of cane and leaf regulation treatments. Lowest cane density (20 canes per vine) recorded maximum cane girth of 8.02 mm and 7.82 mm in Red Globe and Crimson Seedless, respectively after back pruning and lowest leaf density (8 leaves per vine) recorded maximum cane girth of 7.46 mm and 7.03 mm in Red Globe and Crimson Seedless, respectively after forward pruning. These results emphasized that vines with more number of canes and more number of leaves reported to have lesser girth of the cane (Table 1). The maximum number of canes per vine and leaves per cane led to higher competition for absorption of food material. Whereas, reduction in cane number reduced the sink and allowed greater allocation of assimilates. The results are in agreement with findings of Yogeeshappa et al. (2010)[7] in Thompson Seedless and Naor et al. (2002)[8] who opined that decreased number of canes per vine by thinning resulted in increase of all vegetative parameters measured, indicating an increase in the relative sink strength. Similarly decreased number of leaves per vine increased girth of cane in Red Globe and Crimson Seedless, respectively after forward pruning (Table 1). This was mainly due to the competition of the shoot for nutrients and water that might have resulted in to dilution effect, which is generally observed in the vineyard. This is mainly attributed due to more rigorous photosynthates partitioning during peak vegetative and growth phase. This might resulted in more deposition of assimilates at basal portion of the fruiting shoot. Thus, the diameter of fruiting shoot recorded higher values at lower buds and lower at distal end buds. These results are in confirmity with Lopes et al. (2000) [9] observed that the higher crop load per vine reduced the shoot growth in cv. Cabernet Sauvignon.

Table 1: Effect of Source to Sink relationship on inter nodal length (cm) and girth (cm) of the vegetative and fruiting cane in grapes cvs. Red Globe and Crimson Seedless

	Internodal length (cm)								**Girth (cm)**							
Red Globe	**Vegetative cane**				**Fruiting cane**				**Vegetative cane**				**Fruiting cane**			
	L_1	**L_2**	**L_3**	**Mean**	**L_1**	**L_2**	**L_3**	**Mean**	**L_1**	**L_2**	**L_3**	**Mean**	**L_1**	**L_2**	**L_3**	**Mean**
C_1	5.18	5.27	5.09	5.18	5.15	4.80	4.57	4.84	8.26	8.13	7.68	8.02	6.68	6.45	6.19	6.44
C_2	4.92	4.72	4.46	4.70	4.57	4.04	3.92	4.18	7.40	7.22	7.11	7.24	5.95	5.73	5.43	5.70
C_3	4.16	4.23	3.99	4.13	4.03	3.56	3.46	3.68	6.73	6.12	5.96	6.27	5.03	4.69	4.27	4.66
Mean	4.75	4.74	4.51		4.58	4.14	3.98		7.46	7.16	6.92		5.89	5.62	5.30	
Source	SEm		CD (0.05%)		SEm		CD (0.05%)		SEm		CD (0.05%)		SEm		CD (0.05%)	
C (canes)	0.08		0.24		0.08		0.25		0.09		0.26		0.11		0.31	
L (leaves)	0.08		0.24		0.08		0.25		0.09		0.26		0.11		0.31	
C×L	0.14		NS		0.15		NS		0.16		NS		0.19		0.54	
Crimson Seedless	L_1	L_2	L_3	Mean	L_1	L_2	L_3	Mean	L_1	L_2	L_3	Mean	L_1	L_2	L_3	Mean
C_1	7.59	7.07	6.69	7.12	5.88	5.69	5.67	5.75	7.93	8.24	7.28	7.82	5.79	6.33	6.01	6.04
C_2	6.26	6.75	6.55	6.52	5.52	5.03	5.21	5.25	6.84	5.65	6.86	6.45	5.25	5.56	5.36	5.39
C_3	5.97	5.85	5.15	5.65	5.41	4.58	4.22	4.74	6.31	6.71	6.68	6.57	4.26	3.96	4.01	4.08
Mean	6.61	6.56	6.13		5.60	5.10	5.03		7.03	6.87	6.94		5.10	5.28	5.13	
Source	SEm		CD (0.05%)		SEm		CD (0.05%)		SEm		CD (0.05%)		SEm		CD (0.05%)	
C (canes)	0.13		0.37		0.13		0.39		0.18		0.53		0.05		0.14	
L (leaves)	0.13		0.37		0.13		0.39		0.18		NS		0.05		0.14	
C×L	0.22		NS		0.23		NS		0.32		NS		0.08		0.23	

C_1: 20 canes per vine; C_2: 30 canes per vines; C_3: 40 canes per vines
L_1: 8 leaves per canes; L_2: 12 leaves per canes; L_3: 16 leaves per canes

Number of days taken for bud sprouting and panicle initiation from pruning: Days to bud sprout showed significant difference with different levels of cane (source) and leaf (sink) regulation (Table 2). As depicted in internodal length and girth of vegetative and fruiting cane, similar trend observed in both cultivars with bud sprouting. Early bud sprouting observed in lowest cane density (20 canes) regulated vines (16 and 10 days). Meanwhile lowest leaf density resulted in early bud sprouting which has started by 18 and 11 days after forward pruning in Red Globe and Crimson Seedless respectively. Whereas, days taken for panicle initiation differed significantly among the different levels of cane and leaf density treatments (Table 2). Vines regulated at less cane density (20 canes per vine) took less number of days i.e., 37 days and 31 days from back pruning in Red Globe and Crimson Seedless, respectively. Similarly lowest leaf density (8 leaves per cane) resulted in early panicle initiation which took by 39 and 32 days in Red Globe and Crimson Seedless, respectively after forward pruning. Whereas, the interaction between the treatments shown statistically non-significant difference for number of days taken for panicle initiation.

This might be due to lesser number of bud load on the vine with sufficient assimilates availability has triggered the growth rate faster and hence it has taken minimum days for bud burst compared to other cane regulation treatments as reported by Abdel-Mohsen (2013)[10] in grape cv. Crimson Seedless and Porika *et al*. (2015)[11] in grape cv. Red Globe.

Leaf area per cane: The leaf area was significantly influenced by number of canes per vine and number of leaves per cane. The highest leaf area was observed in vines regulated with 30 canes in Red Globe with 2029 cm^2 whereas, 40 canes per vine with 2356 cm^2 in Crimson Seedless. Meanwhile, increased number of leaves per cane, decreased leaf area substantially. The highest leaf area was observed in vine regulated with 12 leaves per canes in Red Globe with 1859 cm^2 whereas, lowest number of leaves per cane 8 leaves per canes shown maximum leaf area per shoot with 2131 cm^2 in Crimson Seedless. It is evident from the data that the treatment effect on the substantial increase in canopy load shown increased leaf area because of availability of more accumulated carbohydrates in leaves (data not shown), increased rate of photosynthesis (data not shown). It is obvious from the present study that a greater number of leaves and canes can definitely increase total leaf area per vine. But, with increase in number of leaves there was reduction in the total leaf area which might be due to reduction in the expansion of individual leaf area. Many findings have shown negative correlation between number of canes, leaves and total leaf area as mentioned by Somkuwar *et al*. (2012) [12] who reported that higher leaf area (0.22 m^2) observed in less canopy load of 30 canes per vine in grape cv. Tas-A-Ganesh. Whereas, Zamboni *et al*. (1997) [13] and Naor *et al*. (2002) [8] in Sauvignon Blanc grape. It is very clear from the data that the number of leaves per vine acted as a principal factor in determining the growth attributes, leaf area and yield attributes was decreased due to less exposure to sunlight and competition for nutrients.

Effect of source sink manipulation on yield attributes of grape varieties

The major yield attributes relationship with various growth attributes were discussed below with respect to data interpreted in table 3.

Berry weight (g): Lowest number of canes per vine (20 canes per cane) showed maximum berry weight (5.18 g) in Crimson Seedless. Whereas, moderate cane density (30 canes per vine) produced the bold berries of the highest berry weight (7.17g) in Red Globe. The increased berry weight might be due to less number of bunches resulted in more accumulation of reserve food materials comparatively than more number of bunches in increased cane density as reported by Chalak *et al*. (2012)[5] in white wine grape varieties; Somkuwar *et al.* (2012)[12] in Tas-A-Ganesh grapes. Meanwhile, moderate leaf regulation (12 leaves per cane) showed maximum berry weight (6.51g and 4.96 g) in Red Globe and Crimson Seedless, respectively. Increased photosynthetic rate has been resulted in increased energy synthesis and hence, whatever metabolites that were produced in source part, were diverted towards sink resulting in more berry size. Similar findings were reported in various studies in grape by Ranpise *et al.* (2002)[14] and Somkuwar and Ramteke (2006)[15].

Table 2: Number of days taken for bud sprouting, panicle initiation after forward pruning, leaf area per cane and leaf area per berry weight in grapes *cvs.* Red Globe and Crimson Seedless as influenced by Source to Sink relationship

Red Globe	Days taken for bud sprouting				Days taken for panicle initiation				Leaf area per shoot (cm^2)				Leaf area per berry weight (cm^2/g)			
	L_1	L_2	L_3	Mean	L_1	L_2	L_3	Mean	L_1	L_2	L_3	Mean	L_1	L_2	L_3	Mean
C_1	16.13	15.91	16.81	16.29	36.25	36.38	38.84	37.16	1289	1344	1286	1307	10.80	9.97	10.51	10.43
C_2	16.76	17.34	18.46	17.52	37.66	40.87	42.17	40.23	2013	2186	1888	2029	13.54	12.09	12.52	12.72
C_3	19.56	19.10	19.88	19.52	42.10	43.61	42.02	42.58	2028	2048	1822	1966	13.25	12.44	12.65	12.78
Mean	17.49	17.45	18.38		38.67	40.29	41.01		1777	1859	1665		12.53	11.50	11.89	
Source	SEm		CD (0.05%)		SEm		CD (0.05%)		S. Em.		CD (0.05%)		S. Em.		CD (0.05%)	
C (canes)	0.34		0.98		0.58		1.70		28.49		82.81		0.16		0.45	
L (leaves)	0.34		0.98		0.58		1.70		28.49		82.81		0.16		0.45	
C×L	0.59		NS		1.01		NS		49.34		NS		0.27		NS	
Crimson Seedless	L_1	L_2	L_3	Mean	L_1	L_2	L_3	Mean	L_1	L_2	L_3	Mean	L_1	L_2	L_3	Mean
C_1	9.58	9.90	10.09	9.86	30.68	29.69	32.55	30.97	1629	1256	1230	1372	12.37	11.07	10.74	11.39
C_2	10.69	9.82	11.88	10.80	30.30	32.15	32.01	31.49	2344	2286	2206	2278	12.69	12.13	11.17	11.99
C_3	12.70	11.91	13.61	12.74	36.11	35.81	36.90	36.28	2422	2406	2241	2356	14.76	13.33	12.63	13.57
Mean	10.99	10.54	11.86		32.36	32.55	33.82		2131	1982	1892		13.27	12.18	11.51	
Source	SEm		CD (0.05%)		SEm		CD (0.05%)		S. Em.		CD (0.05%)		S. Em.		CD (0.05%)	
C (canes)	0.32		0.92		0.59		1.70		0.22		0.65		0.22		0.65	
L (leaves)	0.32		0.92		0.59		1.70		0.22		0.65		0.22		0.65	
C×L	0.55		NS		1.01		NS		0.39		NS		0.39		NS	

C_1: 20 canes per vine; C_2: 30 canes per vines; C_3: 40 canes per vines

L_1: 8 leaves per canes; L_2: 12 leaves per canes; L_3: 16 leaves per canes

Bunch weight (g) and Volume (cm^3): The maximum bunch weight (772.41 g) and bunch volume (386.20 cm^3) was recorded in C_2 (30 canes per vine) in Red Globe. Whereas, maximum bunch weight (433.20 g) and bunch volume (216.60 cm^3) was recorded in C_1 (20 canes per vine) in Crimson Seedless. This might be due to increased availability of carbohydrates (due to lesser bunches per vine) as reported by Palanichamy *et al.* (2004)[16] in grape cv. Pusa Navarang. Meanwhile, leaf regulation also showed substantial difference with maximum bunch weight (727.61g) and bunch volume (363.81 cm^3) on vines regulated with 12 leaves per cane in Red Globe whereas, vines regulated with 16 leaves per cane showed maximum bunch weight (398.07 g) and bunch volume (199.03 cm^3) in Crimson. From the results, it is clear that the weight of bunch as well as volume decreased with decreased leaf numbers. This clearly showed that the source strength is positively influencing the bunch weight through allocation of assimilates into the sink part and this was supported by findings of Cheema *et al.* (2003) in grape *cv.* Perlette[17].

Leaf area per gram berry weight (cm^2 per g): The altering cane and leaf treatment levels showed significant difference for how much leaf area was required to produce per unit berry weight in grape varieties with varying leaf area. The cane regulation data results showed that the minimum leaf area required per gram production of berry was observed in lowest number of cane per vine (20 canes) in Red Globe (10.43 cm^2/g), Crimson Seedless (11.39 cm^2/g). Meanwhile, moderate number of leaves per cane (12 leaves per cane) showed minimum leaf area requirement in Red Globe (11.89 cm^2/g) and highest number of leaves per cane (16 leaves per cane) in case of Crimson Seedless (11.51 cm^2/g). These findings are in line with the outcome of Koblet *et al.* (1994)[18], who reported that the total yield and yield of fruits were reduced as leaf area decreased and recorded that each 1 g of grapes produced by a required leaf area of 16-26 cm^2 in grape cv. Pinot Noir. Whereas, Dokoozlian and Kliewer (1995)[19], showed that the canopy leaf area of 4 cm^2/m canopy length resulted in low density canopies, while canopy leaf areas 8 cm^2/m canopy length resulted in high density canopies.

Table 3: Effect of Source to Sink relationship on berry weight, bunch weight, bunch volume and yield per vine in grapes cvs. Red Globe and Crimson Seedless

Red Globe	**Berry weight (g)**				**Bunch weight (g)**				**Bunch volume (cm^3)**				**Yield per vine (Kg)**			
	L_1	**L_2**	**L_3**	**Mean**	**L_1**	**L_2**	**L_3**	**Mean**	**L_1**	**L_2**	**L_3**	**Mean**	**L_1**	**L_2**	**L_3**	**Mean**
C_1	6.06	6.86	5.99	6.31	718.94	744.11	725.14	729.40	359.47	372.06	362.57	364.70	15.54	16.12	16.62	16.09
C_2	7.35	7.34	6.82	7.17	771.46	795.55	750.21	772.41	385.73	397.78	375.11	386.20	21.02	24.21	23.58	22.94
C_3	5.52	5.31	5.22	5.35	628.47	643.18	634.75	635.47	294.90	321.59	317.38	311.29	25.52	27.57	28.10	27.06
Mean	6.31	6.51	6.01		706.29	727.61	703.37		346.70	363.81	351.68		20.69	22.63	22.77	
Source	S. Em.		CD (0.05%)		S. Em.		CD (0.05%)		S. Em.		CD (0.05%)		S. Em.		CD (0.05%)	
C (canes)	0.10		0.28		6.83		19.86		3.82		11.11		0.13		0.37	
L (leaves)	0.10		0.28		6.83		19.86		3.82		11.11		0.13		0.37	
C×L	0.17		NS		11.83		NS		6.62		NS		0.22		0.64	
Crimson Seedless	L_2	L_3	L_2	Mean	L_1	L_2	L_3	Mean	L_1	L_2	L_3	Mean	L_1	L_2	L_3	Mean
C_1	5.18	5.27	5.09	5.18	395.73	446.44	457.43	433.20	197.87	223.22	228.72	216.60	10.01	11.84	11.53	11.13
C_2	4.92	5.05	4.46	4.81	342.13	385.19	413.01	380.11	171.06	192.59	206.51	190.05	11.97	14.68	13.53	13.39
C_3	4.16	4.56	3.99	4.24	286.67	318.11	323.76	309.52	137.10	159.06	161.88	152.68	10.76	13.51	12.81	12.36
Mean	4.75	4.96	4.51		341.51	383.25	398.07		168.68	191.62	199.03		10.92	13.34	12.63	
Source	S. Em.		CD (0.05%)		S. Em.		CD (0.05%)		S. Em.		CD (0.05%)		S. Em.		CD (0.05%)	
C (canes)	0.09		0.27		1.93		5.60		1.32		3.83		0.07		0.21	
L (leaves)	0.09		0.27		1.93		5.60		1.32		3.83		0.07		0.21	
C×L	0.16		NS		3.34		9.70		2.28		NS		0.12		0.36	

C_1: 20 canes per vine; C_2: 30 canes per vines; C_3: 40 canes per vines
L_1: 8 leaves per canes; L_2: 12 leaves per canes; L_3: 16 leaves per canes

Conclusion

Source to sink modulation through different levels of cane and leaf regulation reveals that the highest source capacity with minimum number of cane and leaf density resulted in increased internodal length, girth of both vegetative and fruiting canes in Red Globe and Crimson Seedless, respectively. Concurrently, both cultivars showed similar trend with early bud sprouting, panicle initiation, leaf area per crop weight in case of lowest cane density (20 canes) regulated vines. Whereas, moderate cane and leaf density (30 canes with 12 leaves) in Red Globe; lowest cane and highest leaf density (20 canes with 16 leaves) showed maximum berry or bunch weight and yield per vine. These results suggests that maximizing source strength through decreasing the cane and leaf density increases assimilate movement to sink at faster rate which in turn results in maximizing the growth and yield of the grape vine.

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