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Influence of cane regulation and bio-regulators on berry quality of grape cv. Crimson seedless

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Abstract

A filed experiment on Studies on the influence of cane regulation and bio-regulators on growth, yield and quality parameters of grape cv. Crimson Seedless was conducted at Fruit Orchard, Division of Fruit Science, MHREC, University of Horticultural Sciences, Bagalkote, during 2021-22 and 2022-23. The combination of cane regulation at 25-33 canes per vine with 300-400 ppm of ethrel treatment at veraison and 30 days after veraison recorded maximum berry length (20.24 and 19.70 mm), berry diameter (17.48 and 16.86 mm),berry weight(3.07 and 2.61 g), berry firmness (21.88 and 21.22 lb/inch^2) Juice percentage (36.63 and 35.77%),TSS (22.64 and 22.61),acidity(0.40 and 0.41%), TSS: acid ratio(55.69 and 55.16).

Keywords: Influence, bio-regulators, veraison, *Vitis vinifera* L.

Introduction

Crimson Seedless grape (*Vitis vinifera* L.) is a late season, attractive, red seedless grape with naturally small berries. Cultivar is the result of five generations of hybridization at the USDA Fresno location, starting in 1926. The source of seedlessness is from Thompson Seedless which was used as parent in the first generation of crossing. C33-199, a late-ripening white seedless grape (With all white grapes in its parentage) was used in final hybridization with emperor to produce `Crimson seedless`. But inadequate colouration and a small size might detract from their quality, because these small berries do not meet the size requirements of the export market. 'Crimson Seedless' vines are vigorous and moderately productive when cane-pruned. Seven to eight canes may be necessary on mature vines to provide commercial production. Spur-pruned vines are unproductive (Ramming and Tarailo, 1995) [23].

Cane regulation is an essential form of canopy management practice in vineyard operation. This is mainly done to regulate the current season growth, yield and quality of grapes. Crop load adjustment should be considered as one of the technical cultural practices suitable to modify grapevine physiology and plant production towards a defined goal (Matti and Ferrini, 2005) [14]. Higher number of shoots per vine *i.e.*, increased shoot density impairs the productivity of shoots. Therefore, april pruning is done to develop shoots at this rate and their vigour may be curtailed by either pinching or thinning of shoots. While in october pruning, depending upon variety more number of canes are retained on vigourous vines, less is retained on less vigourous ones. Hence, cane thinning is considered as a technique which could lead to improvement in grape (Bravdo *et al.*, 1985) [4].

Plant bio-regulators are generally organic (either synthetic or natural) chemical compounds other than nutrients, performs crucial role in growth and development of any crop. Use of bio-regulators especially abscisic acid or ethylene have been shown to have effects on inducing the expression of the encoding genes in the anthocyanin biosynthesis pathway. These hormones have been used widely to increase the colour and quality of red grapes at commercial scale.

Materials and Methods

The present investigation "Studies on the influence of cane regulation & bi-regulators on growth, yield and quality parameters of Grape *cv.* 'Crimson Seedless' was carried out during 2021-22 and 2022-23 at grape orchard, MHREC, Sector no-70, UHS, Bagalkote. The experimental design adopted for the present investigation was split plot design with four main treatments, seven sub treatments and replicated thrice. In each vine five canes were selected randomly and tagged for detailed observation.

Results and Discussion

Berry length (mm), berry diameter (mm) and berry weight (g)

Significant differences were recorded among different levels of canopy management practices and bio- regulator treatments with respect to berry length, berry diameter and berry weight are presented in Table (1). Canopy regulation treatments significantly influenced the berry length, berry diameter and berry weight. The maximum berry length (18.80 mm), berry diameter (17.17 mm) and berry weight (3.19 g) was recorded in C_4.The present investigation revealed that 25 canes per vine is superior as it has recorded highest berry length, berry diameter and berry weight as compared to control. The data revealed that increase in berry parameters was found to be associated with reduction in cane per vine and also contributed to increase in bunch weight and yield per vine. This might be due to more availability of assimilates as there is less competition from source to sink. As the severity of pruning reduced, the berry weight decreased, which means they are inversely proportionate to each other (Palanichamy *et al.* (2004) [17]. Similar findings were reported in various studies in grape Porika (2013) [20] in grape cv. Red Globe, Khalil (2020) [9] in Flame Seedless grapes

The bio-regulator treatments were also significantly influenced the berry length, berry diameter and berry weight. The maximum berry length (18.19 mm), berry diameter (18.19 mm) and berry weight (2.87 g) was recorded in $G_{5.}$ Application of bio-regulators results in increased berry length, berry diameter and berry weight might be due to positive action of bio-regulator helps in stimulating cell elongation process enhances the water absorption by roots and stimulating the biosynthesis of protein will lead to increased berry traits which supported by findings of Amiri *et al.* (2010) [1] in Beidaneh Ghermez grape and Roberto *et al,* (2012) [24].

The interaction effect between canopy regulation and bio-regulators also significantly influenced the berry attributing characters. The maximum berry length (20.24 mm), diameter (17.48 mm) and berry weight (3.39 g) was recorded in C_4G_5. Combined effect of cane regulation and bio-regulator treatments results in increased berry length, berry diameter and berry weight might be due to better mobilization of carbohydrates for better growth and development through cell expansion and cell division.

Berry firmness (lb/inch^2)

The berry firmness was significantly influenced by canopy regulation and bio-regulator treatments were recorded in Table (2). The vine regulated with 25 canes per vine has recorded the better berry firmness (21.00 lb/inch^2). This increase in berry firmness is attributed to increase in pulp and peel thickness of berries. The variation of berry firmness could be due to genetic nature of the cultivar. Similar reports made by Fawzi *et al.* (1984) [5] and Prculovski *et al*. (2021) [22] in cardinal variety of grape.

The bio-regulators showed significant differences with respect to berry firmness. The maximum berry firmness was recorded in G_5 (21.07 lb/inch^2).Increase in berry firmness is strongly associated with turgor pressure of mesocarp cells. The similar results were noticed by Lurie *et al.* (2010) [12] in Crimson Seedless, Amiri *et al.* (2010) [1] in Beidaneh Ghermez grape, Marzouk and Kassem (2011) [15].

The interaction effect between canopy regulation and bio-regulators significantly influenced the berry firmness. In this study the maximum berry firmness (21.88 lb/inch^2) was recorded in C_4G_5. The combination treatment with cane regulation and bio-regulators increased the berry firmness.

Moisture content in berry (%)

Moisture content in berry as influenced by cane regulation and bio-regulators are presented in Table (2).The pooled data showed significant results with respect to moisture content in berry. Among the canopy regulation treatments, the maximum moisture content in berry was recorded in C_4 (16.90) which was followed by C_3 (16.86). The minimum moisture content in berry was recorded in C_1 (15.41).Increase in moisture content in berry is due to the effect of cane regulation helps in more accumulation of photoshynthates results in bigger size berry with more moisture content.

The pooled data showed significant results with respect to moisture content in berry in bio-regulator treatments. The maximum moisture content in berry was recorded in G_1 (17.40) which was followed by G_5 (16.72), G_2 (16.58). The minimum moisture content in berry was recorded in G_4 (15.49). Decreased moisture content in berry mainly attributed to bio-regulators effect as a result of increasing membrane permeability which permits moisture stored in cell vacuoles to respire at faster rate.

The interaction effect between canopy regulation and bio-regulator treatments was significantly influenced the moisture content in berry. The new generation bio-regulators quickly reduces moisture content in berry by respiring at faster rate, hence the maximum moisture content was recorded in cane regulation with control treatment *viz*., C_4G_1 (17.60) which was followed by C_2G_1 (17.59), C_3G_1 (17.50).The minimum moisture content in berry was recorded in C_1G_4 (14.05).

Juice content (%)

The data pertaining to juice content of berry as influenced by canopy management practice and bio-regulators is given in Table 2. The significant differences were recorded with respect to juice content of the berry, among the cane regulation treatments. The highest juice content (36.46%) was recorded in C_4. It is evident from the results that 25 canes per vine was significantly influenced the juice content of the berry. The reason for high juice content might be due to more pulp, more juiciness, less thickness of the skin and bigger size of the berry leads to more juice recovery. The similar results were reported by Bravdo *et al.* (1984) [3] in Carignane grapevines, Porika *et al.* (2015) [21] in Red Globe.

Bio-regulator treatment also significantly influenced the juice content of the berry. The maximum juice content in berry was recorded in G_1 (35.01)

Significant differences were recorded in the interaction effect between canopy regulation and bio-regulators. The maximum juice content (36.63) was recorded in C_4G_5. The higher juice content per gram of fruit in the control may be due to over load of the crop and thin skin of the berry. Similar reports were made by Bravdo *et al.* (1984) [3] in Carignane grapevines, Patil *et al*. (2012) [18] in Cabernet Sauvignon and Shiraz vines and Kaur *et al.* (2013) [30] in Flame seedless grape.

Total soluble solids (^{0}Brix)

The data obtained in respect of total soluble solids (TSS) was influenced by various cane regulation and bio-regulator treatments are reported in Table (3). The data showed significant results with respect to TSS of the berry maximum total soluble solids (21.94°Brix) was recorded in C_4 compared to control (21.34°Brix) as higher shoot number is positively correlated to the number of bunches but negative with girth of the cane which impacted on impairment of accumulation of sugars due to insufficient assimilates for the higher crop load. These results are strongly supported by the findings of Main and Morris (2000) [13] who mentioned that fruits exposed to sunlight are generally rich in total soluble solids and reduced titratable acidity, compared to non-exposed or canopy shaded. Kliewer and Antcliff (1970) [10] opined that increased TSS in shoot thinned vines might be either due to remobilization of stored carbohydrates or an increase in photosynthetic activity of leaves of remaining shoot and improvement in the light microclimate by reduced shoot number thus, an increase in sink strength. The results of present findings are in agreement with results of Kohale *et al.* (2013) [11] in cv. Sharad Seedless, Ashwini *et al,* (2016) [2] in wine grapes.

Bio-regulator treatments use of ABA and Ethrel significantly influenced the TSS content of the berry. The maximum total soluble solids of berry were recorded in G_7 (22.48°Brix). Application of ethrel and abscisic acid results in higher sugar accumulation leads to expression of genes encoding sucrose transporters resulting in higher sucrose translocation from biosynthesis sites to the berry vacuoles in which sucrose is enzymatically converted into glucose and fructose. The observations of increased TSS content by ethrel and abscisic acid treatments are in agreement with those reported earlier by Nanthakumar *et al.* 2021 [16] in Red Globe grape.

The interaction effect between canopy regulations and bio-regulator treatments found significant with respect to TSS of berry. Application of new generation bio-regulators combined with cane regulation improve the total soluble solid content in Crimson Seedless. The maximum total soluble solids (22.48°Brix) were recorded in C_4G_7. The combination treatment with cane regulation and bio-regulators increased the TSS. It is mainly attributed to mobilization of metabolites from source to sink. The increase in sugars might be ascribed to the conversion of starch and acids into sugars in addition to continuous mobilization of carbohydrates from leaves. Similar results were obtained by Amiri *et al.* (2010) [1] in Beidaneh Ghermez grape, Red Globe grape and Kaur *et al.* (2013) [30] in Flame seedless grape.

Titratable acidity (%)

The percent of titratable acidity differed significantly among the canopy management practice and bio-regulator treatments presented in Table (3). The percent titratable acidity significantly increased with increase in number of shoots per vine. The cane regulation treatments significantly influenced the titratable acidity of the berry. the lowest titratable acidity (0.43%) of the berry was recorded in C_4, which was on par with C_2 (0.45%) and C_3 (0.45%). This clearly indicates that crop load has a negative effect on quality of bunches. The deterioration in quality might be due to increase in yield and consequent dilution of sugars in berries. The reason for low titratable acidity in optimum thinned vines might be due to lesser competition for metabolites among the limited number of bunches per vine, availability of more photosynthates consequent to better vigour and physiological activities induced in them. The predominant acids of grape *viz*., malic and tartaric acids are synthesized in leaves. These acids are translocated from leaves to bunch. This higher quantum of acids might have deposited in bunch during development and this could have caused higher acidity in less intensive pruning treatments. Shikhamani *et al.* (2008) [26] reported that the higher number of canes per vine resulted in to denser canopy and decreased the interception of light hence hindered the reduction of acid at the time of berry maturity. These results are in line with Somkuwar and Ramteke, 2007 [2], Jogaiah *et al.* (2012) [8], Harikanth, 2013 [7] and Ashwini *et al.*, 2016 [2].

The pooled data with respect to titratable acidity of the berry in bio-regulator treatments was found to be significant. The lowest acidity (0.41%) of the berry was recorded in G_7 which was at par with G_4 (0.42%),. It clearly indicates the role of application of ethrel and abscisic acid results in reduction in acidity could be due to effect of these bio-regulators in increasing membrane permeability which permits acids stored in cell vacuoles to respire at faster rate. Results obtained are agreement with Peppi *et al.* (2006) [19].

The interaction effect between canopy regulation and bio-regulator treatments significantly influenced the titratable acidity of the berry. The lowest titrable acidity (0.40%) was recorded in C_4G_7 which was on par with C_4G_4 (0.41%). In the present study, cane regulation alone does not influence per ent titratable acidity of berries. The combination treatment with cane regulation and bio-regulators reduce the acidity. Similar results were obtained by Kaur *et al.* (2013) [30] in Flame Seedless grape.

TSS to acid ratio

In the present study, TSS to acid ratio was significantly influenced by cane regulation and bio-regulators are presented in Table (3). Among the cane regulation treatments, the highest TSS: acid ratio was recorded in C_4 (51.09%), which was at par with C_3 (49.24%). The availability of more photosynthates consequent to better vigour and physiological activities. Similar findings were given by Senthil Kumar (2014) [25] in grapes cv. Italia, Porika *et al.* (2015) [21] in grape cv. Red Globe and Veena *et al.* (2015) [29].

Application of new generation bio-regulators *viz*., abscisic acid and ethrel of showed significant differences with respect to TSS to acid ratio. The highest TSS: acid ratio (54.21%) was recorded in G_7 which was at par with G_5 (46.53%). It was obvious that the acidity reduced with an increase in the total soluble solids resulted in increased TSS: Acidity ratio. These findings are in conformity with results those reported earlier by and Singh *et al.* (1994) [27].

The interaction effect between canopy regulations and growth regulator treatments was found significant with respect to TSS: acid ratio of berry. The highest TSS: acid ratio (55.69%) was recorded in C_4G_7. The combination treatment with cane regulation and bio-regulators increased the TSS to Acid ratio. Similar results were obtained by Kaur *et al.* (2013) [30] in Flame Seedless grape'

Table 1: Berry length (mm), berry diameter (mm) and berry weight (g) after October pruning in grapes *cv*. Crimson Seedless as influenced by cane regulation and bio-regulators

Treatment	Berry length (mm)			Berry diameter (mm)			Berry weight (g)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
Main plot (Cane regulation)									
C_1 (Control)	16.35	16.18	16.26	15.57	15.54	15.55	2.17	2.50	2.33
C_2 (50 canes vine^{-1})	16.55	16.53	16.54	16.36	16.34	16.35	2.35	2.54	2.44
C_3 (33 canes vine^{-1})	18.77	18.67	18.72	16.68	16.56	16.62	2.86	2.86	2.86
C_4 (25 canes vine^{-1})	18.80	18.79	18.80	17.19	17.14	17.17	3.25	3.13	3.19
S.Em ±	0.17	0.08	0.08	0.16	0.20	0.10	0.13	0.07	0.07
CD at 5%	0.60	0.29	0.28	0.56	0.68	0.36	0.46	0.23	0.25
Sub plot (Bio- regulators)									
G_1 (Control)	17.84	17.48	17.66	16.05	16.02	16.04	2.30	2.55	2.43
G_2 (ABA 200 ppm)	18.01	17.94	17.98	16.73	16.67	16.70	2.73	2.74	2.73
G_3 (ABA 300 ppm)	17.78	17.64	17.71	16.50	16.47	16.49	2.61	2.83	2.72
G_4 (ABA 400 ppm)	17.40	17.22	17.31	16.09	16.05	16.07	2.63	2.65	2.64
G_5 (Ethrel 300 ppm)	18.21	18.17	18.19	16.83	16.75	16.79	2.82	2.92	2.87
G_6 (Ethrel 350 ppm)	17.33	17.26	17.29	16.61	16.54	16.58	2.84	2.84	2.84
G_7 (Ethrel 400 ppm)	16.78	17.08	16.93	16.33	16.25	16.29	2.67	2.76	2.71
S.Em ±	0.27	0.26	0.16	0.19	0.18	0.14	0.11	0.07	0.06
CD at 5%	0.77	0.73	0.46	0.54	0.51	0.39	0.30	0.20	0.18
Interactions (Main plot × Sub plot)									
C_1G_1	16.53	16.20	16.37	15.58	15.55	15.56	2.04	2.45	2.25
C_1G_2	16.52	16.23	16.38	15.92	15.86	15.89	2.22	2.50	2.36
C_1G_3	16.28	16.18	16.23	15.41	15.39	15.40	2.06	2.55	2.31
C_1G_4	15.68	15.60	15.64	14.90	14.87	14.88	1.99	2.37	2.18
C_1G_5	18.69	18.32	18.50	16.15	16.13	16.14	2.51	2.60	2.55
C_1G_6	15.60	15.57	15.58	15.68	15.65	15.67	2.28	2.53	2.41
C_1G_7	15.15	15.13	15.14	15.33	15.33	15.33	2.08	2.48	2.28
C_2G_1	16.41	16.14	16.28	16.02	16.00	16.01	2.11	2.52	2.32
C_2G_2	17.56	17.28	17.42	16.63	16.61	16.62	2.50	2.62	2.56
C_2G_3	17.70	17.53	17.62	16.51	16.47	16.49	2.19	2.52	2.35
C_2G_4	17.65	17.51	17.58	16.03	15.98	16.01	2.28	2.38	2.33
C_2G_5	19.15	18.74	18.94	16.70	16.70	16.70	2.54	2.67	2.61
C_2G_6	13.65	14.65	14.15	16.60	16.59	16.59	2.49	2.58	2.54
C_2G_7	13.77	13.83	13.80	16.05	16.02	16.04	2.31	2.48	2.39
C_3G_1	18.41	17.78	18.10	16.23	16.22	16.23	2.38	2.62	2.50
C_3G_2	18.33	18.70	18.52	16.92	16.84	16.88	2.97	2.78	2.88
C_3G_3	18.20	17.93	18.07	16.79	16.79	16.79	2.92	2.72	2.82
C_3G_4	17.68	17.68	17.68	16.42	16.38	16.40	2.72	2.87	2.80
C_3G_5	19.76	19.63	19.70	16.98	16.73	16.86	3.05	3.09	3.07
C_3G_6	19.48	19.50	19.49	16.79	16.59	16.69	3.03	3.04	3.04
C_3G_7	18.76	18.77	18.76	16.62	16.35	16.48	2.93	2.92	2.93
C_4G_1	17.55	17.48	17.52	16.38	16.33	16.36	2.67	2.63	2.65
C_4G_2	20.03	19.76	19.89	17.47	17.35	17.41	3.52	3.17	3.35
C_4G_3	19.67	19.63	19.65	17.28	17.25	17.27	3.32	3.15	3.24
C_4G_4	19.22	19.13	19.18	17.02	16.98	17.00	3.16	3.28	3.22
C_4G_5	20.28	20.20	20.24	17.51	17.45	17.48	3.56	3.22	3.39
C_4G_6	19.10	19.35	19.22	17.38	17.34	17.36	3.19	3.32	3.26
C_4G_7	16.57	16.69	16.63	17.29	17.30	17.30	3.35	3.17	3.26
S.Em ±	0.54	0.52	0.33	0.38	0.36	0.28	0.21	0.14	0.12
CD at 5%	1.55	1.47	0.93	1.08	1.02	0.79	0.60	0.41	0.36

Table 2: Berry firmness, moisture percent and juice percentage in grapes *cv*. Crimson Seedless as influenced by cane regulation and bio-regulators

Treatment	Berry firmness (Newton)			Moisture (%)			Juice percentage (v/w)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
Main plot (Cane regulation)									
C_1 (Control)	19.69	19.83	19.76	15.39	15.44	15.41	33.19	33.39	33.29
C_2 (50 canes vine^{-1})	20.00	20.05	20.02	16.24	16.28	16.26	33.33	33.86	33.59
C_3 (33 canes vine^{-1})	20.31	20.52	20.41	16.83	16.89	16.86	34.55	35.53	35.04
C_4 (25 canes vine^{-1})	20.95	21.05	21.00	16.89	16.91	16.90	36.44	36.47	36.46
S.Em ±	0.17	0.16	0.13	0.21	0.17	0.16	0.15	0.20	0.10
CD at 5%	0.58	0.55	0.46	0.73	0.60	0.56	0.51	0.70	0.36
Sub plot (Bio- regulators)									
G_1 (Control)	18.57	18.65	18.61	17.39	17.42	17.40	34.98	35.04	35.01

G_2 (ABA 200 ppm)	20.85	20.86	20.86	16.56	16.60	16.58	34.61	35.06	34.84
G_3 (ABA 300 ppm)	20.60	20.66	20.63	16.05	16.07	16.06	34.49	34.69	34.59
G_4 (ABA 400 ppm)	20.04	20.22	20.13	15.47	15.51	15.49	34.22	34.28	34.25
G_5 (Ethrel 300 ppm)	21.02	21.12	21.07	16.68	16.76	16.72	34.34	35.27	34.80
G_6 (Ethrel 350 ppm)	20.68	20.69	20.69	16.40	16.42	16.41	34.21	34.51	34.36
G_7(Ethrel 400 ppm)	19.89	20.36	20.13	15.82	15.88	15.85	33.78	34.86	34.32
S.Em ±	0.21	0.27	0.18	0.21	0.17	0.15	0.25	0.21	0.17
CD at 5%	0.59	0.77	0.51	0.58	0.48	0.43	0.71	0.60	0.47
Interactions (Main plot × Sub plot)									
C_1G_1	18.08	18.26	18.17	16.87	16.98	16.93	33.51	33.54	33.53
C_1G_2	20.21	20.23	20.22	15.43	15.49	15.46	33.09	33.50	33.30
C_1G_3	20.08	20.07	20.08	14.52	14.55	14.54	33.25	33.15	33.20
C_1G_4	19.64	19.80	19.72	14.01	14.09	14.05	33.04	33.27	33.15
C_1G_5	20.21	20.55	20.38	16.01	16.07	16.04	33.35	33.34	33.34
C_1G_6	20.05	20.09	20.07	15.85	15.86	15.86	32.95	33.70	33.33
C_1G_7	19.61	19.85	19.73	15.01	15.02	15.02	33.13	33.20	33.17
C_2G_1	18.34	18.44	18.39	17.55	17.59	17.57	34.25	34.24	34.25
C_2G_2	20.55	20.55	20.55	16.55	16.57	16.56	33.89	34.30	34.10
C_2G_3	20.15	20.21	20.18	16.01	16.04	16.03	33.57	33.78	33.67
C_2G_4	19.90	19.92	19.91	15.02	15.06	15.04	32.88	32.91	32.90
C_2G_5	20.84	20.75	20.80	16.56	16.59	16.57	33.13	33.15	33.14
C_2G_6	20.46	20.38	20.42	16.02	16.06	16.04	32.07	34.14	33.11
C_2G_7	19.74	20.12	19.93	16.01	16.03	16.02	33.50	34.51	34.01
C_3G_1	18.63	18.65	18.64	17.53	17.50	17.52	35.70	35.83	35.77
C_3G_2	21.10	21.10	21.10	17.27	17.31	17.29	34.96	35.89	35.42
C_3G_3	20.77	20.90	20.84	16.84	16.88	16.86	35.07	35.40	35.23
C_3G_4	19.88	20.36	20.12	16.34	16.38	16.36	34.25	34.87	34.56
C_3G_5	21.17	21.27	21.22	17.30	17.33	17.31	34.50	36.00	35.25
C_3G_6	20.79	20.94	20.86	16.87	16.90	16.89	34.14	35.24	34.69
C_3G_7	19.81	20.43	20.12	15.67	15.91	15.79	33.25	35.50	34.37
C_4G_1	19.25	19.25	19.25	17.60	17.60	17.60	36.47	36.53	36.50
C_4G_2	21.55	21.55	21.55	17.00	17.03	17.02	36.52	36.54	36.53
C_4G_3	21.39	21.48	21.44	16.81	16.80	16.81	36.30	36.30	36.30
C_4G_4	20.75	20.78	20.77	16.51	16.50	16.51	36.51	36.20	36.35
C_4G_5	21.87	21.90	21.88	16.85	17.05	16.95	36.41	36.85	36.63
C_4G_6	21.44	21.37	21.40	16.88	16.85	16.86	36.43	36.45	36.44
C_4G_7	20.42	21.03	20.72	16.57	16.55	16.56	36.45	36.44	36.45
S.Em ±	0.42	0.54	0.36	0.41	0.34	0.30	0.50	0.42	0.33
CD at 5%	1.18	1.53	1.02	1.17	0.97	0.86	1.41	1.19	0.94

Table 3: TSS, titratable acidity (%) and TSS: acid (%) in grapes *cv*. Crimson Seedless as influenced by cane regulation and bio-regulators

Treatment	**TSS (° Brix)**			**Titratable acidity (%)**			**TSS: acid (%)**		
	2021	**2022**	**Pooled**	**2021**	**2022**	**Pooled**	**2021**	**2022**	**Pooled**
Main plot (Cane regulation)									
C_1 (Control)	21.30	21.37	21.34	0.482	0.479	0.481	44.48	44.99	44.74
C_2 (50 canes vine^{-1})	21.83	21.83	21.83	0.450	0.447	0.448	49.03	48.85	48.94
C_3 (33 canes vine^{-1})	21.87	21.87	21.87	0.450	0.452	0.451	49.12	49.36	49.24
C_4 (25 canes vine^{-1})	21.89	21.99	21.94	0.431	0.430	0.430	51.09	51.09	51.09
S.Em ±	0.06	0.06	0.05	0.007	0.009	0.004	0.33	0.20	0.16
CD at 5%	0.22	0.20	0.17	0.023	0.030	0.015	1.13	0.68	0.55
Sub plot (Bio- regulators)									
G_1 (Control)	20.64	20.65	20.64	0.527	0.527	0.527	39.24	39.21	39.23
G_2 (ABA 200 ppm)	21.37	21.44	21.40	0.476	0.469	0.473	45.04	45.68	45.36
G_3 (ABA 300 ppm)	21.86	21.87	21.86	0.446	0.445	0.445	49.21	49.29	49.25
G_4 (ABA 400 ppm)	22.42	22.43	22.42	0.418	0.418	0.418	53.73	53.74	53.74
G_5 (Ethrel 300 ppm)	21.40	21.59	21.50	0.463	0.463	0.463	46.31	46.75	46.53
G_6 (Ethrel 350 ppm)	21.91	21.92	21.91	0.428	0.430	0.429	51.36	51.03	51.20
G_7 (Ethrel 400 ppm)	22.48	22.47	22.48	0.416	0.412	0.414	54.12	54.29	54.21
S.Em ±	0.13	0.15	0.11	0.012	0.010	0.008	2.68	2.59	2.03
CD at 5%	0.37	0.44	0.31	0.033	0.030	0.022	7.62	7.35	5.78
Interactions (Main plot × Sub plot)									
C_1G_1	20.49	20.43	20.46	0.550	0.550	0.550	37.26	37.18	37.22
C_1G_2	20.90	20.93	20.92	0.503	0.500	0.502	41.53	41.91	41.72
C_1G_3	21.29	21.31	21.30	0.483	0.477	0.480	44.05	44.73	44.39
C_1G_4	22.01	22.04	22.03	0.453	0.447	0.450	48.56	49.39	48.98
C_1G_5	20.92	21.33	21.13	0.487	0.490	0.488	42.99	43.56	43.28

C_1G_6	21.40	21.40	21.40	0.470	0.467	0.468	45.55	45.87	45.71
C_1G_7	22.11	22.13	22.12	0.430	0.423	0.427	51.44	52.32	51.88
C_2G_1	20.61	20.63	20.62	0.520	0.520	0.520	38.67	38.47	38.57
C_2G_2	21.51	21.52	21.51	0.477	0.467	0.472	44.50	45.47	44.98
C_2G_3	22.02	22.02	22.02	0.450	0.440	0.445	51.62	50.11	50.86
C_2G_4	22.51	22.52	22.52	0.407	0.407	0.407	55.81	55.00	55.40
C_2G_5	21.55	21.57	21.56	0.467	0.460	0.463	45.87	45.91	45.89
C_2G_6	22.06	22.06	22.06	0.417	0.427	0.422	52.95	52.54	52.75
C_2G_7	22.58	22.49	22.53	0.410	0.410	0.410	53.78	54.42	54.10
C_3G_1	20.69	20.69	20.69	0.533	0.537	0.535	39.80	39.80	39.80
C_3G_2	21.52	21.53	21.52	0.483	0.473	0.478	45.16	46.19	45.68
C_3G_3	22.05	22.07	22.06	0.427	0.440	0.433	49.02	50.17	49.59
C_3G_4	22.56	22.56	22.56	0.403	0.410	0.407	55.48	55.47	55.48
C_3G_5	21.54	21.56	21.55	0.470	0.470	0.470	46.18	46.91	46.54
C_3G_6	22.09	22.09	22.09	0.417	0.420	0.418	53.05	51.78	52.42
C_3G_7	22.60	22.61	22.61	0.420	0.413	0.417	55.15	55.17	55.16
C_4G_1	20.75	20.83	20.79	0.503	0.500	0.502	41.23	41.39	41.31
C_4G_2	21.54	21.78	21.66	0.440	0.437	0.438	48.97	49.17	49.07
C_4G_3	22.07	22.07	22.07	0.423	0.423	0.423	52.13	52.15	52.14
C_4G_4	22.58	22.59	22.59	0.410	0.410	0.410	55.08	55.11	55.09
C_4G_5	21.59	21.91	21.75	0.430	0.430	0.430	50.22	50.62	50.42
C_4G_6	22.09	22.11	22.10	0.410	0.407	0.408	53.88	53.94	53.91
C_4G_7	22.63	22.65	22.64	0.403	0.400	0.402	56.12	55.26	55.69
S.Em ±	0.26	0.31	0.22	0.023	0.021	0.015	0.77	0.75	0.59
CD at 5%	0.74	0.88	0.63	0.066	0.059	0.043	2.20	2.12	1.67

Conclusion

From this study, it can be clearly concluded that, the cane regulation is essential form of thinning in vineyard operation and considered as a technique which could lead to tremendous improvement in quality parameters of Crimson Seedless as it is very vigourus cultivar. Application bio-regulator is one of important operations to get export quality standards and has more demand in market. In case of bio- regulator treatments, application ethrel 300-400 ppm at veraison stage has positively influenced berry quality like, berry, length, berry diameter, berry weght TSS, acidity, juice percentage, TSS: Acid ratio and Total anthocyanins in skin and berry. Among the interaction effects, the vines regulated with 25-33 canes per vine with the application of ethrel 300-400 ppm at veraison stage followed by vines regulated with 25-33 canes per vine with the application of abscisic acid 200-400 ppm at veraison stage was found superior over the control and other interactions.

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