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INFLUENCE OF CANE REGULATION AND GROWTH REGULATORS ON YIELD AND QUALITY PARAMETERS OF GRAPES CV. KR WHITE

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ABSTRACT

A field experiment was conducted to know the impact of canopy management and growth regulators application on grapes cv. K R White at Division of Fruit Science, MHREC, University of Horticultural Sciences, Bagalkot, during 2018-19 and 2019-20. For the study, cane regulations and growth regulators were considered as main and sub treatments. Significant differences were recorded with respect to cane regulation treatments. The higher bunch length (21.07cm), bunch width (15.73cm), bunch weight (598.11g), berry length (20.45mm), berry diameter (15.06mm), berry weight (3.11g) was recorded when the cane was regulated for 25 canes per vine. Whereas, 33 canes per vine were recorded higher TSS: acid ratio (34.07), reducing sugars (16.90%), non reducing sugars (0.84%), total sugars (17.78 %). The maximum yield (41.83 t/ha) was recorded in 50 canes per vine. Similarly, in sub plot treatment with respect to growth regulator application schedule -3 was recorded the highest bunch length (20.91cm), bunch width (15.30cm), bunch weight (599.49g), berry length (20.48mm), berry diameter (15.16mm) berry weight (3.15g), yield (18.37kg/vine and 43.04 t/ha), TSS (21.83°Brix), reducing sugars (17.00 %), non reducing sugars (0.85%), total sugars (17.90 %) and lower titratable acidity (0.73%). Further, 25 canes in combination with S_3 treatment has recorded the highest bunch length (21.96cm), bunch width (16.80cm), bunch weight (653.13g) berry length (21.86mm), berry diameter (15.78 mm), berry weight (3.38g) total sugars (17.99%). From the study, it can be concluded that 25 canes per vine in combination with gibberellic acid and brassinosteroids positively influenced the bunch and berry parameters.

Key words : Cane regulation, Gibberellic acid, Brassinosteroides, Bud burst, Bud sprouting.

Introduction

India is one of the largest grape-producing countries in the world covering an area of 161.91 thousand hectares occupying 2.30 % of the total area of fruits production in 2021-22 (3rd Advance Estimate). The country is also a major exporter of fresh grapes to the world. The country has exported 267,950.39 MT of Grapes to the world, worth Rs. 2,543.42 crores/ 313.70 USD Millions during the year 2022-23. Grapes are grown in various states across India, with Maharashtra being the largest grape-producing state. Maharashtra is the largest grape-producing state in India, accounting for more than 80% of the total grape production in the country. Other major grape-producing states in India include Karnataka, Andhra Pradesh, Tamil Nadu and Telangana. The most widely grown grape varieties in India are Thompson Seedless, Bangalore Blue, Anab-e-Shahi, Sharad Seedless and Manik Chaman. Grape cultivation in India is mostly done on a commercial scale, with large farms and vineyards spread across the country.

The grape season in India typically starts in December and lasts until May. The Indian grape industry has undergone significant growth in recent years, with the adoption of modern cultivation techniques, better infrastructure and increased exports to foreign markets. The export of grapes from India has been growing rapidly in recent years. The major export destinations for Indian grapes include the United Arab Emirates, the Netherlands,

the United Kingdom, Bangladesh and Saudi Arabia. The grape industry in India faces various challenges, including disease and pest management, lack of adequate storage and transportation infrastructure and price volatility. However, the government and private sector are working together to overcome these challenges and support the growth of the grape industry in the country.

Cane regulation is an essential form of pruning in grape vineyard operation, mainly done to regulate the current season growth, yield and quality of grapes. Crop load adjustment should be considered as one of the cultural practices suitable to modify grapevine physiology and plant production towards a defined goal (Matti and Ferrini, 2005). Higher number of shoots per vine, *i.e.* increased shoot density impairs the productivity of shoots. Therefore, foundation bud pruning is done to develop shoots at this rate and their vigour may be curtailed by either pinching or thinning of shoots. While pruning for fruiting, more numbers of canes are retained on vigorous vines, less number of canes are retained on less vigorous ones. Hence, cane thinning is considered as a technique, which could lead to improvement in grape and in wine quality. Cane thinning in grapes induced a canopy microclimate that was less favourable to the development of fungal diseases.

To maintain the quality standards, the cultivation practices like precision in use of balanced nutrition, water management and bio-regulators *etc*., play an important role in the growth and development of the crop. In grapes, nutritional factors are mainly related to the synthesis of proteins and carbohydrates. The utilization of these metabolites depends on the hormonal status of the plants. Use of growth regulators particularly GA_3 has become a common practice among the grapes growers in India. The phyto-hormones are also being used for root initiation, dormancy termination, flowering, fruit set, delay in abscission, senescence and enhanced growth rate. Plant hormones are extremely important chemicals in the integration of several metabolic processes and are also concerned with response of plants to external physical environment. Grape cultivation is nearly impossible without the use of plant growth regulators.

Gibberellic acid is especially used in viticulture, which affects grape berry by means formation of flower cluster, berry set, berry enlargement, cluster length elongation, berry and cluster thinning, prevention of berry cracking *etc*. The role of gibberellic acid as pollinicide in grapes is also well known.

Brassinosteroids represent a group of hormones first isolated from pollen extracts of *Brassica napus* L. (Mitchell *et al*., 1970). The isolation of brassinolide, the most active of these hormones (Grove *et al*., 1979) and the identification of its receptor (Wang *et al*., 2001) made it possible to study this hormone in various species, including grape species. Similar to animal hormones, brassinosteroids play crucial roles in diverse aspects of plant biology, including cell elongation, cell division, root growth, photo-morphogenesis, stomatal and vascular differentiation, seed germination, immunity and reproduction. Brassinosteroids are also involved in regulating the metabolism of plant oxidation radicals, ethylene synthesis and root gravitropic response and have a role in mediating plant responses to stress, such as freezing, drought, salinity, disease, heat and nutrient deficiency. This subfamily of hormones regulates a broad range of processes in plant development and responses to environmental stresses and their analogues have been shown to bring substantial increases in grain yield depending on growth status.

The basic characteristic of modern table grape production is its adaptation to the requirements of the market aiming to improve grape quality such as equal cluster size, equal size and shape of the berry, equal colouration of all the berries in the cluster and higher resistance to transportation. Furthermore, an important attribute of the grape berry quality is the seedlessness. Seedless cultivars are characterized with small grains and require management for improvement of their size. In order to improve the grape quality and to increase the berry size, plant growth regulators are usually applied (Nampila *et al*., 2010). Introduction and popularization of new table varieties throughout India is gaining attention of the farmers. New table seedless varieties *viz*., 2A-Clone, KR White, Flame Seedless, Crimson Seedless and Fantasy Seedless have to be replaced with existing varieties as these are excellent fruit qualities and well suited for table purpose. Very meagre work has been done in the past with respect to standardization of cane regulation and use of growth regulators in grape in these varieties of grapes particularly in Indian conditions.

Keeping in view of the above facts and requirements, the present investigation was undertaken to study the influence of cane regulation and growth regulators on growth, yield and quality parameters of grapes cv. KR White.

Materials and Methods

The present investigation on "Studies on the influence of cane regulation and growth regulators on growth, yield and quality parameters of grapes (*Vitis vinifera* L.)" cv. KR White was carried out during 2018-2020 in the grape

vineyard, Main Horticultural Research and Extension Centre, University of Horticultural Sciences, Bagalkot. It is situated under northern dry zone of Karnataka (Zone-3 and Region II). The average annual rainfall for the past 10 years at MHREC, Bagalkot was 552 mm. The climate is warm and dry throughout the year and rainfall is scarce. The months of September and December accounts for 52% of the total annual rainfall. The maximum and minimum temperature ranged between 33.15°C and 18.85°C, respectively and mean relative humidity of morning and evening were 74.26 and 56.67 per cent, respectively.

The experimental design consists of four main treatments, three sub plot treatments. Five canes in each vine per replication were selected randomly for recording the observations on growth parameters. The experimental design adopted for the present investigation was split plot design with the following treatments

Main plot treatments

C_1 (control: without cane regulation),

C_2 (50 canes/vine)

C_3 (33 canes/vine)

C_4 (25 canes/vine)

Sub plot treatments: Growth regulators

Schedule 1 (S_1)

- 10 ppm GA_3 at parrot green stage (21 days after fore pruning (DAFP))
- 20 ppm GA_3 at pre bloom stage (25 DAFP)
- 40 ppm GA_3 bunch dipping at 3-4 mm berry stage
- 30 ppm GA_3 bunch dipping at 6-7 mm berry stage

Schedule 2 (S_2)

- 10 ppm GA_3 at parrot green stage (21 DAFP)
- 20 ppm GA_3 at 1 week after first treatment
- 30 ppm GA_3 bunch dipping at 3-4 mm berry stage
- 40 ppm GA_3 bunch dipping at 6-7 mm berry stage
- 50 ppm GA_3 bunch dipping at 1 week after 4th treatment.

Schedule 3 (S_3)

- 10 ppm GA_3 at parrot green stage (21DAFP)
- 20 ppm GA_3 at pre bloom stage
- 40 ppm GA_3 + 1 ppm Brassinosteroids bunch dipping at 3-4 mm berry stage
- 30 ppm GA_3+ 1.50 ppm Brassinosteroids bunch dipping at 6-7 mm berry stage.

Firmness of the grape berries was determined using TAXT plus texture analyser (Make: Stable Micro System, Model: Texture Export Version 1.22). The force with the sample get cut was recorded in the graph and the peak force value in the graph was taken as the texture value in terms of Newton force (N). Juice content of the berries was noted by weighing fifty gram of berries and the juice was extracted. The juice content was measured in volume by weight basis. Total soluble solids in berry juice (TSS) were determined by means of digital hand refractometer having a scale of (0 to 32%) °Brix and expressed as degrees Brix. TSS/acid ratio was calculated by dividing TSS (°Brix) by acidity (%). Reducing sugars in the berry preserved in 80 per cent alcohol was estimated as per the Dintrosalicyclic acid (DNSA) method (Miller, 1972). The total sugar content present in the berry was estimated by anthrone reagent method. The values obtained were expressed in percentage. The per cent non-reducing sugar was obtained by subtracting the value of reducing sugar from that of total sugar as given by Miller (1972).

Statistical analysis of the data was done by following the Fischer's method of analysis of variance as given by Panse and Sukhatme (1967). The level of significance used in 'F' and't' test was p=0.05 and critical difference (CD at 5%) values were worked out whenever 'F' test was significant.

Results and Discussion

Bunch length (cm) and bunch width (cm) and bunch weight (g)

Significant differences were recorded with respect to bunch length, bunch width and bunch weight among different levels of cane regulation and growth regulator treatments (Table 1).

Cane removal significantly altered the bunch traits, wherein twenty five canes per vine produced significantly, the highest bunch length (21.07cm), bunch width (15.73cm) and bunch weight (598.11g).

In control treatment the lowest bunch length (19.45cm) bunch width (13.90cm) and bunch weight (493.79g) were noted among the cane regulation treatments. Bunches developed on vines without cane regulation showed inferior bunch characters. The highest bunch length, bunch width and bunch weight recorded in 25 canes per vine may be due to increased berry weight, berry length and berry diameter. Healthy functional leaves, climatic conditions during the growth time are some of the important factors for good production and accumulation of food materials. Bunch acts as a sink while the leaves are the source so the balance between sources to sink has resultant in to good length, width and weight of the bunch. Thus, production of food material

Table 1 : Bunch length (cm), bunch width (cm) and bunch weight (g) in grapes var. KR White as influenced by the cane regulation and growth regulators.

Treatments	Bunch length (cm)			Bunch width (cm)			Bunch weight (g)		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
Main plot (Cane regulation)									
C_1 (Control : without cane regulation)	18.55	20.35	19.45	13.22	14.58	13.90	490.33	497.26	493.79
C_2 (50 canes per vine)	19.12	20.65	19.88	13.54	14.77	14.16	520.01	511.89	515.95
C_3 (33 canes per vine)	19.53	22.30	20.92	14.23	15.47	14.85	553.69	557.00	555.35
C_4 (25 canes per vine)	19.81	22.32	21.07	14.98	16.49	15.73	579.56	616.67	598.11
S.Em ±	**0.27**	**0.50**	**0.25**	**0.17**	**0.16**	**0.16**	**22.02**	**9.83**	**12.10**
CD at 5 %	**0.65**	**1.23**	**0.61**	**0.41**	**0.40**	**0.40**	**53.88**	**24.06**	**29.61**
Sub plot (Growth regulators)									
S_1 : Schedule 1	18.86	20.60	19.73	13.38	14.73	14.06	494.19	444.25	469.22
S_2 : Schedule 2	19.37	21.32	20.34	13.91	15.34	14.62	520.97	586.42	553.69
S_3 : Schedule 3	19.53	22.30	20.91	14.69	15.91	15.30	592.53	606.45	599.49
S.Em ±	**0.32**	**0.31**	**0.23**	**0.12**	**0.11**	**0.09**	**21.18**	**8.84**	**11.73**
CD at 5 %	**NS**	**0.67**	**0.48**	**0.25**	**0.23**	**0.18**	**44.90**	**18.74**	**24.87**
Interactions (Main plot × Sub plot)									
C_1S_1	18.30	20.36	19.33	12.64	14.16	13.40	409.20	421.33	415.27
C_1S_2	18.12	19.89	19.01	13.21	14.51	13.86	501.11	545.67	523.39
C_1S_3	19.21	20.81	20.01	13.82	15.08	14.45	560.67	524.79	542.73
C_2S_1	19.60	19.98	19.79	13.12	14.37	13.75	499.35	406.00	452.68
C_2S_2	18.61	20.57	19.59	13.48	14.71	14.10	457.10	622.00	539.55
C_2S_3	19.15	21.40	20.27	14.04	15.23	14.63	603.58	507.67	555.62
C_3S_1	19.08	21.25	20.17	13.74	14.89	14.32	582.48	429.33	505.91
C_3S_2	20.10	22.23	21.17	14.24	15.58	14.91	463.00	564.33	513.67
C_3S_3	19.39	23.43	21.41	14.71	15.94	15.32	615.60	677.33	646.47
C_4S_1	18.44	20.82	19.63	14.03	15.51	14.77	485.73	520.33	503.03
C_4S_2	20.62	22.59	21.61	14.71	16.54	15.63	662.67	613.67	638.17
C_4S_3	20.35	23.57	21.96	16.19	17.41	16.80	590.27	716.00	653.13
S.Em ±	**0.87**	**0.95**	**0.63**	**0.34**	**0.32**	**0.28**	**58.95**	**24.85**	**32.62**
CD at 5 %	**1.86**	**NS**	**1.37**	**0.75**	**0.71**	**0.62**	**127.66**	**53.96**	**70.61**

NS: Non significant

S_1: 10 ppm GA_3 at parrot green stage (21 days after fore pruning (DAFP) 20 ppm GA_3 at pre bloom stage (25 DAFP)
40 ppm GA_3 bunch dipping at 3-4 mm berry stage 30 ppm GA_3 bunch dipping at 6-7 mm berry stage

S_2: 10 ppm GA_3 at parrot green stage (21 DAFP) 20 ppm GA_3 at 1 week after first treatment
30 ppm GA_3 bunch dipping at 3-4 mm berry stage 40 ppm GA_3 bunch dipping at 6-7 mm berry stage
50 ppm GA_3 bunch dipping at 1 week after 4th treatment

S_3: 10 ppm GA_3 at parrot green stage (21DAFP) 20 ppm GA_3 at pre bloom stage
40 ppm GA_3 + 1 ppm Brassinosteroids bunch dipping at 3-4 mm berry stage
30 ppm GA_3 + 1.50 ppm Brassinosteroids bunch dipping at 6-7 mm berry stage.

and translocation of it towards the sink might be responsible for increasing the bunch length, width and weight. Apart from this, shoot thinning must have increased the total photosynthetic capacity of leaf by better interception of light to the vines, which resulted in higher accumulation of photosynthates in the developing clusters. During the period of growth after forward pruning, these factors were at optimum and have resulted in more production of food and thus, increased length of the bunch. Satisha *et al*. (2013) opined that due to diversion of photosynthates to the available bunches by reduced number of canes resulted in increased cane thickness, which attributed to bunch length. The results obtained in the present investigation are in corroboration with the findings of Shubhangini (2016) in Red Globe grapes, Aswini *et al*. (2017) in wine grapes and Khalil (2020) in Flame

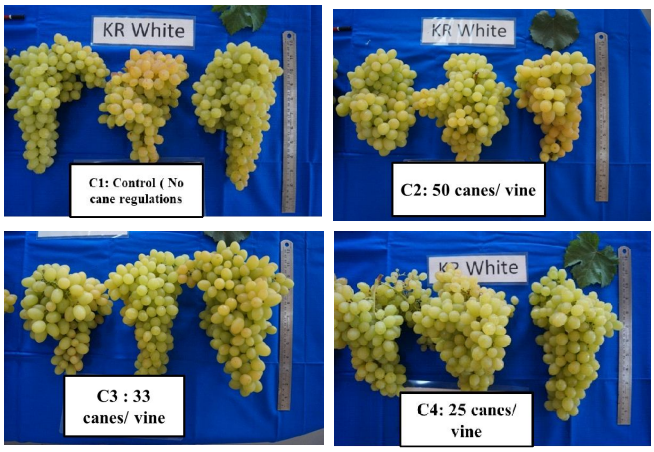

Plate 1 : Harvested bunches of var. KR White after different cane regulation and plant growth regulators treatment.

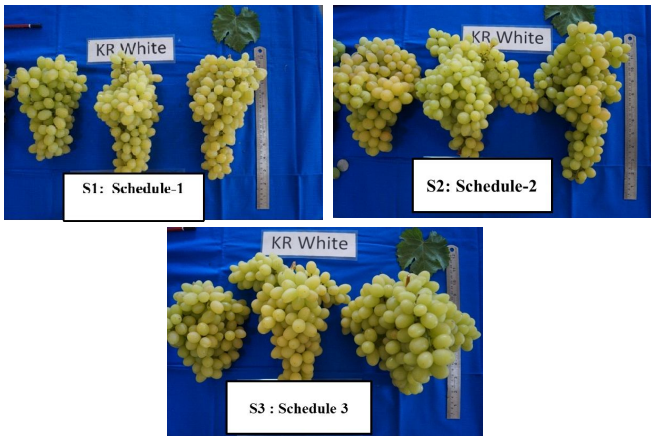

Plate 2 : Grape bunches in var. KR White after cane regulation and growth regulator treatments.

Seedless grapes.

The perusal of data with respect to bunch length, width and weight revealed significant difference in sub plot treatments. Growth regulator treatments significantly altered the bunch traits. Treatment S_3 produced significantly the highest bunch length (20.91 cm) bunch width (15.30 cm) and bunch weight (599.49 g) than that of bunches treated with schedule-1 and schedule- 2 of gibberellic acid alone. The reason may be as the grape bunches in schedule-3 set of application of gibberellic acid and brassinosteroid treatments got four times application of gibberellic acid starting from parrot green stage of the vine up to 6-7 mm berry size stage and two times berry dip application of brassinosteroids contributes in development of elongated bunches in the grapes. This possible effect might be attributed to certain changes in the metabolism of fruits for the improvement of sink strength followed by efficient partitioning of assimilates towards the developing sink in response to application of gibberllic acid and brasinosteroids. The increase in bunch length, width and weight due to application of brassinosteroids may be related to increased assimilation efficiency of photosynthetic carbon. Similar results were observed in earlier studies by Senthilkumar *et al*. (2018) in new grape cv. Italia; Khalil *et al*. (2020) in Flame Seedless and Anjum *et al*. (2020) in Sulatania grapes.

The interaction effect between cane regulation and growth regulator treatments significantly influenced the bunch length, width and weight. The highest bunch length (21.96 cm) and bunch width (15.30 cm) and bunch weight (653.13 g) was recorded in the treatment C_4S_3 which was found to be superior over other treatments in both the seasons. In the present study, it was recorded that 25 canes per vine with application of schedule-3 treatments was found optimum and effective in adding the better bunch traits. Shoot thinning might have increased the total photosynthetic capacity of leaf by better interception of light to the vines which resulted in higher accumulation of photosynthates in the developing clusters. Apart from this, combined application of gibberllic acid and brassinosteroids might have increased the size by increasing cell division and elongation. GA_3 is also reported to stimulate growth by promoting plasticity of the cell walls and the hydrolysis of starch into sugars that reduces the cells' water potential, inducing the entry of water into the cells and causing elongation and expansion (Marini, 2006). The combined treatment of GA_3 and BRs increased the clusters and berries' weight more than GA_3 alone, suggesting the synergistic effect between GA_3 and BRs. These findings are in confirmation with the findings of Tomar (1999) in Thompson Seedless and Habibi *et al.* (2009).

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

Significant differences were recorded among different levels of cane regulation and growth regulator treatments with respect to berry length, berry diameter and berry weight (Table 2). Cane regulation treatments were significantly influenced the berry length, berry diameter and berry weight. The highest berry length (20.45 mm), berry diameter (15.06 mm) and berry weight (3.11 g) was recorded. 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. Similar findings were reported

Table 2 : Berry length (mm), berry diameter (mm) and berry weight (g) in grapes var. KR White as influenced by the cane regulation and growth regulators.

Treatments	Berry length (mm)			Berry diameter (mm)			Berry weight (g)		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
Main plot (Cane regulation)									
C_1 (Control : without cane regulation)	18.93	19.11	19.02	14.34	14.75	14.54	2.76	2.86	2.81
C_2 (50 canes per vine)	19.17	19.18	19.17	14.54	14.79	14.67	2.80	2.99	2.89
C_3 (33 canes per vine)	19.83	20.20	20.01	14.71	15.10	14.91	2.88	3.10	2.99
C_4 (25 canes per vine)	20.14	20.60	20.45	14.84	15.29	15.06	2.98	3.24	3.11
S.Em ±	**0.20**	**0.24**	**0.12**	**0.19**	**0.17**	**0.10**	**0.02**	**0.10**	**0.06**
CD at 5 %	**0.48**	**0.59**	**0.29**	**NS**	**NS**	**0.25**	**0.05**	**0.24**	**0.13**
Sub plot (Growth regulators)									
S_1 : Schedule 1	18.84	19.01	18.92	14.51	14.61	14.56	2.71	2.58	2.64
S_2 : Schedule 2	19.34	19.83	19.59	14.16	15.16	14.66	2.83	3.28	3.05
S_3 : Schedule 3	20.36	20.48	20.48	15.15	15.18	15.16	3.03	3.28	3.15
S.Em ±	**0.18**	**0.21**	**0.16**	**0.19**	**0.20**	**0.13**	**0.04**	**0.07**	**0.03**
CD at 5 %	**0.38**	**0.45**	**0.33**	**0.40**	**0.43**	**0.28**	**0.08**	**0.14**	**0.07**
Interactions (Main plot × Sub plot)									
C_1S_1	18.56	18.69	18.62	14.18	14.42	14.30	2.59	2.57	2.58
C_1S_2	18.98	19.18	19.08	14.29	14.79	14.54	2.57	2.95	2.76
C_1S_3	19.25	19.46	19.35	14.55	15.03	14.79	3.11	3.05	3.08
C_2S_1	18.43	18.78	18.61	14.99	14.76	14.88	2.74	2.80	2.77
C_2S_2	19.30	19.18	19.24	13.90	15.00	14.45	2.92	3.19	3.06
C_2S_3	19.77	19.58	19.67	14.72	14.62	14.67	2.74	2.97	2.85
C_3S_1	18.87	19.56	19.21	14.54	14.52	14.53	2.68	2.44	2.56
C_3S_2	19.53	20.07	19.80	14.38	15.16	14.77	2.94	3.29	3.12
C_3S_3	21.10	20.96	21.03	15.20	15.63	15.42	3.02	3.58	3.30
C_4S_1	19.51	18.99	19.25	14.33	14.74	14.54	2.82	2.51	2.66
C_4S_2	19.56	20.89	20.23	14.05	15.68	14.86	2.90	3.67	3.29
C_4S_3	21.34	21.91	21.86	16.13	15.44	15.78	3.23	3.54	3.38
S.Em ±	**0.51**	**0.60**	**0.42**	**0.52**	**0.55**	**0.36**	**0.10**	**0.20**	**0.10**
CD at 5 %	**1.10**	**1.30**	**0.91**	**1.13**	**NS**	**0.77**	**0.22**	**0.43**	**0.22**

NS: Non significant

S_1: 10 ppm GA_3 at parrot green stage (21 days after fore pruning (DAFP)
20 ppm GA_3 at pre bloom stage (25 DAFP)
40 ppm GA_3 bunch dipping at 3-4 mm berry stage
30 ppm GA_3 bunch dipping at 6-7 mm berry stage

S_2: 10 ppm GA_3 at parrot green stage (21 DAFP)
20 ppm GA_3 at 1 week after first treatment
30 ppm GA_3 bunch dipping at 3-4 mm berry stage
40 ppm GA_3 bunch dipping at 6-7 mm berry stage
50 ppm GA_3 bunch dipping at 1 week after 4th treatment.

S_3: 10 ppm GA_3 at parrot green stage (21DAFP)
20 ppm GA_3 at pre bloom stage
40 ppm GA_3 + 1 ppm Brassinosteroids bunch dipping at 3-4 mm berry stage
30 ppm GA_3 + 1.50 ppm Brassinosteroids bunch dipping at 6-7 mm berry stage.

in various studies in grape by Shubhangini (2016) in Red Globe grapes; Ashwini *et al*. (2017) in wine grapes and Khalil (2020) in Flame Seedless grapes.

The sub plot treatments were also significantly influenced the berry length, berry diameter and berry weight. The treatment schedule-3 was significantly influenced the berry parameters. The highest berry length (20.48 mm), berry diameter (15.16 mm) and berry weight (3.11 g) were recorded. The application of schedule-3 treatment was significantly influenced the superior berry traits as compared to schedule 1 and 2. It is evident from the results that the combination of gibberllic acid and brassinosteroids applications has significantly influenced the superior berry parameters as compared to gibberllic

acid alone. It was mainly due to cell division in the initial stages and later due to faster cell expansion associated with the influx of water and metabolites into the berries which leads to an overall increase in the weight of berries. According to Richard (2006), gibberellic acid is reported to promote growth by increasing plasticity of the cell wall followed by the hydrolysis of starch into sugars which reduces the cell water potential, resulting in the entry of water into the cell thus causing an increase in size. BRs induced cell division, expansion and differentiation are well documented by Khalil (2020) in Flame Seedless grapes. Endogenous BRs even at nanomolar concentrations enhance the growth of tissues synergistically and in an independent manner to auxin (Taiz and Zeiger, 2010). These results comply with those reported by Champa *et al*. (2014) in cv. Flame Seedless and Anjum *et al*. (2020) in Sulatania grapes.

The interaction effect between cane regulation and growth regulators also significantly influenced the berry attributing characters. In the present study, 25 canes per vine in combination with schedule-3 was recorded maximum berry length (21.86 mm) berry diameter (15.78 mm) and berry weight (3.38 g). Similar results were obtained by Tomar *et al*. (1999), who reported that application of GA_3 significantly increased the berry length in Thompson Seedless, mainly due to its effect on distal than proximal parenchymatous tissues of berry. Lakshmanan *et al*. (1992), who also reported that, the berry development in Thompson Seedless grapes might be due to the role of hormones which mobilize elaborated food material, increase in water uptake, solute storage and synthesis of cell components. Water influx contributes towards the berry weight and it is possibly under an indirect hormonal control because of the promotional effect of auxin, cytokinin and GA_3. BRs induced cell division, expansion and differentiation are well documented (Taiz and Zeiger, 2010). Endogenous BRs even at nanomolar concentrations enhance the growth of tissues synergistically and in an independent manner to auxin (Taiz and Zeiger, 2010).

Yield (kg/vine and t/ha)

Yield was significantly influenced by different levels of cane regulation and growth regulator treatments (Table 3). Among the varieties, higher yield (19.20 kg/vine) in C_2 and lowest yield per vine (14.85 kg/vine) was recorded in C_4 among the cane regulation treatments. Similarly, the higher yield (41.83 t/ha) and lowest yield (32.35 t/ha) was recorded. In the present investigation, higher yield was recorded in canes regulated with 50 canes per vine which was on par with control and 33 canes per vine. Lower yield was recorded in 25 canes per vine. It was recorded that yield was positively correlated with number of clusters. The higher yield in control might be positive correlation of number of canes per vine with the number of panicles, which contributed for the total yield of vine. But from perusal of yield data of cane regulated vines, even with reduction of 34, 42 and 50 per cent of shoots the yield difference was only 07, 20 and 25 per cent, respectively. Because cane regulated vines gave the higher bunches per cane and bold berries which compensated by heavy bunches. 33 canes per vine was on par with 50 canes and control treatment but it was recorded superior quality attributes such as bunch length, bunch width, berry weight, berry diameter which may fetch more price in the market as compared to control because of superior quality parameters etc. Similar findings were recorded by Fawzi *et al.* (2010) and Raj kumar *et al*. (2017) in variety Muscat Hamburg.

Sub plot treatments significantly influenced the yield. The higher yield (19.76 kg/vine) and (43.04 t/ha) was recorded in treatment S_3. It is revealed from the results that the schedule-3 treatments comprising of different concentration of gibberllic acid in combination with brassinosteroids at different stages has recorded higher yield. The increase in yield with the application of GA_3 and BRs may be due to increased assimilation efficiency of photosynthetic carbon as BRs stimulate greater CO_2 assimilation besides stimulation of cell division by GA_3. The growth stimulation may also be related to an increase in RNA and DNA content, polymerase activity and protein synthesis as reported by Khalil (2020) in Flame Seedless grapes.

The interaction effect between cane regulations and growth regulator treatments also significantly influenced the yield. The present findings revealed that, higher yield (22.35 kg/vine) and yield (48.68 t/ha) was recorded in C_2S_3. The higher yield was recorded, where more number of canes per vine were retained. Increase in yield was directly proportional to the higher number canes per vine which resulted in more number of bunches per vine that contributed to the higher yield. The similar findings were obtained byMyers *et al*. (2008) in Sangiovese grape vines, Somkuwar *et al*. (2010) in grape vines. Along with the cane regulation treatments, the application of gibberllic acid in combination with brassinosteroids was also found effective for increasing the yield. Brassinosteroids induced the yield and yield attributing parameters may be due to stimulation of elongation, pollen tube growth and reproductive devel-opment. These results are in accordance with the results of Champa *et al.* (2014) in Flame Seedless grapes and Isci and Gokbayrak (2015) in Alphonse Lavallée grapes.

Table 3 : Yield in grapes var. KR White as influenced by the cane regulation and growth regulators.

Treatments	Yield (kg/vine)			Yield (t/ha)		
	2018	2019	Pooled	2018	2019	Pooled
Main plot (Cane regulation)						
C_1 (Control : without cane regulation)	15.95	20.30	18.13	34.73	44.22	39.48
C_2 (50 canes per vine)	17.79	20.62	19.20	38.74	44.92	41.83
C_3 (33 canes per vine)	17.12	18.41	17.76	37.28	40.09	38.69
C_4 (25 canes per vine)	13.78	15.92	14.85	30.02	34.67	32.35
S.Em ±	**0.91**	**0.91**	**0.83**	**1.99**	**1.98**	**1.80**
CD at 5 %	**2.23**	**2.22**	**2.02**	**4.86**	**4.84**	**4.40**
Sub plot (Growth regulators)						
S_1 : Schedule 1	15.49	14.82	15.16	33.75	32.28	33.02
S_2 : Schedule 2	14.61	20.46	17.54	31.83	44.56	38.20
S_3 : Schedule 3	18.37	21.16	19.76	40.00	46.08	43.04
S.Em ±	**0.96**	**0.84**	**0.49**	**2.10**	**1.83**	**1.07**
CD at 5 %	**2.04**	**1.78**	**1.05**	**4.45**	**3.88**	**2.28**
Interactions (Main plot × Sub plot)						
C_1S_1	12.82	15.86	14.34	27.91	34.55	31.23
C_1S_2	15.51	25.35	20.43	33.79	55.22	44.50
C_1S_3	19.52	19.69	19.60	42.51	42.89	42.70
C_2S_1	17.80	15.75	16.78	38.77	34.31	36.54
C_2S_2	13.69	23.28	18.48	29.82	50.70	40.26
C_2S_3	21.87	22.84	22.35	47.63	49.74	48.68
C_3S_1	18.58	14.79	16.68	40.46	32.20	36.33
C_3S_2	14.45	16.92	15.68	31.47	36.86	34.16
C_3S_3	18.33	23.52	20.92	39.91	51.22	45.57
C_4S_1	12.79	12.88	12.84	27.85	28.06	27.96
C_4S_2	14.81	16.29	15.55	32.26	35.48	33.87
C_4S_3	13.76	18.58	16.17	29.96	40.47	35.22
S.Em ±	**2.65**	**2.35**	**1.52**	**5.78**	**5.13**	**3.31**
CD at 5 %	**5.72**	**5.11**	**3.36**	**12.47**	**11.12**	**7.33**

NS: Non significant

S_1: 10 ppm GA_3 at parrot green stage (21 days after fore pruning (DAFP)
20 ppm GA_3 at pre bloom stage (25 DAFP)
40 ppm GA_3 bunch dipping at 3-4 mm berry stage
30 ppm GA_3 bunch dipping at 6-7 mm berry stage

S_2: 10 ppm GA_3 at parrot green stage (21 DAFP)
20 ppm GA_3 at 1 week after first treatment
30 ppm GA_3 bunch dipping at 3-4 mm berry stage
40 ppm GA_3 bunch dipping at 6-7 mm berry stage
50 ppm GA_3 bunch dipping at 1 week after 4th treatment.

S_3: 10 ppm GA_3 at parrot green stage (21DAFP)
20 ppm GA_3 at pre bloom stage
40 ppm GA_3 + 1 ppm Brassinosteroids bunch dipping at 3-4 mm berry stage
30 ppm GA_3 + 1.50 ppm Brassinosteroids bunch dipping at 6-7 mm berry stage.

Quality parameters

Berry firmness (Newton)

The berry firmness was significantly influenced by cane regulation and growth regulator treatments (Table 4). The vine regulated with 33 canes per vine has recorded the better berry firmness (81.74 N). This increase in berry firmness is attributed to increase in pulp and peel thickness of berries. The variation of berry firmness among the varieties could be due to genetic nature of the variety. Similar reports made by Fawzi *et al*. (1984).

The sub plot treatments of growth regulators showed significant differences with respect to berry firmness. Schedule-3 has recorded significantly higher berry firmness (81.47 Newton) as compared to schedule-2 and 1. This increase in berry firmness of grapes treated with

schedule-3 comprising of gibberellic acid and brassinosteroids treatment was attributed to increase in pulp and peel thickness of berries compared to schedule-2 and 1. Further increase in firmness of grapes is also attributed to the division of cell wall material into uronic acids (pectin), neutral sugars (peptic side chains and hemicelluloses) and cellulose was affected by a gibberellin treatment (Weksler *et al*., 2012). Similar reports were also made by Xu *et al*. (2019). Brassinosteroids also enhances the fruit firmness due to by increasing Ca^{2+}protopectin and pectin of cell walls (Peng *et al*., 2004).

The interaction effect between cane regulations and growth regulators significantly influenced the berry firmness. In this study, 33 canes per vine with the application of schedule-3 treatments was recorded better berry firmness [87.31 (Newton)]. This increase in berry firmness of grapes treated with gibberellic acid and brassinosteroidss is attributed to increase in peel thickness of berries compared to gibberellic acid alone. BRs enhance fruit firmness by increasing Ca^{2+} protopectin and pectin of cell walls (Peng *et al.*, 2004). Furthermore, it can be assumed that, BRs being antagonistic to ethylene inhibit weakening of cell walls at the abscission zone by repressing cell wall degrading enzymes such as celllulase and polygalactouronase, which might account for better berry firmness. Further increase in firmness of grapes is also attributed to the division of cell wall material into uronic acids (pectin), neutral sugars (peptic side chains and hemicelluloses) and cellulose was affected by a gibberellin treatment (Weksler *et al.*, 2012) and also due to reduced cell wall loosening (Rokaya *et al.*, 2016). Firmness of berries at harvest was significantly affected by BRs treatment. The highest firmness was observed in berries which received 0.5 mg l^{-1} brassinosteroids (Champa *et al*., 2014) in Fantasy grapes.

Juice content (%)

The data pertaining to juice content of berry as influenced by cane regulation and growth regulator was given in Table 4. The significant differences were recorded with respect to juice content of the berry, among the cane regulation treatments. The highest juice content (59.94%) was recorded in control and the lowest juice content (52.25%) was recorded in 25 canes per vines. It is evident from the results that control was significantly influenced the juice content of the berry. The reason for high juice content in control vines might be due to lesser pulp, more juiciness, less thickness of the skin and smaller size of the berry leads to more juice recovery.

Sub plot treatment also significantly influenced the juice content of the berry. The application of schedule-3 significantly increases juice content in var. 2A Clone however juice content was higher in KR White with the application of schedule-2 treatments.

Significant differences were recorded in the interaction effect between cane regulation and growth regulators. The maximum juice (63.66%) content was recorded in control with the application of schedule-2 treatments. 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 Patil *et al*. (2012) in Cabernet Sauvignon and Shiraz vines.

Total soluble solids (^{0}Brix)

The data obtained in respect of total soluble solids (TSS) was influenced by various cane regulation and growth regulator treatments (Table 4). The data showed no significant results with respect to TSS of the berry, among the cane regulation treatments. However, the maximum TSS (21.45^o Brix) was recorded in 33 canes per vine. In the present study, the 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) that mentioned that fruits exposed to sunlight are generally rich in total soluble solids and reduced titratable acidity, compared to non-exposed or canopy shaded. The results of present findings are in agreement with results of Ashwini *et al.* (2017) in wine grapes.

Sub plot treatments significantly influenced the TSS content of the berry. The highest TSS (21.83^o Brix). In the present investigation, application of schedule-3 treatments has recorded significantly higher TSS content of berry which was followed by schedule-2 and schedule-1. This might be due to combined application of GA_3 and Brassinosteroides, as GA_3 increases total sugar by increasing the capacity of fruits to draw more carbohydrates through increased auxin content directly or indirectly due to the quick metabolic transformation of soluble compounds (Singh *et al*., 1993). The rise in TSS by application of GA_3 and BR might be due to mobilization of metabolites from source to sink and also the conversion of starch and acids into sugars. The observations of increased TSS content by GA_3 treatments are in agreement with those reported earlier by Francisco and Gomez (2000) and Wu *et al*. (2001). Luan *et al*. (2013) and Xi *et al.* (2013), who also observed an increase in the sugar content of berries as a consequence of 24-epibrassinolide applications. More recent studies have shown that this increase can be explained by the over

Table 4 : Berry firmness (Newton), juice percentage (v/w), RSS (°Brix) and titratable acidity (%) in grapes var. KR White as influenced by the cane regulation and growth regulators.

Treatments	Firmness (Newton)			Juice percentage (v/w)			TSS (° Brix)			Titratable acidity (%)		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
Main plot (Cane regulation)												
C_1 (Control : without cane regulation)	77.77	73.03	75.40	65.56	54.32	59.94	21.10	20.49	20.79	0.87	0.68	0.78
C_2 (50 canes per vine)	78.39	67.53	72.96	63.21	47.94	55.57	21.46	19.98	20.72	0.72	0.65	0.68
C_3 (33 canes per vine)	82.49	80.98	81.74	59.64	47.37	53.50	22.14	20.76	21.45	0.62	0.64	0.63
C_4 (25 canes per vine)	81.26	80.49	80.88	58.92	45.58	52.25	21.57	20.53	21.05	0.65	0.65	0.65
S.Em ±	**1.04**	**1.23**	**0.72**	**1.56**	**1.80**	**0.96**	**0.24**	**0.44**	**0.27**	**0.03**	**0.02**	**0.02**
CD at 5 %	**2.56**	**3.00**	**1.76**	**3.83**	**4.40**	**2.35**	**0.59**	**NS**	**NS**	**0.08**	**NS**	**0.05**
Sub plot (Growth regulators)												
S_1 : Schedule 1	78.09	71.94	76.60	62.27	49.51	53.97	21.06	20.07	20.56	0.77	0.67	0.80
S_2 : Schedule 2	78.37	75.11	75.15	64.13	51.22	57.68	21.44	19.78	20.61	0.70	0.67	0.80
S_3 : Schedule 3	83.47	79.48	81.47	59.09	45.68	54.30	22.20	21.47	21.83	0.68	0.63	0.73
S.Em ±	**1.00**	**1.45**	**0.74**	**1.80**	**1.28**	**1.16**	**0.37**	**0.43**	**0.32**	**0.03**	**0.02**	**0.02**
CD at 5 %	**2.13**	**3.07**	**1.56**	**3.82**	**2.72**	**2.47**	**0.79**	**0.92**	**0.68**	**0.07**	**NS**	**0.04**
Interactions (Main plot × Sub plot)												
C_1S_1	75.81	70.78	74.96	64.14	54.53	55.39	20.95	20.20	20.57	0.91	0.70	0.80
C_1S_2	76.33	74.11	73.56	65.54	61.77	63.66	21.06	19.40	20.23	0.90	0.70	0.80
C_1S_3	81.17	74.20	77.69	66.99	46.65	60.76	21.28	21.87	21.58	0.82	0.64	0.73
C_2S_1	74.64	62.33	69.70	61.06	51.78	55.11	20.52	19.40	19.96	0.86	0.65	0.76
C_2S_2	76.53	64.76	69.43	63.87	42.88	53.38	21.36	20.33	20.85	0.64	0.66	0.65
C_2S_3	83.99	75.49	79.74	64.69	49.16	58.24	22.49	20.20	21.35	0.65	0.63	0.64
C_3S_1	80.79	75.60	79.58	62.36	49.31	53.78	21.34	20.27	20.81	0.66	0.68	0.67
C_3S_2	81.03	78.37	78.31	63.64	47.60	55.62	21.84	19.93	20.89	0.63	0.65	0.64
C_3S_3	85.64	88.98	87.31	52.91	45.19	51.11	23.23	22.09	22.66	0.58	0.61	0.59
C_4S_1	81.12	79.06	82.15	61.54	42.41	51.62	21.43	20.40	20.91	0.65	0.65	0.65
C_4S_2	79.57	83.19	79.32	63.47	52.63	58.05	21.50	19.47	20.48	0.64	0.65	0.64
C_4S_3	83.08	79.24	81.16	51.75	41.70	47.08	21.78	21.72	21.75	0.67	0.64	0.66
S.Em ±	**2.79**	**3.93**	**2.03**	**4.91**	**3.77**	**3.16**	**1.00**	**1.21**	**0.88**	**0.09**	**0.052**	**0.05**
CD at 5%	**NS**	**8.46**	**4.39**	**10.57**	**8.26**	**6.79**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

NS: Non significant

S_3: 10 ppm GA_3 at parrot green stage (21DAFP)
40 ppm GA_3 + 1 ppm Brassinosteroids bunch dipping at 3-4 mm berry stage
20 ppm GA_3 at pre bloom stage
30 ppm GA_3+ 1.50 ppm Brassinosteroids bunch dipping at 6-7 mm berry stage.

S_2: 10 ppm GA_3 at parrot green stage (21 DAFP)
30 ppm GA_3 bunch dipping at 3-4 mm berry stage
50 ppm GA_3 bunch dipping at 1 week after 4th treatment.
20 ppm GA_3 at 1 week after first treatment
40 ppm GA_3 bunch dipping at 6-7 mm berry stage

S_1: 10 ppm GA_3 at parrot green stage (21 days after fore pruning (DAFP)
40 ppm GA_3 bunch dipping at 3-4 mm berry stage
20 ppm GA_3 at pre bloom stage (25 DAFP)
30 ppm GA_3 bunch dipping at 6-7 mm berry stage

expression of hexose transporter genes VvHT2, VvHT3, VvHT4, VvHT5 and VvHT6 as a consequence of 24-epibrassinolide application (Xu *et al*., 2015). These findings are in line with Champa *et al.* (2014) in Flame Seedless grapes; Ghorbani *et al*. (2017) in 'Thompson Seedless' grape and Anjum *et al*. (2020) in Sulatania grapes.

The interaction effect between cane regulations and growth regulator treatments found non significant with respect to TSS of berry.

Titratable acidity (%)

The per cent of titratable acidity differed significantly among the cane regulation treatments (Table 4). The per cent 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 minimum titratable acidity (0.63%) and maximum titratable acidity (0.78%) was recorded. The present investigation revealed that, significantly the minimum titratable acidity was recorded in 33 canes per vine which was at par with 25 canes per vine. 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) 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 studies conducted by Shubhangini (2016) in Red globe variety and Ashwini *et al.* (2017).

The pooled data with respect to titratable acidity of the berry in sub plot treatments was found to be significant. The lowest acidity (0.73%) with the application of schedule-3 treatments. It clearly indicates the role of gibberllic acid in combination with brassinosteroids in decreasing the titratable acidiy of the berry. Ghorbani *et al*. (2017) showed that the manipulation of brassinosteroids levels *via* the application of exogenous brassinosteroids can significantly promote berry ripening (TSS and TA) and increased quality of berry in 'Thompson Seedless' grape.

The interaction effect between cane regulation and growth regulator treatments significantly influenced the titratable acidity of the berry. Significantly, the lowest acidity (0.59%). However, it was non significant in KR White variety. The combination of 33 canes per vine and application of schedule- 3 treatments significantly influenced the titratable acidity which was at par with 25 canes per vine and schedule-3. In the present study, cane regulation alone does not influence per cent titratable acidity of berries. Gibberellic acid and brassinosteroids application alone and along with different cane regulation treatments influenced variedly and accordingly. The results are in accordance with results of Belgrade grapes and Taleb and Salameh (2012).

TSS to acid ratio

In the present study, TSS to acid ratio was significantly influenced by cane regulation treatments (Table 5). The vine regulated with 33 canes per vine was recorded the maximum TSS to acid ratio (34.07).The reason for high TSS to acid ratio in optimum thinned vines might be due to lesser competition for metabolites among the limited number of bunches per vine. The availability of more photosynthates consequent to better vigour and physiological activities. Similar findings were given by Veena *et al*. (2015), Senthilkumar (2014) in grapes cv. Italia and Fawzi *et al*. (2015) in Superior grape cultivar.

The sub plot treatments showed significant differences with respect to TSS to acid ratio. The application of schedule-3 treatments has recorded significantly higher TSS to acid ratio (33.07%) as compared to schedule-2 and 1. It is evident from the results that, gibberllic acid in combination with brassinosteroids was recorded maximum TSS to acid ratio. It is always true that the acidity reduced with an increase in the total soluble solids resulted in increased TSS: acidity ratio. GA_3 reduced fruit set accounting for better nutrition of the remaining berries and higher TSS: acidity ratio (Singh and Singh, 1980). Similar reports were made by Chaitakhob *et al*. (2014) in Perlette grapes. Accelerated development of TSS to acid ratio with BRs observed in our study is consistent with findings of Champa *et al.* (2014), who also recorded the highest TSS/TA ratio in berries treated with 1.0 mg l^{-1} BRs, while the lowest was observed in control.

The interaction effect between cane regulations and growth regulator treatments was found non significant with respect to TSS: acid ratio of berry.

Table 5 : TSS to acid ratio (%), ascorbic acid (mg/100g), reducing and non-reducing sugars (%) in grapes var.KR White as influenced by the cane regulation and growth regulators.

Treatments	TSS: acid ratio (%)			Ascorbic acid (mg/100g)			Reducing sugars (%)			Non reducing sugars (%)		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
Main plot (Cane regulation)												
C_1 (Control : without cane regulation)	24.44	30.26	27.35	5.87	5.05	5.46	16.80	15.76	16.28	0.83	0.74	0.78
C_2 (50 canes per vine)	30.71	30.82	30.77	6.25	4.92	5.59	16.71	15.81	16.26	0.81	0.71	0.76
C_3 (33 canes per vine)	35.99	32.15	34.07	7.08	5.83	6.46	17.53	16.26	16.90	0.91	0.77	0.84
C_4 (25 canes per vine)	33.36	31.86	32.61	6.18	5.15	5.67	16.99	16.16	16.58	0.89	0.75	0.82
S.Em ±	**1.24**	**1.21**	**0.85**	**0.21**	**0.12**	**0.07**	**0.06**	**0.16**	**0.07**	**0.02**	**0.02**	**0.01**
CD at 5 %	**3.03**	**NS**	**2.09**	**0.52**	**0.30**	**0.18**	**0.15**	**0.39**	**0.18**	**0.05**	**0.04**	**0.03**
Sub plot (Growth regulators)												
S_1 : Schedule 1	28.31	30.14	29.22	6.08	4.96	5.52	16.95	16.15	16.55	0.86	0.73	0.79
S_2 : Schedule 2	31.62	29.72	30.67	6.04	5.03	5.54	16.27	15.64	15.96	0.80	0.73	0.76
S_3 : Schedule 3	33.44	33.97	33.70	6.92	5.72	6.32	17.80	16.20	17.00	0.92	0.77	0.85
S.Em ±	**1.65**	**1.02**	**0.90**	**0.34**	**0.17**	**0.21**	**0.31**	**0.13**	**0.16**	**0.02**	**0.02**	**0.01**
CD at 5 %	**3.50**	**2.15**	**1.91**	**0.73**	**0.37**	**0.44**	**0.65**	**0.28**	**0.35**	**0.04**	**0.03**	**0.02**
Interactions (Main plot × Sub plot)												
C_1S_1	23.24	29.10	26.17	6.40	4.68	5.54	17.07	16.08	16.57	0.82	0.72	0.77
C_1S_2	23.88	27.64	25.76	5.50	4.94	5.22	16.09	15.02	15.56	0.74	0.72	0.73
C_1S_3	26.20	34.03	30.11	5.72	5.52	5.62	17.24	16.17	16.71	0.92	0.78	0.85
C_2S_1	23.90	29.87	26.88	6.02	4.32	5.17	15.87	16.43	16.15	0.77	0.69	0.73
C_2S_2	33.77	30.69	32.23	6.10	5.07	5.59	16.29	15.71	16.00	0.80	0.70	0.75
C_2S_3	34.47	31.90	33.18	6.62	5.38	6.00	17.97	15.30	16.63	0.85	0.75	0.80
C_3S_1	32.82	29.88	31.35	6.87	5.52	6.20	17.55	16.02	16.78	0.93	0.76	0.84
C_3S_2	34.62	30.45	32.53	6.55	5.52	6.04	16.53	16.12	16.33	0.80	0.77	0.79
C_3S_3	40.53	36.13	38.33	7.82	6.45	7.14	18.52	16.64	17.58	1.00	0.78	0.89
C_4S_1	33.28	31.69	32.49	5.03	5.33	5.18	17.31	16.08	16.69	0.90	0.73	0.82
C_4S_2	34.22	30.09	32.15	6.01	4.60	5.30	16.18	15.72	15.95	0.85	0.72	0.78
C_4S_3	32.57	33.81	33.19	7.50	5.52	6.51	17.48	16.70	17.09	0.93	0.79	0.86
S.Em ±	4.44	2.89	2.47	**0.91**	**0.47**	**0.54**	**0.79**	**0.38**	**0.43**	0.05	0.04	0.03
CD at 5 %	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**0.83**	**NS**	**NS**	**NS**	**NS**

NS: Non significant

S_3: 10 ppm GA_3 at parrot green stage (21DAFP)
40 ppm GA_3 + 1 ppm Brassinosteroids bunch dipping at 3-4 mm berry stage
20 ppm GA_3 at pre bloom stage
30 ppm GA_3+ 1.50 ppm Brassinosteroids bunch dipping at 6-7 mm berry stage.

S_2: 10 ppm GA_3 at parrot green stage (21 DAFP)
30 ppm GA_3 bunch dipping at 3-4 mm berry stage
50 ppm GA_3 bunch dipping at 1 week after 4th treatment.
20 ppm GA_3 at 1 week after first treatment
40 ppm GA_3 bunch dipping at 6-7 mm berry stage

S_1: 10 ppm GA_3 at parrot green stage (21 days after fore pruning (DAFP)
40 ppm GA_3 bunch dipping at 3-4 mm berry stage
20 ppm GA_3 at pre bloom stage (25 DAFP)
30 ppm GA_3 bunch dipping at 6-7 mm berry stage

Ascorbic acid content (mg/100g)

The significant differences were recorded with respect to ascorbic acid content of the berry in cane regulation treatment (Table 5). The vine regulated with 33 canes per vine significantly increased ascorbic acid (6.46 mg/100g). The reason for high ascorbic acid in severely thinned vines might be due to lesser competition for metabolites among the limited number of bunches per vine, the better interception of the light within the canopy, availability of more photosynthates consequent to better vigour and physiological activities induced in them.

Sub plot treatment also significantly influenced the ascorbic acid content of the berry. The highest ascorbic acid (6.32%) was recorded with the application of schedule-3 treatments as compared to schedule-2 and schedule-1. In the present study, it was found that the ascorbic acid level depended on the sugar content of the fruit of the grapevine variety. The prospective increase in ascorbic acid might also be due to catalytic activities of GA_3 on precursor glucose-6-phoshate which in combination with brassinosteroids. Similar findings were made by Gougoulias and Masheva (2010) and Kaplan *et al*. (2019) in Einset Seedless grapes. The interaction effect between cane regulation and growth regulator treatments found non significant.

Reducing sugars, Non reducing sugars and total sugars (%)

In the present study, reducing sugars, non reducing sugars and total sugars were varied with cane regulation and growth regulator treatments (Tables 5 and 6). The maximum reducing sugars (16.15%), non reducing sugars (0.84%) and total sugars (17.09%) was recorded in the vines regulated with 33 canes per vine. The reason for high sugars in optimum thinned vines might be due to lesser competition for metabolites among the limited number of bunches per vine. The better interception of the light within the canopy, availability of more photosynthates consequent to better vigour and physiological activities. These findings are strongly supported by the findings of Joon and Singh (1983), who opined that sugars of grape juice increased with increased intensity of cane regulation levels. Similar findings were reported by Senthilkumar (2014) in Italia grapes.

The sub plot treatments of growth regulators showed significant differences with respect to reducing sugars, non reducing sugars and total sugars. In the present study, application of schedule-3 treatments was recorded significantly higher reducing sugars (17.00%), non reducing sugars (0.85%) and total sugars (17.90%) was recorded as compared to schedule-2 and 1. The combined application of gibberllic acid and brassinosteroids have increased the sugar compounds. 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. Synergistic interaction between brassinosteriods with gibberellins was also elaborated by Gregory and Mandava (1982). The result corroborate with the earlier records of Padashetti *et al*. (2010) in Arka Neelamani and Thompson Seedless by foliar application of GA_3 @ 50 ppm + BR @ 1 ppm twice at fruit set stage resulted in increased reducing sugar per cent. Similar results were obtained by Zhu *et al*. (2010 and Rather *et al*. (2011) in Perlette grapes.The interaction effect between cane regulations and growth regulator treatments are non significant.

Pedicel thickness (mm)

The results with respect pedicel thickness was significant among the cane regulation treatments. Vines regulated with 25 canes per vine was recorded the maximum pedicel thickness (1.56 mm) (Table 6). It could be because of the lesser competition for the assimilates. The size of the bunch is directly proportional to the thickness of pedicel as the bunch size in 25 canes per vine recorded higher due to less number of bunches and less competition for the assimilates.

Sub plot treatments had significantly influenced the pedicel thickness. The maximum pedicel thickness (1.57 mm) was recorded with the application of schedule-3 treatment. However, the lowest pedicel thickness (1.48 mm) was recorded with the application of schedule-1 treatment which was at par with schedule-2. The grape bunches treated with schedule-3 treatment comprising of gibberellic acid and brassinosterids have resulted in to thicker pedicel of the berries. It might be due to the favorable role of gibberellic acid and brassinosteroids in developing thicker pedicel as these growth regulators are involved in cell division, cell elongation and nutrient diversion from source as compared to gibberellic acid alone (Gupta and Chakrabarty, 2013). Brassinosteroids induces cell division, expansion and differentiation are well documented by Taiz and Zeiger (2010). Isci and Gokbayrak (2015), who also opined that application of 22S-, 23S homobrassinolide at high concentration resulted in stronger attachment between the pedicel and the stalk. Similar results were reported by Zoffoli *et al*. (2009).

The interaction effect between cane regulation and growth regulators was non significant with respect to pedicel thickness.

Table 6 : Total sugars (%), pedicle thickness (mm), shelf life of berries (days) and raisin recovery (%) in grapes var. KR White as influenced by the cane regulation and growth regulators.

Treatments	Total sugars (%)			Pedicel thickness (mm)			Shelf life of berries (Days)			Raisin recovery (%)		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
Main plot (Cane regulation)												
C_1 (Control : without cane regulation)	17.67	16.53	17.10	1.44	1.49	1.46	9.33	9.78	9.56	30.97	22.69	26.83
C_2 (50 canes per vine)	17.56	16.56	17.06	1.50	1.48	1.49	10.11	10.56	10.33	30.26	22.16	26.21
C_3 (33 canes per vine)	18.49	17.07	17.78	1.54	1.53	1.54	11.89	11.67	11.78	29.52	20.77	25.14
C_4 (25 canes per vine)	17.93	16.95	17.44	1.54	1.58	1.56	11.78	11.11	11.44	29.55	20.67	25.11
S.Em ±	**0.06**	**0.16**	**0.08**	**0.03**	**0.02**	**0.02**	**0.37**	**0.31**	**0.18**	**0.98**	**0.46**	**0.59**
CD at 5 %	**0.14**	**0.39**	**0.20**	**NS**	**0.05**	**0.06**	**0.92**	**0.76**	**0.45**	**NS**	**1.14**	**NS**
Sub plot (Growth regulators)												
S_1 : Schedule 1	17.85	16.91	17.38	1.50	1.48	1.49	10.58	10.42	10.50	31.20	21.52	26.36
S_2 : Schedule 2	17.11	16.41	16.76	1.47	1.49	1.48	10.92	10.67	10.79	30.36	22.15	26.25
S_3 : Schedule 3	18.77	17.02	17.90	1.54	1.59	1.57	10.83	11.25	11.04	28.67	21.05	24.86
S.Em ±	**0.30**	**0.13**	**0.16**	**0.02**	**0.01**	**0.01**	**0.31**	**0.25**	**0.20**	**0.75**	**0.51**	**0.41**
CD at 5 %	**0.64**	**0.27**	**0.34**	**0.04**	**0.03**	**0.02**	**NS**	**0.53**	**0.41**	**1.59**	**NS**	**0.87**
Interactions (Main plot × Sub plot)												
C_1S_1	17.93	16.83	17.38	1.42	1.47	1.44	8.67	9.67	9.17	30.93	22.00	26.47
C_1S_2	16.87	15.78	16.33	1.39	1.44	1.41	9.67	9.33	9.50	32.03	23.66	27.85
C_1S_3	18.21	16.99	17.60	1.51	1.55	1.53	9.67	10.33	10.00	29.95	22.42	26.19
C_2S_1	16.68	17.16	16.92	1.46	1.46	1.46	10.33	10.67	10.50	29.85	22.60	26.23
C_2S_2	17.13	16.44	16.78	1.46	1.46	1.46	10.33	10.33	10.33	31.54	21.95	26.74
C_2S_3	18.86	16.09	17.47	1.57	1.54	1.55	9.67	10.67	10.17	29.40	21.92	25.66
C_3S_1	18.53	16.82	17.67	1.57	1.49	1.53	11.33	11.00	11.17	32.87	20.91	26.89
C_3S_2	17.37	16.94	17.16	1.53	1.52	1.52	11.67	11.67	11.67	29.03	21.42	25.23
C_3S_3	19.57	17.46	18.52	1.52	1.59	1.56	12.67	12.33	12.50	26.66	19.97	23.32
C_4S_1	18.26	16.85	17.55	1.55	1.51	1.53	12.00	10.33	11.17	31.13	20.58	25.86
C_4S_2	17.07	16.47	16.77	1.51	1.55	1.53	12.00	11.33	11.67	28.84	21.57	25.20
C_4S_3	18.46	17.53	17.99	1.56	1.68	1.62	11.33	11.67	11.50	28.69	19.87	24.28
S.Em ±	**0.79**	**0.36**	**0.42**	**0.06**	**0.04**	**0.04**	**0.89**	**0.72**	**0.54**	**2.17**	**1.39**	1.21
CD at 5 %	**NS**	**0.79**	**NS**	**NS**	**NS**	**0.08**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

NS: Non significant

S_1: 10 ppm GA_3 at parrot green stage (21 days after fore pruning (DAFP)
40 ppm GA_3 bunch dipping at 3-4 mm berry stage
20 ppm GA_3 at pre bloom stage (25 DAFP)
30 ppm GA_3 bunch dipping at 6-7 mm berry stage

S_2: 10 ppm GA_3 at parrot green stage (21 DAFP)
30 ppm GA_3 bunch dipping at 3-4 mm berry stage
50 ppm GA_3 bunch dipping at 1 week after 4th treatment.
20 ppm GA_3 at 1 week after first treatment
40 ppm GA_3 bunch dipping at 6-7 mm berry stage

S_3: 10 ppm GA_3 at parrot green stage (21DAFP)
40 ppm GA_3 + 1 ppm Brassinosteroids bunch dipping at 3-4 mm berry stage
20 ppm GA_3 at pre bloom stage
30 ppm GA_3+ 1.50 ppm Brassinosteroids bunch dipping at 6-7 mm berry stage.

Shelf life of the berries

Significant results were recorded with respect shelf life of the berries, among the cane regulation treatments. The vine regulated with 33 canes per vine was recorded maximum shelf life (11.78 days) of berries, which was on par with 25 canes per vine whereas the minimum shelf life (9.56 days) of berries was recorded in control *i.e.* no cane regulation treatment. The maximum shelf life of berries in severely thinned vines could be due to higher pulp and thickness of the berries might have retained the moisture in the berries.

Significant differences were recorded with respect to shelf life berries in sub plot treatment. The maximum shelf life (11.04 days) was recorded with the application of schedule-3 treatment as compared to schedule 2 and 1. In the present investigation, the per cent loss of a bunch weight was found maximum in the grapes treated with gibberllic acid alone as compared to combination of gibberllic acid and brassinosteroides. Application of both growth regulators increases berry firmness due to increased pulp quantity and thickness of the skin could be the reasons for increased shelf life of berries. The increase in the keeping quality of the berries during the shelf life obtained in the current study might be interpreted by the positive influence of the GA_3 and BRs in increasing fruit firmness, reducing physiological loss in weight and delaying ripening. Positive inhibition of ethylene biosynthesis by gibberellic acid is already indicated (Tumminelli *et al*., 2005). Ethylene is considered to a ripening hormone which increases as advances the ripening. Similar findings were made by Khalil (2020) in Flame seedless grapes. There are convincing evidences that, pre-harvest treatments of BRs increased fruit firmness (Peng *et al*., 2004) and during postharvest, it reduced decay causing organisms and delayed fruit senescence by suppression of rates of respiration and ethylene production (Zhu *et al*., 2010). Champa *et al.* (2014) reported that, pre-harvest foliar spray of 0.5 mg l-1 BRs could be an effective means of maintaining quality and extending postharvest life of grape cv. Flame Seedless during cold storage.

The interaction effect of cane regulations and plant growth regulators found non significant with respect to shelf life of the berries.

Raisin recovery (%)

The pooled results with respect to raisin recovery percentage are non significant, among the cane regulation treatments (Table 6).

Sub plot treatments had significantly influenced the raisin recovery percentage. Significantly, the maximum raisin recovery (26.36%) was recorded with the application of schedule-1 treatment. From the investigation, it was recorded that the maximum raisin recovery was obtained with the application of schedule-1, which contains only gibberellic acid. The application of schedule 3 treatment comprises combination GA_3 and BRs have recorded lowest raisin recovery percentage as these growth regulators might have increased pulp and peel thickness and also the size of the berry which are not a good parameters for quality raisin production.

Conclusion

From this study, it can be clearly stated that, the cane regulation and application of growth regulators is essential forms of thinning in vineyard operation and considered as a technique, which could lead to tremendous improvement in yield and quality parameters of grapes cv. KR White. Thus, cane regulation of 25 and 33 canes per vine and application of growth regulators such as GA_3 and brassinosteriods can is a promising and valuable recommendation for farmers for commercial cultivation of grapes.

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