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Yield and Quality Aspects of 'Sra Roucha' Seedless Grapes as Affected by Gibberellic Acid

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ABSTRACT: 'Sra Roucha' is an early ripening seedless variety grown successfully under Steppe climate of Afghanistan. Its main problems are lower yield and quality, in terms of, cluster compactness, berry size and firmness. This experiment was undertaken for three growing seasons (2015-2017) at Ordokhan research station in Herat province of Afghanistan to investigate the effect of GA_3 on yield, cluster and berry characters as well as sensory features. Treatments were: control, 10mg/L GA_3 pre-bloom; 20mg/L GA_3 pre-bloom; 10mg/L GA_3 at 40% bloom; 20mg/L GA_3 at 40% bloom; 10mg/L GA_3 at 40% bloom + 10mg/L GA_3 at 80% bloom; 20mg/L GA_3 at 40% bloom + 20mg/L GA_3 at 80% bloom; 10mg/L GA_3 pre-bloom + 60 mg/L GA_3 at 4 mm berry-size stage; 10mg/L GA_3 pre-bloom + 60mg/L GA_3 at 4 mm berry-size stage). Each treatment was replicated thrice with one vine per replicate. The experiment was run as split-plot in the frame of randomized complete block design. Data pertinent with sensory attributes were analyzed by Friedman's non-parametric two-way ANOVA. Results showed that GA_3 treatments significantly affected yield, cluster length, weight and compactness, berry diameter, berry length and berry TSS, color, taste and firmness. Application of 20 mg/L GA_3 before flowering plus 60 mg/L GA_3 at 4 mm berry-size stage, resulted in higher yield, cluster and berry characteristics as well as berry sensory features. Therefore, GA_3 (20 mg/L pre-bloom + 60 mg/L at 4mm berry-size stage) is the reasonable technique for enhancing yield and quality aspects of 'Sra Roucha' seedless grapes.

KEY WORDS: 'Sra Roucha', gibberellic acid, compactness, yield, quality

INTRODUCTION

Grape is the first deciduous fruit to be grown in Afghanistan both in terms of cultivation area and production. In 2018, the area under grape cultivation was 87,517 ha, with a yield of 984,081 tons, based on which the average yield is approximately 11 tons per hectare (NSIA, 2018). Grapes are consumed in fresh (table) and dried (raisins) forms. In 2018, about 200295 tons of fresh grapes, 56426 tons of red raisins, 4948 tons of green raisins and 7533 tons of black raisins were exported to foreign countries such as India, Pakistan, and China (NSIA, 2018). Grape production depends on abundant varieties that are spread and grown all over the country (Shirzad, 1994).

There are more than 48 registered grape varieties in Afghanistan (Krochmal & Nawabi, 1961) among which 'Sra Roucha' is one of the seedless table grapes grown under Steppe climate (Arez, 1967) and is well adapted to climatic conditions of Western Afghanistan (Shirzad, 1994, 1982). It is an early ripening variety which provides early market supply thus results in good return. . 'Sra Roucha' produces small, short, conical-shaped, and highly compacted clusters with dark-red-colored, oboviod-shaped and smaller-sized berries. Its main problems are lower yield and quality (Krochmal & Nawabi, 1961). It is essential; therefore, to develop a reasonable strategy that would improve quantity and quality aspects alongside maintaining sensory features. One solution to this problem is to encourage cell division and enlargement, often using agronomic techniques such as girdling, thinning, and plant growth regulators. The most widely used growth regulator in grapes is gibberellic acid. However, gibberellic acid at what concentration and at what time has the desired effect on the characteristics of the cluster and berries, is said to be the main problem of this research.

There are over 125 gibberellins members known so far which are based *ent* gibberellane structure. Gibberellic acid (GA_3) is the commercially available gibberellin, which is a fungal product (Arteca, 1996). It stimulates cell division and/or cell elongation (Davies, 2004; Arteca, 1996). GA_3 plays an essential role in improving grape quantity such as cluster elongation (Hed et al., 2011), bunch weight and yield (Meena *et al.*, 2012; Özer *et al.*, 2012), bunch width (Kassem et al., 2011; Özer *et al.*, 2012), and enhances berry size and weight (Roller, 2003; Molitor *et al.*, 2012; Ozer *et al.*, 2012; Durner, 2013), greater berry length-to-width ratio (Retamles *et al.*, 1995), as well as improves berry firmness and total soluble solids (Kassem *et al.*, 2011).

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Even though GA_3 are used more in seedless than in seeded grapes (Lavee, 1987; Mullins *et al*., 1992), the effects vary with cultivar, climatic conditions, concentration, and application time and method (Molitor *et al.*, 2012).

As stated formerly, 'Sra Roucha' is one of the economic and highly profitable grape varieties in Afghanistan as it hits market ahead of other locally grown varieties. A potential problem; however, associated with this variety is the lower yield and poor yield quality due to compacted clusters, small berries and firmness. This research was; therefore, undertaken to investigate the effects of different concentrations of GA_3 applied at pre-bloom, at bloom or post-bloom stages on yield, cluster features, berry quality and sensory characteristics of 'Sra Roucha' seedless grapes.

MATERIALS AND METHODS

The study was carried out for three growing seasons (2015-2017) at Herat PHDC-Urdokan research station in Herat province of Afghanistan on 6-year old vines of 'Sra Roucha' grapes. Vines were planted at 3 × 3 m^2 spacing and were trained as T–trellis with both cane and pruning techniques. All cultural practices were kept same as per local standard.

GA_3 treatments were practiced as immersion method and applied before bloom, at 40 and 80% bloom, and at 4 mm berry size stage (fruit set). The following GA_3 treatments were applied.

Treatment	Description		
T_1	Control (no GA_3)		
T_2	10 mg/L GA_3 before bloom		
T_3	20 mg/L GA_3 before bloom		
T_4	10 mg/L GA_3 at 40% bloom		
T_5	20 mg/L GA_3 at 40% bloom		
T_6	10 mg/L GA_3 at 40% bloom	+	10 mg/L GA_3 at 80% bloom
T_7	20 mg/L GA_3 at 40% bloom	+	20 mg/L GA_3 at 80% bloom
T_8	10 mg/L GA_3 before bloom	+	60 mg/L GA_3 at 4 mm berry size
T_9	20 mg/L GA_3 before bloom	+	60 mg/L GA_3 at 4 mm berry size

The experiment was conducted as RCB design with 4 replications and one vine per each replicate. The parameters studied were cluster growth (weight, width, length, compactness) and berry characters (diameter, length, TSS, firmness, color, taste).

For measurement of berry diameter, length and TSS, 50 berries were randomly selected per cluster, whilst for cluster weight, length and width, 10 cluster were randomly chosen per vine. Cluster weight, length and weight as well as berry length and diameter were measured using common ruler while the TSS were measured by hand refractometer. Sensory parameters such as berry firmness, taste, color, and cluster compactness were evaluated through organoleptic 9-point hedonic scaling test (1=dislike extremely through 9=like extremely) by a panel consisted of 20 semi-naïve and 20 professional panel as a ranking measurement (Vindras & Sinoir, 2020).

Data were pooled (over years) in the frame of split-plot design (years as random and treatments as fixed variables) to study variability of GA_3 treatments and to adopt the best treatments (Gomez & Gomez, 1984). Data were analyzed using Statistical Analysis System (SAS®) package (version # 9) for analysis of variance (ANOVA) and *LSD* test was used for mean comparison at 5% level of probability. Data of organoleptic tests were analyzed through Friedman's non-parametric test as two-way analysis of variance (AOV) and *LSD* test (P<0.05) was used for mean comparison of median scores according to Vindras & Sinoir (2020) and Townend (2002).

RESULTS AND DISCUSSION

Results showed that the highest number of clusters per vine (41.33) was obtained with T_3 treatment and was significantly different from the control treatment (25.33), but all the other treatments were not significantly different from the control treatment (Figure 1). Also, the highest yield per vine (18.65 kg) and the lowest yield per vine (7.23 kg) were obtained with T_6 and control (T_1) treatments, respectively and both were significantly different from each other. The T_6 treatment resulted in about 61% increase in yield compared to the control treatment. Vine yield gradually increased from T_1 to T_3 treatments but decreased through T_4 and T_5

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treatments and then increased again through T_6, T_7, T_8 and T_9 treatments (Figure 1). The T_6 treatment was not significantly different from the T_7, T_8 and T_9 treatments, but the difference with the control treatment (T_1) was significant. Figure 1 shows that the pre-bloom application of gibberellic acid (treatments T_2 and T_3) increased the yield, but the bloom application (treatments T_4 and T_5) decreased the yield. But dual application of GA_3 i.e. pre-bloom plus post-bloom (T_8 and T_9) and bloom plus post-bloom (T_6 and T_7) increased yield obviously (Figure 1).

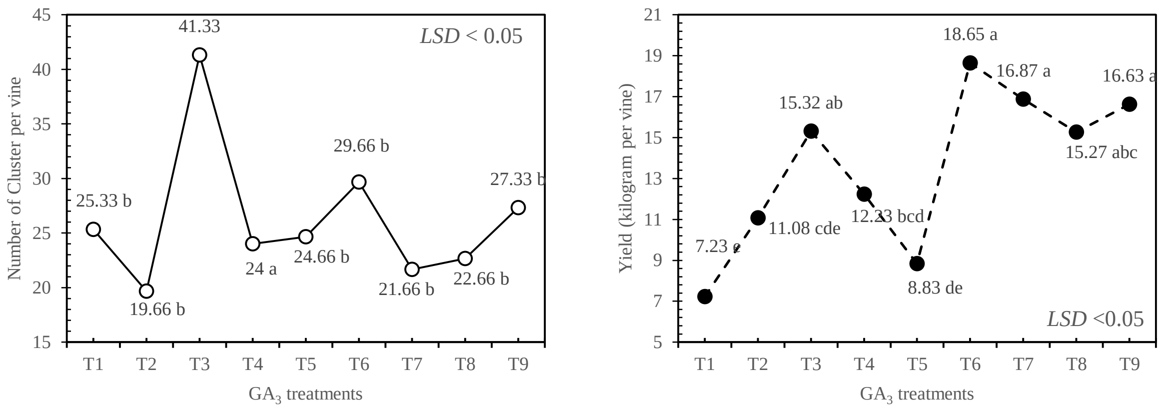

Fig 1. Effect of various GA_3 treatments on mean cluster number per vine (A) and mean yield per vine (B) of ''Sra Roucha') seedless grapes.

From this result, it is appeared that the use of gibberellic acid during bloom stage only causes berry thinning and with increasing concentration, the intensity of thinning increases and may reduce the yield compared to the control treatment. If gibberellic acid is re-applied at fruit setting stage, the reduced number of berries compensates by increased berry volume until the yield is increased 34-61% in comparison with control treatment (Fig.1).

Cluster weight was significantly affected by GA_3 treatments and year (Table 1). Cluster weight significantly differed during threes growing seasons. T_9 and T_1 were resulted in maximum (636 g) and minimum (302.3 g) cluster weights, respectively which shows that T_9 increased cluster weight by 52.46% compared to T_1 (Table 2). Moreover, the lower cluster weight was recorded on control (T_1) treatment but was not statistically different from T_3 and T_4.

Analysis showed highly significant effects of GA_3 treatments and year on cluster length (Table 1). Table 2 revealed that maximum cluster length (19.9 cm) was obtained by T_9 whilst the minimum cluster length (17.4 cm) was produced by T_1. As compared to T_1, treatment T_9 resulted in 12.5 % increment in cluster weight. Mean comparison showed that except T_9, the control treatment (T_1) had better results in terms of cluster length than remained GA_3 treatments applied either before flowering or at flowering (Table 2).

Some grape cultivars such as 'Sra Roucha' are prone to rotting and a control strategy is based on the hypothesis that rotting can be prevented by modifying the structure of the cluster. Most of the agronomic practices for this modification are done using thinning, girdling and gibberellic acid.

In this study, it was shown that pre-bloom and bloom application of gibberellic acid reduced the compactness of the clusters, but at bloom application was better than pre-bloom application. Results showed that the longest clusters (Table 2) and the lowest compacted clusters (Figure 2) were obtained by applying 20 mg/L GA_3 at pre-bloom plus 60 mg/L GA_3 at post-bloom (4 mm) stages (T_9). With this treatment, the color, taste and firmness of the fruit were also better than other treatments. Researchers have shown that applying GA_3 before bloom, at bloom, and after bloom promotes cluster vegetative growth (lengthens clusters), thins berries (berry thinning), and increases berry size in the result of stimulating rachis (Deepthi, 2016) and berry growth (Casanova *et al.*, 2009), respectively.

Statistical analysis showed that GA_3 treatments and year significantly influenced cluster width (Table 1). Highest (13.1 cm) and lowest (12 cm) cluster widths was produced by T_9 and T_1 treatments, respectively (Table 2). Treatment T_9 increased cluster width by 8.39 % compared to T_1. Furthermore, though the maximum bunch width was produced by T_9, based on LSD test, it had similar

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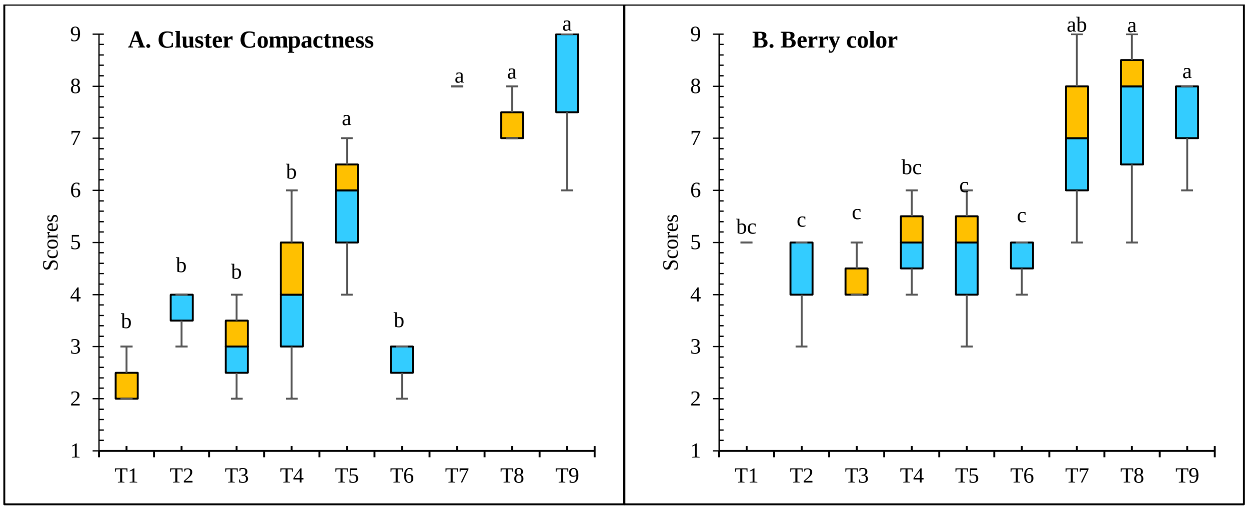
effects as T_1. Cluster widths during first and second seasons were significantly different but in third season, difference was insignificant with first and second seasons. These results are in harmony with those of Mullins *et al.* (1992) and Molitor *et al*. (2012). Results showed that the berry diameter was significantly (P<0.0001) affected by GA_3 treatments and year (Table 1). T_9 gave the highest berry diameter (12.50 mm) compared control (10 mm) which shows 20 % increment (Table 3). Base on LSD test, difference between T_9 and T_1 was significant, differences between T_1 and T_3 were not significant (Table 3).
Data analysis, presented in Table 1, indicates that GA_3 treatments significantly affected berry length. The highest (13.5 mm) and lowest (10.6 mm) berry lengths were produced by T_9 and T_1 treatments, respectively (Table 3). Treatment T_9 increased berry length about 21.5 % compared to treatment T_1. Additionally, berry length gradually increased over three growing seasons with significant difference (Table 3).
Data presented in Table 1 revealed that the berry sugar content was significantly (*$P<0.0001$*) influenced by various GA_3 treatments. The best treatment in terms of sugar content (23.94 ºBrix) was T_9 as compared to T_1 (18.08 Brix) indicates about 24.5 % increment in sugar content (Table 3). Additionally, treatment T_9 was significantly different from remaining treatments, whereas T_1 and T_8 had non-significant effects on sugar content (Table 3). Berry sugar contents non-significantly differed during first two years (2015, 2016) but in third (2017) year sugar content was significantly different from first two year (Table 3).
Seedless grapes such as 'Sra Roucha' have smaller berries, and one strategy to increase the size of small berries is based on the hypothesis that by stimulating cell division/enlargement, the size of the berries can be increased. Nowadays the most useful technique for this purpose is using gibberellic acid. The yield increases with the increase in berry size. Our study showed that treatment T_3 (20 mg/L GA_3 before bloom) significantly increased the number of clusters in vine compared to the control treatment (T_1) and other treatments, but the highest yield in vine and highest cluster weight were obtained by T_9 (20 mg/L GA_3 before bloom plus 60 mg/L GA_3 after bloom). With this treatment (T_9), the maximum berry diameter, length and sugar content were obtained. The increase in yield by T_3 and T_4 might be due to flower or fruit thinning, following which, indirectly the rest berries prepare more opportunity to increase in size. But in case of T_9 the potential reason of higher yield may be relate to post-application of GA_3 that enhance berry size directly through stimulation of cell division or enlargement. The main cause of higher yield through T_3 may possibly be the result of higher number of clusters or stimulating auxin biosynthesis which prevents flower and fruit drop or stickiness of peduncle and rachis.
Application of GA_3 before bloom causes berry thinning, following which, the number of berries per cluster decreased and allows the rest berries to grow well (Roller, 2003; Durner, 2013; Ozer *et al*., 2012, Molitor *et al*., 2012; Perez and Gomez, 2000) and translocate more photosynthates into berries (Deepthi, 2016; Casanova *et al.*, 2009; Ferrara *et al*., 2014). In the present study, the effects of GA_3 on berry characters, over three growing seasons, were vary. This variations are raised from cultivar, environment and GA_3 application method and time (Zoffoli *et al*., 2009; Mullins *et al.*, 1992; Molitor *et al.*, 2012; Kaplan, 2011; Acheampong *et al*., 2017).



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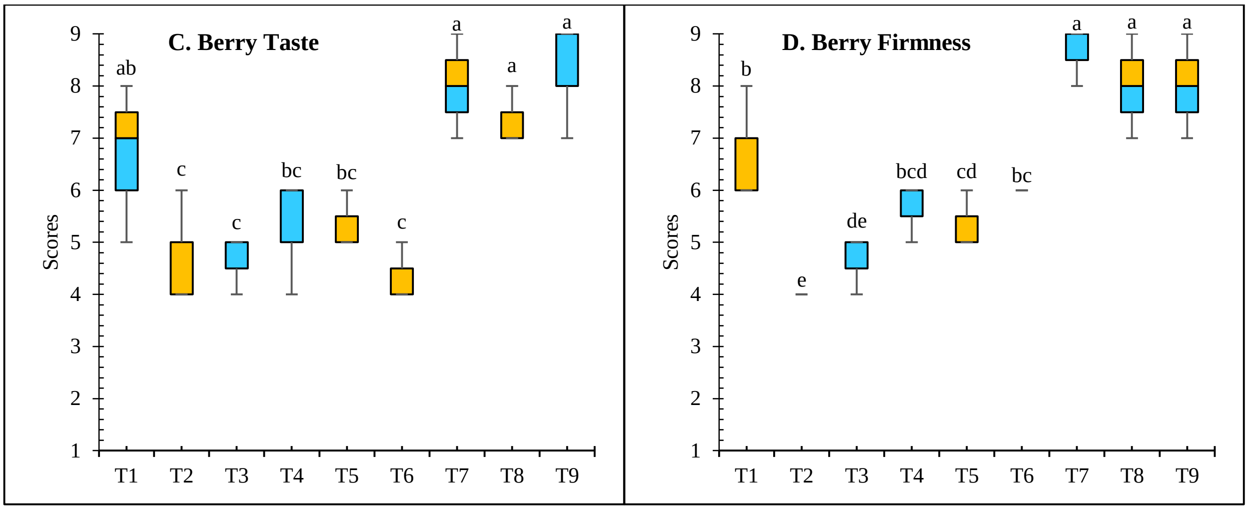

Figure 2. Effect of GA_3 treatments on mean (A) cluster compactness; (B) berry color; (C) berry taste and (D) berry firmness of 'Sra Roucha' grapes. Box plot means with the same letter were not significantly different using *LSD* test results ($P<0.05$).

Organoleptic tests showed that there was a gradually significant ($P<0.05$) increase in scores with respect to cluster compactness from control treatment (T_1) to treatment T_9 (Figure 2.A). Although the treatments T_6, T_7, T_8 and T_9 were resulted in higher median scores of cluster compactness than control (T_1), but were not significantly different from each other (Figure 2.A). The berry color was significantly affected by various GA_3 treatments as the higher scores were recorded on T_7, T_8 and T_9, while the lower scores were obtained by T_1, T_2, T_3, T_4, T_5 and T_6 (Figure 2.B). As shown in Figure 2.C, although the berry taste was substantially influenced by GA_3 treatments, the higher taste scores were resulted by T_1, T_7, T_8 and T_9 and the lower scores were related to T_2, T_3, T_4, T_5 and T_6. Berry firmness was also varied with various GA_3 treatments, as the higher scores were recorded on T_7, T_8 and T_9 and the lower scores were produced by T_2 (Figure 2.C).
In the study it was shown that GA_3 treatments improved cluster compactness, berry color, berry taste and firmness and this results are confirmed by (Ben-Arie *et al.*, 1998; Roller, 2003, Hed *et al.*, 2011) who have reported that increasing berry size through GA_3, exerts pressure on the skin, as the berries are enlarged the skin become thinner. Also, in numerous trails, it has been shown that the berry size, color and shape are increased or decreased following GA_3 application (Roller, 2003) and GA_3 application pre-bloom and at bloom stages reduces cluster compactness (Hed *et al.*, 2011)

Table 1. ANOVA for various parameters of 'Sra Roucha' seedless grapes (2015-17).

SOV	DF	Berry Diameter	Berry length	TSS (Brix^O)	Cluster length	Cluster weight	Cluster width
Block	3	1.14	2.87	2.36	14.23	34719.81	11.83
Year	2	29.14**	66.25**	98.57**	156.25**	403619.69**	35.00*
Error (a)	6	1.44	1.16	4.33	19.75	22378.12	12.65
GA_3 treatments	8	13.64**	12.74**	47.76**	23.12**	139092.81**	10.12
Year × GA_3	16	5.10**	8.15**	17.82**	18.01**	94447.72**	16.69
Error (b)	72	1.35	1.39	1.74	4.66	6652.17	3.61
CV (%)		10.24	9.63	6.54	12.36	19.119	15.98

* and ** shows significantly difference at 5% and 1% of probability.

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Table 2. Effect of different GA3 treatments on cluster characteristics of 'Sra Roucha' grapes during three consecutive years (2015-17).

Treatment	Cluster characteristics											
	Fresh weight (g)			GA_3	Length (cm)			GA_3	Width (cm)			GA_3
	2015	2016	2017	Mean	2015	2016	2017	Mean	2015	2016	2017	Mean
T_1	321.5	264.2	321.2	302.3 e	20.0	14.7	17.5	17.4 bc	12.5	11.0	12.5	12.0 ab
T_2	713.5	219.0	359.7	430.7 c	20.5	14.5	16.0	17.0 bcd	12.2	8.2	9.7	10.0 c
T_3	297.2	225.0	385.0	302.4 e	15.7	15.0	15.0	15.2 d	10.7	10.2	11.7	10.9 bc
T_4	452.5	182.2	408.2	347.6 de	23.2	13.2	16.7	17.7 bc	14.0	9.0	12.7	11.9 bc
T_6	525.0	356.0	357.5	412.8 cd	20.7	16.2	15.7	17.5 bc	10.7	11.7	14.2	12.2 ab
T_5	481.0	228.7	606.0	438.5 c	18.2	17.2	17.7	17.7 bc	11.2	9.2	15.5	12.0 ab
T_7	595.7	382.5	328.2	435.5 c	17.7	14.7	15.0	15.8 cd	12.7	12.5	10.7	12.0 ab
T_8	393.5	263.7	942.2	533.1 b	18.0	14.7	23.2	18.6 ab	10.5	11.0	16.7	12.7 a
T_9	652.2	618.5	637.2	636.0 a	21.7	18.0	20.0	19.9 a	12.2	15.2	12.0	13.1 a
Mean for Year	492.4 A	304.4 B	482.8 A		19.5 A	15.3 B	17.4 AB		11.8 A	10.9 B	12.8 A	

Means that have at least one similar uppercase or lowercase letter within column or row, are not significantly different according to *LSD* test (P < 0.05).

Table 3. Effect of different GA_3 treatments on berry characteristics of 'Sra Roucha' grapes during three growing seasons (2015-17).

Treatment	Berry characteristics											
	Diameter (mm)			GA_3 Mean	Length (mm)			GA_3 Mean	Total soluble solids (^{O}Brix)			
	2015	2016	2017		2015	2016	2017		2015	2016	2017	
T_1	10.2	9.0	10.7	10.0 c	9.7	10.0	12.2	10.6 c	14.7	16.2	23.2	18.0 e
T_2	14.5	9.7	10.0	11.4 b	11.2	11.5	11.0	11.2 bc	16.4	19.4	24.2	20.0 dc
T_3	8.5	9.2	10.0	9.2 c	12.0	11.2	11.7	11.6 bc	18.7	18.4	22.2	19.8 dc
T_4	12.0	10.5	11.2	11.2 b	10.2	12.2	13.0	11.8 b	19.4	16.4	22.7	19.5 d
T_6	12.5	10.7	12.0	11.7 ab	10.7	12.0	13.0	11.9 b	21.1	22.1	23.1	22.1 b
T_5	13.2	11.0	11.7	12.0 ab	10.5	12.7	17.0	13.4 a	22.0	21.7	18.8	20.8 c
T_7	13.2	11.7	11.0	12.0 ab	10.7	13.7	15.2	13.2 a	18.0	20.2	20.7	19.7 dc
T_8	13.7	11.7	10.2	11.9 ab	11.0	15.0	12.7	12.9 a	18.1	16.3	17.4	17.3 e
T_9	13.5	13.2	11.0	12.5 a	10.5	15.7	14.2	13.5 a	22.9	23.0	25.8	23.9 a
Mean for Year	12.3 A	10.7 B	10.8 B		10.7 C	12.6 B	13.3 A		19.0 B	19.3 B	22.0 A	

Means that have at least one similar uppercase or lowercase letter within column or row, are not significantly different according to *LSD* test (P < 0.05).

CONCLUSIONS

The results of this study showed that the application of 20 mg/L gibberellic acid before bloom together with 60 mg/L at 4-mm berry size stage (T_9), significantly increased yield, cluster, berry and sensory characteristics of 'Sra Roucha' grapes (Figure 3). Cluster weight, cluster length, and cluster width and also berry weight, berry length and berry diameter were higher due to applying 20 mg/L GA_3 at pre-bloom plus 60 mg/L GA_3 at 4-mm berry size stage than remained treatments (Figure 3). Pre-bloom application of

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GA_3 results in flower thinning which finally gives opportunity to remained flowers to grow better and the post-bloom application likely promotes cell enlargement which in turn causes berry growth and also induces the transport of photosynthates into berries.

Figure 3. Comparison of 'Sra Roucha' clusters as treated by GA_3 application to those of the control.

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