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# Effect of growth regulators on yield and quality of Sahebi grape (*Vitis vinifera*) under temperate conditions

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ABSTRACT

A field experiment was conducted during 2015–16 at the research farm of Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar Campus, Srinagar, Jammu and Kashmir to see the effect of growth regulators on yield and quality of 23 years old Sahebi grape (*Vitis vinifera* L.). The experiment comprised of 9 treatments with 2 growth regulators, viz. $GA_3$ (20 and 40 ppm), 6-BA (10 and 20 ppm) and their combinations were sprayed at 3 stages, viz. $S_1$, pre-bloom (single spray); $S_2$, 3–4 mm berry size (single spray); $S_3$, pre-bloom + 3–4 mm berry size (double superimposed spray) were replicated thrice in randomized block design (RBD). Observations were recorded on berry yield, bunch and physico-chemical characteristics. Application of $GA_3$ @40 ppm + 6-BA @10 ppm at pre-bloom + 3–4 mm berry size (double superimposed spray) stage resulted in highest berry yield, bunch weight, bunch length and total sugars followed by treatment $G_6S_3$ during both the years, however treatment $G_8S_3$ recorded significantly higher bunch diameter, berry length, berry weight, total soluble solids, TSS/acid ratio and juice content. The interaction studies had no influence on berry diameter, acidity, ascorbic acid and anthocyanin content.

**Keywords**: Berry, Grape, Growth regulators, Quality, Yield

Grape (*Vitis vinifera* L.) is one of the oldest cultivated vines in the world. It is a woody, perennial and an important fruit crop of temperate zone, which has acclimatized to sub-tropical and tropical agro-climatic conditions prevailing in the Indian sub-continent. In India, grapes are cultivated in an area of 140 thousand ha with an annual production of about 3125 thousand MT (NHB 2020). In the country, the grapes are mainly harvested during February-June, however in Kashmir valley grapes are harvested during August-September which is an off season for the rest of the country and can therefore, fetch higher remuneration inspite of low productivity. The major constraints of grape production in Kashmir valley are climatic factors like low temperature and low heat unit accumulation which result in low TSS, high acidity and also suffers from problems such as small berry and bunch size, unattractive clusters and poor yield, thereby reducing the consumer acceptability. Other reasons of low productivity and quality of grapevines are due to unscientific orchard management practices. The productivity and quality of grapes is dependent upon a number of factors eg. pruning, proper fertilization and optimum use of growth regulators. Among these plant growth regulators, viz. gibberellins and cytokinins are most commonly employed in grape production for varied uses, such as thinning of berries, improving fruit-set, hastening or delaying maturity of berries (Ozer *et al.* 2012), improving the berry quality (Khan *et al.* 2009) of berries and for inducing seedlessness in berries (Tian 2014). The most popular grape growing belt of Kashmir valley is district Ganderbal and Sahebi is the predominating variety. The productivity and quality of this grape is very poor and the possible cause is unscientific grape cultivation with respect to application of growth regulators. Thus, present investigation was carried out to standardize the proper dose and timing of growth regulator application for improving the yield and quality of Sahebi grape.

## MATERIALS AND METHODS

The experiment was conducted on 23 year old grape vines at the research farm of Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar Campus, Srinagar, Jammu and Kashmir for two consecutive years (2015 and 2016). The vines planted at a distance of 14 ft. × 30 ft., trained on bower system were pruned before the starting of experiment to maintain a uniform bud load and were provided with all uniform cultural

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practices. The experiment was laid out in a randomized block design replicated thrice. Nine treatments comprised of two growth regulators, viz. $GA_3$ (Gibberellic acid) and 6-BA (6-benzyladenine) with treatment combinations of $G_1$, control; $G_2$, $GA_3$ @20 ppm; $G_3$, $GA_3$ @40 ppm; $G_4$, 6-BA @10 ppm; $G_5$, 6-BA @20 ppm; $G_6$, $GA_3$ @20 ppm + 6-BA @10 ppm; $G_7$, $GA_3$ @20 ppm + 6-BA @20 ppm; $G_8$, $GA_3$ @40 ppm + 6-BA @10 ppm; $G_9$, $GA_3$ @40 ppm + 6-BA @20 ppm which were sprayed at 3 stages, viz. $S_1$, pre-bloom (single spray); $S_2$, 3–4 mm berry size (single spray); $S_3$, pre-bloom + 3–4 mm berry size (double superimposed spray). Fresh spray solutions of $GA_3$ and 6-BA were prepared from the stock solution just before use. From these respective stock solutions, the desired strength of spray solution was prepared by diluting with water to which Tween-20 (surfactant) was added to facilitate effective absorption.

*Observations recorded*: Yield per vine was calculated based on the number of bunches and the mean weight of bunches at harvest. Five bunches for bunch parameters and ten berries for berries parameters from each replication were taken for observations. Bunch weight, bunch length, bunch diameter, berry weight, berry length and berry diameter were taken as per the standard procedures. Total soluble solid (°B), acidity (%) and ascorbic acid content (mg/100 g) were estimated as per the standard procedures (AOAC 2012). The juice content was estimated as:

$$\text{Juice content (\%)} = \frac{\text{Juice yield (ml)}}{\text{Weight of berries (g)}} \times 100$$

Anthocyanin content was extracted with ethanolic hydrochloride and the intensity of the colour appeared was measured colorimetrically (Kaur and Dhillon 2007). The data generated were subjected to statistical analysis as per the procedures described by Snedecor and Cochran (1994).

## RESULTS AND DISCUSSION

Growth regulators and stages of the application significantly influenced the yield per vine, bunch length and bunch diameter during both the years (Table 1). Maximum yield per vine was obtained with $G_8S_3$ (24.63 and 25.94 kg, respectively) which were statistically higher among all treatment interaction in first year, however in second year $G_8S_3$ was statistically at par with $G_6S_3$ (25.81 kg). Lowest yield during both the year was recorded in the control (18.34 and 19.46 kg, respectively). The increase in yield might be due to higher fruit set with increase in the number of fruitful buds, length, diameter and bunch weight, proper nutritional supply to the developing bunches and reduced fruit drop with the application of $GA_3$ and 6-BA both at pre-bloom and when berries were 3–4 mm in size (Usha *et al*. 2005, Warusavitharana *et al*. 2008). Treatment $G_8S_3$ registered maximum bunch length (21.25 and 21.50 cm) and bunch diameter (13.62 and 14.10 cm) during both the year which was statistically higher among all treatment interactions except bunch length in the second year which was statistically at par with $G_7S_3$ (21.38 cm) whereas minimum

Table 1 Effect of foliar application of growth regulators in different stages on yield, bunch length, bunch diameter and bunch weight of grape cv. Sahebi

| Treatment | Yield (kg/vine) | | | | | | Bunch length (cm) | | | | | | Bunch diameter (cm) | | | | | | Bunch weight (g) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st year | | | 2nd year | | | 1st year | | | 2nd year | | | 1st year | | | 2nd year | | | 1st year | | | 2nd year | | |
| | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ |
| $G_1$ | 18.34 | 18.34 | 18.34 | 19.46 | 19.46 | 19.46 | 17.67 | 17.67 | 17.67 | 17.88 | 17.88 | 17.88 | 11.64 | 11.64 | 11.64 | 11.92 | 11.92 | 11.92 | 332.71 | 332.71 | 332.71 | 345.62 | 345.62 | 345.62 |
| $G_2$ | 22.10 | 20.24 | 23.66 | 21.31 | 23.70 | 21.63 | 18.61 | 17.83 | 20.42 | 19.10 | 18.00 | 20.84 | 12.32 | 11.67 | 12.91 | 12.93 | 12.10 | 13.53 | 395.31 | 378.81 | 410.12 | 388.54 | 401.38 | 390.57 |
| $G_3$ | 22.42 | 20.77 | 24.12 | 23.36 | 21.42 | 25.64 | 20.56 | 17.88 | 18.82 | 21.08 | 18.30 | 19.67 | 13.00 | 11.72 | 12.40 | 13.58 | 12.27 | 13.09 | 398.50 | 381.61 | 414.18 | 396.36 | 408.21 | 421.64 |
| $G_4$ | 21.64 | 18.68 | 23.13 | 22.68 | 21.17 | 23.12 | 18.43 | 17.75 | 20.28 | 18.86 | 17.96 | 20.80 | 13.13 | 11.78 | 12.48 | 13.62 | 12.30 | 13.20 | 390.22 | 373.20 | 406.41 | 398.91 | 385.18 | 396.12 |
| $G_5$ | 21.87 | 20.00 | 23.47 | 24.31 | 19.88 | 24.53 | 20.17 | 17.70 | 18.54 | 20.72 | 17.91 | 18.94 | 12.81 | 12.08 | 13.48 | 13.41 | 12.72 | 14.02 | 393.18 | 376.95 | 407.00 | 411.26 | 384.73 | 414.12 |
| $G_6$ | 22.78 | 21.18 | 24.45 | 22.13 | 24.00 | 25.81 | 19.37 | 17.91 | 20.78 | 20.04 | 18.18 | 20.95 | 13.26 | 11.82 | 12.56 | 13.76 | 12.35 | 13.26 | 403.12 | 385.36 | 415.56 | 394.21 | 406.42 | 424.21 |
| $G_7$ | 23.84 | 20.58 | 22.25 | 24.78 | 25.13 | 23.54 | 19.00 | 18.08 | 20.91 | 19.33 | 18.62 | 21.38 | 12.60 | 11.90 | 13.31 | 13.33 | 12.48 | 13.82 | 411.30 | 385.70 | 397.64 | 416.36 | 389.32 | 398.51 |
| $G_8$ | 23.00 | 21.37 | 24.63 | 22.47 | 24.27 | 25.94 | 19.84 | 18.26 | 21.25 | 20.25 | 18.75 | 21.50 | 12.64 | 12.17 | 13.62 | 13.37 | 12.77 | 14.10 | 403.56 | 387.15 | 417.25 | 396.42 | 419.82 | 425.71 |
| $G_9$ | 24.20 | 20.92 | 22.64 | 25.37 | 21.84 | 23.88 | 21.09 | 18.15 | 19.65 | 21.24 | 18.44 | 19.82 | 12.88 | 11.95 | 13.40 | 13.45 | 12.66 | 13.93 | 415.23 | 384.42 | 400.78 | 421.21 | 392.44 | 403.26 |
| CD (P=0.05) | | | | | | | | | | | | | | | | | | | | | | | | |
| S | | 0.10 | | | 0.14 | | | 0.10 | | | 0.11 | | | 0.02 | | | 0.04 | | | 3.47 | | | 2.52 | |
| G | | 0.13 | | | 0.16 | | | 0.12 | | | 0.12 | | | 0.04 | | | 0.03 | | | 2.56 | | | 3.72 | |
| S × G | | 0.15 | | | 0.18 | | | 0.15 | | | 0.14 | | | 0.06 | | | 0.05 | | | 4.01 | | | 4.06 | |

Treatment details are given in Materials and Methods.

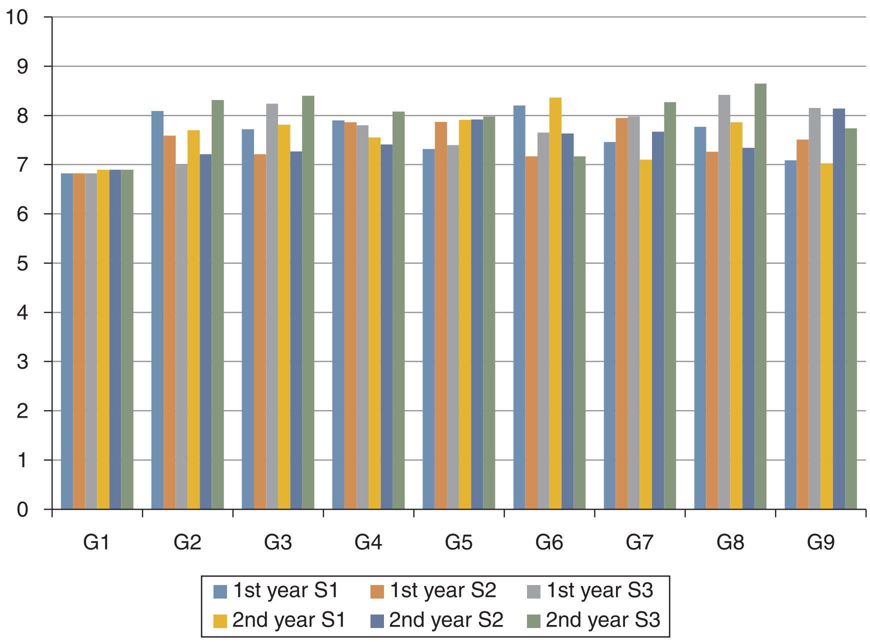


Fig 1 Effect of foliar application of growth regulators at different stages on berry weight (g) of grape cv. Sahebi. Treatment details are given in Materials and Methods.

bunch length (17.67 and 17.88 cm) and bunch diameter (11.64 and 11.92 cm) was recorded under control during both the years (Table 1). Increment in bunch length and diameter as a result of the application of $GA_3$ and 6-BA might be due to the elongation and expansion of the rachis (Han and Lee 2004, Warusavitharana *et al.* 2008).

Maximum bunch weight during both the year was observed when $GA_3$ @40 ppm + 6-BA @10 ppm was applied at pre-bloom + 3–4 mm berry size- double superimposed spray i.e. $G_8S_3$ (417.25 and 425.71 g, respectively) (Table 1). During the first year, $G_8S_3$ treatment was statistically at par with $G_6S_3$ (415.56 g), $G_9S_1$ (415.23 g) and $G_3S_3$ (414.18 g) treatments, whereas in second year, $G_8S_3$ treatment was statistically at par with $G_6S_3$ (424.21 g). Minimum bunch weight was recorded under control (332.71 and 345.62 g) during both the years. The present findings are in line with those of Warusavitharana *et al.* (2008) and El-Gendy *et al.* (2012).

Berry length was significantly increased by all growth regulator treatments (Table 2). During both the years, maximum berry length was recorded in treatment $G_8S_3$ (3.08 and 3.12 cm) which was statistically higher among all treatment interactions in first year whereas in second year $G_8S_3$ treatment was statistically at par with $G_3S_3$ (3.10 cm) treatment. Minimum berry length during both the year was recorded in the control (2.50 and 2.56 cm). Maximum (1.75 and 1.77 cm) and minimum (1.37 and 1.39 cm) berry diameter during both years were recorded in treatment $G_5S_3$ and control, respectively. During both the years, statistically higher berry weight was recorded in $G_8S_3$ (8.42 and 8.65 g) treatment, i.e. $GA_3$ @40 ppm + 6-BA @10 ppm applied at pre-bloom + 3–4 mm of berry size-double superimposed spray (Fig 1). Application of $GA_3$ has a positive effect on stimulating cell elongation process, enhancing the water absorption and stimulating the biosynthesis of proteins which leads to increase in berry characters while cytokinins enhance cell division, cell elongation as well as play a great role in activating the biosynthesis of proteins, RNA and DNA.

Significantly maximum TSS (18.27 and 18.77°B) during both the years was recorded in $G_8S_3$ treatment (Table 2). However, minimum TSS during both the years was recorded under control (15.51 and 15.77°B). Enhanced photosynthetic efficiency of the leaves as a result of increased leaf area and a possible increase in the translocation of assimilates with the application of $GA_3$ and 6-BA might be the possible reason of high TSS (Mohsen and Ali 2019). The results obtained in the present study are in conformity with El-Gendy *et al.* (2012). During both the years, acidity was only influenced by the stage of application of growth regulators. Minimum acidity (0.52 and 0.54%) was reported in stage $S_3$ (pre-bloom + 3–4 mm berry size) however maximum acidity (0.62 and 0.64%) was recorded under control during both the years (Table 2). Significantly higher TSS/acid ratio was observed in treatment combinations of $G_8S_3$ (35.06 and 34.71) whereas minimum TSS/acid ratio was recorded under control (25.01 and 24.64) during both the years (Table 3). The decrease in berry acidity accompanied by increased accumulation of total soluble solids content indicates chemically mediated degradation of starch and metabolism of organic acids into soluble sugars.

Growth regulators and stage of application resulted in significant increase in juice content and total sugars (Table 3). Highest juice content (67.52 and 68.28%) was obtained in treatment $G_8S_3$ during both the year which was significantly higher among all treatments, however minimum juice content was recorded under control (61.24 and 61.31%). Increased juice content in berries may be as a result of increased berry size with the application of growth regulators (Marzouk and Kassem 2011). Maximum total sugars were reported in $G_8S_3$ (14.72 and 14.84%) treatment during both the years, which was statistically at par with $G_6S_1$ (14.65%), $G_4S_3$ (14.56 %) and $G_7S_3$ (14.50%) during the first year and $G_9S_3$ (14.76%) and $G_7S_3$ (14.70%) during the second year. Minimum total sugars (12.56 and 12.61%) during both the years were registered under control. $GA_3$ stimulates invertase activity which led to the accumulation of sugars in the berries (Han and Lee 2004). However, Khalid *et al.* (2012) reported that total sugars were not affected by the application of BA and kinetin. Growth regulators significantly increased ascorbic acid content, however stage of application and their interaction effect had non-significant effects (Table 3). $G_8S_3$ (8.17 and 8.36 mg/100

Table 2 Effect of foliar application of growth regulators in different stages on berry length, berry diameter, total soluble solids and titrable acidity of grape cv. Sahebi

| Treatment | Berry length (cm) | | | | | | Berry diameter (cm) | | | | | | Total soluble solids (ºB) | | | | | | Titrable acidity (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st year | | | 2nd year | | | 1st year | | | 2nd year | | | 1st year | | | 2nd year | | | 1st year | | | 2nd year | | |
| | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ |
| $G_1$ | 2.50 | 2.50 | 2.50 | 2.56 | 2.56 | 2.56 | 1.37 | 1.37 | 1.37 | 1.39 | 1.39 | 1.39 | 15.51 | 15.51 | 15.51 | 15.77 | 15.77 | 15.77 | 0.62 | 0.62 | 0.62 | 0.64 | 0.64 | 0.64 |
| $G_2$ | 2.80 | 2.60 | 2.99 | 2.80 | 2.65 | 3.04 | 1.51 | 1.40 | 1.64 | 1.69 | 1.43 | 1.55 | 17.65 | 15.80 | 16.74 | 16.13 | 17.76 | 17.05 | 0.54 | 0.59 | 0.56 | 0.56 | 0.60 | 0.58 |
| $G_3$ | 2.83 | 2.65 | 3.02 | 2.87 | 2.70 | 3.10 | 1.55 | 1.43 | 1.67 | 1.43 | 1.57 | 1.71 | 15.71 | 16.61 | 17.73 | 16.25 | 17.13 | 17.88 | 0.60 | 0.57 | 0.53 | 0.61 | 0.58 | 0.56 |
| $G_4$ | 2.78 | 2.95 | 2.61 | 2.95 | 2.76 | 2.60 | 1.66 | 1.41 | 1.53 | 1.58 | 1.45 | 1.73 | 15.55 | 16.35 | 17.38 | 17.70 | 16.84 | 15.86 | 0.60 | 0.57 | 0.55 | 0.62 | 0.59 | 0.57 |
| $G_5$ | 2.75 | 2.55 | 2.97 | 2.78 | 2.58 | 2.97 | 1.62 | 1.50 | 1.75 | 1.64 | 1.49 | 1.77 | 15.62 | 16.48 | 17.54 | 15.93 | 16.92 | 17.70 | 0.59 | 0.57 | 0.55 | 0.61 | 0.58 | 0.56 |
| $G_6$ | 3.06 | 2.68 | 2.86 | 3.07 | 2.67 | 2.85 | 1.58 | 1.48 | 1.72 | 1.60 | 1.46 | 1.73 | 17.93 | 16.00 | 17.02 | 18.11 | 16.48 | 17.42 | 0.53 | 0.58 | 0.56 | 0.55 | 0.59 | 0.57 |
| $G_7$ | 2.74 | 2.54 | 2.91 | 2.99 | 2.62 | 2.80 | 1.70 | 1.47 | 1.58 | 1.65 | 1.52 | 1.40 | 15.87 | 16.90 | 17.81 | 17.27 | 16.37 | 18.00 | 0.59 | 0.56 | 0.53 | 0.60 | 0.57 | 0.55 |
| $G_8$ | 2.88 | 2.70 | 3.08 | 2.90 | 2.74 | 3.12 | 1.60 | 1.48 | 1.73 | 1.61 | 1.47 | 1.76 | 16.28 | 17.30 | 18.27 | 16.62 | 17.54 | 18.77 | 0.58 | 0.56 | 0.52 | 0.59 | 0.57 | 0.54 |
| $G_9$ | 3.00 | 2.57 | 2.80 | 2.65 | 2.82 | 3.00 | 1.56 | 1.45 | 1.69 | 1.42 | 1.54 | 1.67 | 16.13 | 17.18 | 18.10 | 16.77 | 17.66 | 18.45 | 0.58 | 0.56 | 0.52 | 0.59 | 0.57 | 0.54 |
| CD (P=0.05) | | | | | | | | | | | | | | | | | | | | | | | | |
| S | | 0.01 | | | 0.01 | | | NS | | | NS | | | 0.03 | | | 0.05 | | | 0.01 | | | 0.01 | |
| G | | 0.01 | | | 0.02 | | | 0.02 | | | 0.02 | | | 0.05 | | | 0.02 | | | NS | | | NS | |
| S × G | | 0.03 | | | 0.03 | | | NS | | | NS | | | 0.08 | | | 0.06 | | | NS | | | NS | |

Treatment details are given in Materials and Methods.

Table 3 Effect of foliar application of growth regulators in different stages on TSS/acid ratio, juice content, total sugars and ascorbic acid of grape cv. Sahebi

| Treatment | TSS/acid ratio | | | | | | Juice content (%) | | | | | | Total sugars (%) | | | | | | Ascorbic acid (mg/ 100 g) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st year | | | 2nd year | | | 1st year | | | 2nd year | | | 1st year | | | 2nd year | | | 1st year | | | 2nd year | | |
| | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ |
| $G_1$ | 25.01 | 25.01 | 25.01 | 24.64 | 24.64 | 24.64 | 61.24 | 61.24 | 61.24 | 61.31 | 61.31 | 61.31 | 12.56 | 12.56 | 12.56 | 12.61 | 12.61 | 12.61 | 6.42 | 6.42 | 6.42 | 6.85 | 6.85 | 6.85 |
| $G_2$ | 32.92 | 26.91 | 29.68 | 28.80 | 29.74 | 29.54 | 66.21 | 65.00 | 62.45 | 65.67 | 63.24 | 67.35 | 14.46 | 12.70 | 13.68 | 12.72 | 12.82 | 13.30 | 7.15 | 6.55 | 7.65 | 7.48 | 6.90 | 7.85 |
| $G_3$ | 26.27 | 29.34 | 33.26 | 26.63 | 29.53 | 32.21 | 65.32 | 63.27 | 67.24 | 66.18 | 63.56 | 67.84 | 12.62 | 13.58 | 14.36 | 12.83 | 13.52 | 14.58 | 8.02 | 7.42 | 6.78 | 8.11 | 7.57 | 7.13 |
| $G_4$ | 25.91 | 28.48 | 31.48 | 28.54 | 28.73 | 27.97 | 61.82 | 61.56 | 65.86 | 64.83 | 64.58 | 66.73 | 12.93 | 12.58 | 14.56 | 13.41 | 13.12 | 12.67 | 7.33 | 6.72 | 7.83 | 7.63 | 7.16 | 8.31 |
| $G_5$ | 26.42 | 28.86 | 31.89 | 26.02 | 28.97 | 31.38 | 63.74 | 65.98 | 64.11 | 66.62 | 61.66 | 61.92 | 12.60 | 13.54 | 14.20 | 12.76 | 12.72 | 14.42 | 7.04 | 6.63 | 7.70 | 7.32 | 7.00 | 8.04 |
| $G_6$ | 34.15 | 27.58 | 30.39 | 33.16 | 27.83 | 30.40 | 66.82 | 62.88 | 65.15 | 67.66 | 65.10 | 62.82 | 14.65 | 13.07 | 14.08 | 12.83 | 14.65 | 13.67 | 7.77 | 7.28 | 6.66 | 7.93 | 7.41 | 6.97 |
| $G_7$ | 27.12 | 30.01 | 33.60 | 29.02 | 28.51 | 32.60 | 64.52 | 62.10 | 66.13 | 62.57 | 65.44 | 67.14 | 12.82 | 13.81 | 14.50 | 13.07 | 12.90 | 14.70 | 7.95 | 6.80 | 7.47 | 8.27 | 7.07 | 7.51 |
| $G_8$ | 28.21 | 31.17 | 35.06 | 28.26 | 30.88 | 34.71 | 65.64 | 63.54 | 67.52 | 66.45 | 63.87 | 68.28 | 13.22 | 14.20 | 14.72 | 13.76 | 12.87 | 14.84 | 6.85 | 7.50 | 8.17 | 7.21 | 7.68 | 8.36 |
| $G_9$ | 27.85 | 30.78 | 34.60 | 28.42 | 30.98 | 34.10 | 62.60 | 64.83 | 66.47 | 62.20 | 66.86 | 65.90 | 13.42 | 14.13 | 14.02 | 12.92 | 13.84 | 14.76 | 7.56 | 6.93 | 8.26 | 7.74 | 7.26 | 8.41 |
| CD (P=0.05) | | | | | | | | | | | | | | | | | | | | | | | | |
| S | | 0.12 | | | 0.13 | | | 0.06 | | | 0.05 | | | 0.20 | | | 0.15 | | | NS | | | NS | |
| G | | 0.16 | | | 0.10 | | | 0.08 | | | 0.07 | | | 0.12 | | | 0.13 | | | 0.01 | | | 0.01 | |
| S × G | | 0.20 | | | 0.17 | | | 0.10 | | | 0.11 | | | 0.23 | | | 0.18 | | | NS | | | NS | |

Treatment details are given in Materials and Methods.

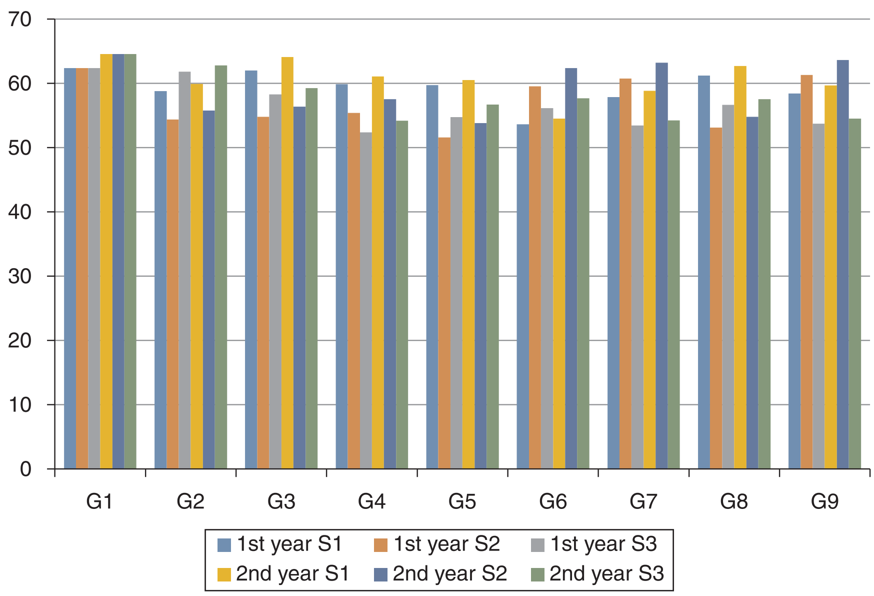


Fig 2 Effect of foliar application of growth regulators at different stages on anthocyanin content of grape cv. Sahebi. Treatment details are given in Materials and Methods.

g) treatment registered highest ascorbic acid during both the years, respectively however lowest ascorbic acid was recorded under control (6.42 and 6.85 mg/100 g). Increase in ascorbic acid may be due to role of $GA_3$ in delaying the activity of ascorbinase enzyme which converts ascorbic acid into dehydroascorbic acid by oxidation (Lou *et al.* 2012).

Minimum (51.62 and 53.81 g) and maximum (62.40 and 64.57 g) anthocyanin content was recorded in $G_8S_3$ and control during both the years, respectively (Fig 2). Decrease in anthocyanin content due to growth regulators application may be due to the effect of $GA_3$ and cytokinins on PAL (Phenylalanine ammonia lyase activity), a key enzyme in anthocyanin biosynthesis. $GA_3$ is known to retard the activity of enzyme chlorophylase which hampers degradation of chlorophyll resulting in poor colour development (Han and Lee 2004).

From the above results, it is concluded that combined application of the $GA_3$ @40 ppm + 6-BA @10 ppm at pre-bloom and when berries were of 3–4 mm in size proved to be the best in improving the berry yield and quality of Sahebi grapes.

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