PRE-HARVEST IMPLICATIONS AND UTILITY OF PLANT BIOREGULATORS ON GRAPE: A REVIEW

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Abstract
Application of plant bioregulators have been focused by many researchers in areas of plant physiology. Several fruit development activities like chemical thinning, increasing fruit set and size, enhancing colouration and enhancing or delaying ripening of fruits have been reported to be affected by the use of various growth regulators. Among several growth regulators, gibberellic acid found to have a potentiality on enhancing the division and expansion of pericarp cells of grape berries in both seeded and seedless grape cultivars. CPPU (Forchlorfenuron) acts synergistically with natural auxins and its primary effects cause the regulation of fruit set, berry growth and development. Brassinosteroids (BR) shown to be involved in numerous plant processes like promotion of cell division, cell wall regeneration, cell expansion and cell elongation, in synergism with auxin and promotion of vascular differentiation in grape.

Key words: Grape, plant bioregulators, gibberellic acid, CPPU, brassinosteroid.

Introduction
Grape is one among the most delicious, refreshing and nourishing fruits of the world. The berries are a good source of sugars and minerals like Ca, Mg, Fe, and vitamins like B1, B2, and C. Grape has so many uses and are so unique that no fruit can challenge their superiority. It is the most widely cultivated fruit and was carried from region to region by civilized man in all the temperate climates and has been grown more recently in tropical and subtropical climates. Quality improvement is an important criterion in grape culture which can be achieved with the use of plant bioregulators. Nowadays, plant bioregulators are widely used in viticulture for promoting better fruit production and quality improvement and for many years, gibberellic acid is in use for the production of quality grape. Among the different bioregulators, GA3, CPPU and BR play a significant role for production of export quality grapes. In the recent past, the efficiency of new chemicals like brassinosteroid and CPPU are being evaluated for the improvement of fruit quality in different grape growing regions of the world. Although various scientific outcomes have proved the potentiality of several bioregulators in grape over a period of time, their usage at the right stage with optimized concentration is essential for the improvement of yield and quality for any of the particular variety. In above point of view, the potentiality of pre-harvest applications of bioregulators for yield and quality improvement in both of seeded and seedless grapes is much essential.

Gibberellic acid on yield parameters in grape
Gibberellic acid is widely used in vineyards, all over the world, to increase cluster weight, berry weight and size of grape cultivars which in turn increase the vine yield. It is also known to reduce the bunch compactness and tends to improve quality. The timing of GA3 application is critical with regard to the physiological developmental stages of bunches. Their application is effective only during a short physiological stage of berry growth. GA3 spray on bunches, after berry set phase at lower concentrations, ensures both even berry size and a top quality product that avoids the incurring of more labour expenses for operations like thinning.

El-Hodairi et al. (1995) observed that fruit yield of Sultanina Seedless grape in Egypt was significantly increased by GA3 treatment particularly when 50 ppm
was applied after fruit set. According to Shehata and El-Barbary (1996), fruit length and weight was increased with the treatment of GA$_3$ at 5 ppm + fruit thinning in ‘Flame Seedless’ table grapes in Egypt. However, this treatment decreased cluster weight and yield by 16.6% and 26.5%, respectively compared with spraying with GA$_3$ 5 ppm alone. Lu et al. (1997) reported that the GA$_3$ treated berries of seeded muscadine grape cultivar Triumph weighed significantly more as compared to that of non treated vines. Those treated with GA$_3$ at 200 and 300 ppm weighed ~20% more berry weight than control. The effect of GA$_3$ in bunches and berries of grape cultivar Maria was assessed by Kalil et al. (1999). With the application of GA$_3$ (20 ppm) 14 days after flowering, there was an increase in mass, length and width of clusters including berry characters. Tomar (1999) showed that the application of GA$_3$ in Thompson Seedless in Himachal Pradesh at the pinhead stage gave significantly greater bunch length than application at the pea stage.

Application of GA$_3$ as spray to clusters twice at 10 ppm at cluster length of 5 to 7 cm and again after 5 to 7 days increased the bunch weight and berry diameter (El-Ghany, 2001). Boskov et al. (2002) studied the effect of gibberellic acid (GA$_3$) on technological properties in Italia grape vine variety with two stages of applications, one at berry size of 7-8 mm and other at 7 days upon the initial treatment. The results revealed that two applications of GA$_3$ at high rates (80 ppm) induced an increase in berry weight of 9.1 g compared to control (8.1 g). It also had a significant effect on berry length and width and size uniformity within the cluster. Godara et al. (2002) reported that maximum increase in the bunch weight was observed with the application of 50 ppm GA$_3$ at full bloom followed by 50 ppm GA$_3$ at berry set stage. Roberto et al. (2002) observed that the application of gibberellic acid at 3 g/100 liter in ‘Rubin’ grapes at 30 days after flowering recorded more weight and width of berries.

According to Gowda et al. (2006), the application of GA$_3$ (20, 25, 30 and 40 ppm) at 45, 50, 55 and 60 days after October pruning in ‘Thompson Seedless’ grapes significantly decreased the number of berries per bunch. Maximum berry size, diameter, weight and maximum pedicel size were noticed with 20 ppm GA$_3$ at pre bloom stage along with clipping of berries at pea stage (Selvaraju et al., 2007). Jegadeeswari (2008) studied the effect of certain growth regulators on yield and quality in grape cv. Muscat and found that grape vines treated with 25 ppm of GA$_3$ had recorded the maximum bunch weight, and yield per vine in grape cv. Muscat. The berry characters like berry weight and berry diameter were higher in vines treated with GA$_3$ at 25 ppm in grape cultivar Muscat. However, the bunches treated with GA$_3$ at 100 ppm had recorded the maximum berry length and minimum seed weight. Casanova et al. (2009) reported that application of GA$_3$ (80 ppm) 21 days after fruit set increased commercial berry weight by 50-90%, reaching similar size to that of ‘Aledo’ seeded grape, used as a comparison.

Abu-Zahra (2010) evaluated the influence of GA$_3$ on the fruit quality and productivity of cane pruned Thompson Seedless and reported that the bunch and berry characters were increased. Formolo et al. (2010) reported that double the application of GA$_3$ (30 ppm) at 5 mm berry diameter and 30 days after, increased cluster weight, berry length, diameter and weight significantly. In Thompson seedless grapes, application of GA$_3$ 50 ppm resulted increased bunch length and weight, hastened berry diameter and produced larger berries in comparison to control (Abu-Zahra, 2010). Among the different concentration of GA$_3$ (5, 10 and 20 ppm) in two different seedless cultivars viz., Thompson and Belgrade, application of GA$_3$ at concentration of 20 ppm increased the cluster mass, number of berries, berry length and weight in both the cultivars significantly (Dimovska et al., 2011).

Rizk-Alla et al. (2011) found that spraying clusters with 20 ppm GA$_3$ + 75 ppm NAA resulted in highest cluster and berry weight, berry size, length and diameter. Mixture of GA$_3$ (50 ppm) and NOA (0.2%) were shown to have a significant effect on berry length irrespective of method of application in Einset Seedless grape (Kap³an, 2011). An investigation carried out by Rafaat et al. (2012) for three consecutive years in Thompson Seedless showed that spraying GA$_3$ (40 ppm) increased weight, size, length, diameter and berry index shape of berries. Positive effects with application of GA$_3$ (25 ppm) on cluster weight and physical characteristics of berries i.e., berry weight and length were noticed when treated at full bloom stage in Perlette grapes (Meena et al., 2012).

Depending upon the variety, application of GA$_3$ at lower concentrations ranging 2.5 to 20 ppm, induces moderate cluster elongation and minimizes bunch rot in wine grapes (Grant, 2013). GA$_3$ significantly increased cluster weight, fruit L/D ratio, volume and fresh flesh weight in both cultivars Perlette and Yaghuti with 50 ppm GA$_3$ applied at berry set stage, when berries were 4 mm in size (Zahedi et al., 2013). Chaitakhob et al. (2014) reported bunch dipping with GA$_3$ (30 µL L$^{-1}$) at 50% full bloom and BA (10 µL L$^{-1}$) at fruit set stage (pea size) affected bunch size, width and increased the berry length/width ratio in Perlette grapes. Application of 20 ppm GA$_3$ at 7-10 days before blooming and 7-10 days after blooming.
in Flame seedless grapes increased bunch weight, length and width. It also influenced berry length, width, weight and berry shape index significantly (Dimovska et al., 2014).

**Gibberellic acid on quality parameters in grape**

Khan et al. (1996) reported that GA₃ treatments at 25 to 75 ppm, applied to bunch at full bloom and one month later significantly influenced TSS and reducing sugar contents and acidity of ‘Kishmish Charni’ grapes. The highest TSS (15.4%) and reducing sugar content (6.96%) were observed following treatment with GA₃ at 75 ppm. With increasing concentration of GA₃, percentage of acidity decreased. According to Zabadal and Dittmer (2000), the application of GA₃ at 50 ppm when berries averaged 5 mm in diameter were most effective for increasing fruit soluble solids in Vanessa Seedless grapes in USA. However, Fietosa (2002) reported that there was no significant difference in the levels of soluble solids, but acidity showed the highest values with application of GA₃ (20 ppm) and in control in grape cultivar Italia.

Highest TSS (%) and TSS: acid ratio were noticed by application of 40 ppm GA₃ at full bloom stage in combination with trunk girdling in Pusa Urvashi grape (Sasi Kumar et al., 2004). According to Feza Ahmad and Zargar (2005), GA₃ (50 ppm) coupled with Trunk girdling and ethephon resulted in increased TSS, TSS/ acidity ratio and decreased acidity as compared to control when applied at 50 per cent bloom in Perlette grapes. Application of GA₃ at 25 ppm had produced the highest TSS content and Sugar-acid ratio in grape cv. Muscat (Jegadeeswari, 2008). Ramteke et al. (2008) found that spraying GA₃ with concentration 40 and 30 ppm after berry set improved the quality of ‘Sharad Seedless’ grapes. Abu-Zahra (2010) evaluated the influence of GA₃ on the fruit quality and productivity of cane pruned Thompson Seedless and reported that it influenced the quality parameters of soluble solids and titerable acidity.

Among the different concentrations of GA₃ (5, 10 and 20 ppm) applied during the three different periods of the vine growing (before blooming, after blooming and before veraison) in two different seedless cultivars viz., Thompson and Belgrade, higher levels of sugar and total acids were determined in the Thompson grapes with the addition of gibberellic acid at 20 ppm (Dimovska et al., 2011). Rather et al. (2011) recorded that, Girdling + 40 ppm of GA₃ proved most effective in increasing the quality in terms of total soluble solids (TSS) (17.47 %), total sugar (8.94%), reducing sugar (10.35%), TSS: acid ratio (27.24%) and resulted in decrease in acidity (24.59%) in Perlette grapes. Spraying with 20 ppm GA₃ + 75 ppm NAA generally resulted in the lowest values of TSS percentage and TSS: acid ratio and the highest percentage of acidity in the juice as compared to control in Black Monukka grape (Rizk-Alla et al., 2011).

Taleb and Naser (2012) found 50 ppm of GA₃ was effective in increasing the total soluble solids and decreasing total titratable acidity significantly in cv. Black Magic. Highest TSS (%) was recorded with 50 ppm GA₃ applied at berry set stage when berries were 4 mm in length in cultivar Perlette under Iran condition (Zahedi et al., 2013). Chaitakhob et al. (2014) reported bunch dipping with GA₃ (30 ppm) at 50% of full bloom increased the TSS, reduced acidity and increased TSS: acidity ratio significantly in Perlette grapes. Application of 20 ppm GA₃ at 7-10 days before blooming and 7-10 days after blooming in Flame seedless grapes decreased the acidity in berries (Dimovska et al., 2014).

**Gibberellic acid on berry thinning in grape**

Application of GA₃ on Thompson Seedless grapes at bloom stage produced a very loose cluster (Weaver and Pool, 1965). Application of 10 ppm GA₃ during flowering caused thinning in Perlette variety (Kasimatis et al., 1971). Tripathi (1968) observed thinning effect of GA₃ at 125 ppm applied during pre bloom and at shatter stages in Perlette grapes. Nijjar and Gill (1971) reported that 50, 75 and 100 ppm of GA₃ at full bloom stage resulted in berry thinning. Nangia and Bakhshi (1971) observed that 50 to 100 and 125 ppm GA₃ increased the length of panicles and thereby loosened the clusters in the Perlette variety.

When Pusa Seedless grape clusters were treated with 25, 50, 70 or 100 ppm GA₃ at post bloom stage, it resulted in undesirable compactness but the application at full bloom could make the bunch very loose (Dass and Randhawa, 1972). Pishbin et al. (1983) observed elongated clusters in Askari variety when treated with 20 to 80 ppm GA₃ at pre bloom or post bloom stages. In Perlette variety, loosened and elongated bunches were found when GA₃ was applied (50 or 100 ppm) at pre bloom stage (Dhalwal, 1983). Gowda et al. (2006) indicated that the application of GA₃ at early stages of bunch development had a slight thinning effect.

**CPPU on yield parameters in grape**

CPPU (N-(2-Chloro-4-Pyridyl)-N-Phenylurea) is a growth regulator which has a significant physiological activity in many fruit crops, including grapes. The mode of action is similar to that of cytokinins (Dokoozlian et al., 1994) and, when applied in bunches after fruit set, the CPPU increases berry size and causes delayed
maturation. Diaz and Maldonado (1990) also opined that the higher concentration of CPPU treatment delayed the maturity in grape.

According to Pires (1998), depending on the variety, CPPU can determine the skin and pedicel thickness in grapes. Gao-Huanzhang and Gao (1999) reported that final berry weight of Fujimimori grape in China was highest (13.1 g) in vines sprayed with CPPU 10 ppm at 5 days after full bloom as compared to control (8.9 g).

Ezzahouani (2000) reported that post bloom applications of forchlorfenuron (5 and 10 ppm) in Perlette in Morocco increased berry weight and yield per vine compared to control. Chen and Jing (2002) reported that the treatment with forchlorfenuron to the clusters of Kyoho grape, 15 days after flowering increased the yield and berry weight and made berry glossier. Feitosa (2002) revealed that the best result was obtained with the application of CPPU (10 ppm) which resulted in an increase of 13.6% berry diameter and the berry weight by 32%.

Mellilo (2005) reported in California, the grape cultivar ‘Flame Seedless’ had a strong response to CPPU with regard to berry size. Application of 1 or 2 ppm of CPPU to the bunches having 3-6 and 7-10 or more leaves showed variation in berry size and bunches with 10 leaves significantly increased the berry diameter (Ramteke and Somkuwar, 2005).

Thomas and Martin (2006) studied the relative response of both seedless ‘Vanessa’ and ‘Lakemont’ and seeded ‘Concord’ and ‘Niagara’ grape cultivars with the application of CPPU at various concentrations (0, 5, 10 or 15 ppm) to clusters (4-6 mm berry diameter) and observed that CPPU at all the concentrations increased seedless berry diameter except ‘Lakemont’. The cluster and berry weight increased significantly in ‘Vanessa’ whereas berry size increased with two seeded cultivars.

Vidhya (2008) reported that among the different growth regulator treatments imposed, 16 ppm forchlorfenuron (0.1%) had a maximum bunch weight of 240.20 g over control in grape variety Muscat. The average berries per bunch were found to be higher in the treatment with foliar spray of forchlorfenuron (0.1%) 2 ppm. The fruit characters namely berry weight, length and breadth were increased linearly with increasing trends of forchlorfenuron (0.1%).

Berry pedicel thickness was enhanced by the application of forchlorfenuron (0.1%). Among the different Forchlorfenuron levels, application of 16 ppm concentration enhanced the pedicel thickness (Vidhya, 2008).

Salunkhe et al. (2008) recorded maximum 100 berry weight, length and diameter of berry were observed in vines with application of CPPU at 2 ppm at 3-4 mm berry diameter stage with recommended schedule of plant growth regulators in Thompson seedless. Application of CPPU followed by ABA might increase the size of ‘Flame Seedless’ grapes without excessively inhibiting coloring (Peppi and Matthew, 2008).

Strydom (2013) reported that, CPPU dosages of 2, 5 and 3 ppm significantly increased berry diameter in Flame Seedless, Red Globe and Crimson Seedless respectively. 

**CPPU on quality parameters in grape**

Application of 5 ppm of Sitofex in grape cv. King’s Ruby with a load of 10 or 15 clusters per vine did not increase the TSS content in the berries (El-Hammady et al., 2000). Ezzahouani (2000) revealed the soluble solids decreased while acidity increased, reflecting a late maturation of berries on CPPU treated vines. According to Das et al. (2001), TSS content of Pusa Seedless was not affected by the application of CPPU, dormex and GA₃.

Chen and Jing (2002) reported that, the treatment with forchlorfenuron to the clusters of Kyoho grapes, 15 days after flowering increased total soluble solids content and made the berry glossier. However, the fruit quality was not as good as at lower concentrations. In grape cv. Fujimimori, application of CPPU (10 or 20 ppm) dipping at 7 or 15 days after full bloom decreased soluble solids significantly (Sheng-Baolong et al., 2004).

Peppi and Matthew (2008) revealed that forchlorfenuron, a synthetic cytokinin, applied after fruit set increased the size and firmness of table grape cultivar ‘Flame Seedless’, but reduced soluble solids and berry colour. Application of growth regulators did not influence the TSS content of grapes. However, 2 ppm of Forchlorfenuron had registered a maximum TSS, total and reducing sugar contents, among the different levels of growth regulators used. Moreover, spraying of the growth regulators found to have positive impact on quality parameters over dipping (Vidhya, 2008).

According to Rodrigues et al. (2011), the use of CPPU alone in the pea berry stage resulted in reduction of soluble solids content of the berries. There was no influence with the improvement in quality of grape cv. Italia. Rafaat et al. (2012) found that, 5 ppm CPPU increased TSS and reduced acidity in Thompson Seedless. CPPU (5 ppm) increased TSS in Red Globe and CPPU (3 ppm) increased total titrable acidity in Crimson Seedless (Strydom, 2013).
Brassinosteroid on yield and quality in grape

Brassinosteroid (BR) are compounds that exert a wide range of biological activities. They are essential for plant growth, reproduction and responses to various biotic and abiotic stresses. Usually, BR are steroidal hormones, which are essential for normal plant growth and development.

Watanabe et al. (1997) studied the potential of BR compound (TS303) as a growth regulator. They sprayed TS303 (BR) in the 12 years old vines of grape cv. Kyoho, 7 days before flowering and observed that application promoted better fruit set. Brassinosteroid (BR) are the widely distributed natural products that promote growth and possess all properties necessary for classification as a plant hormone (Clouse and Sasse, 1998). They were first isolated from the pollen of Brassica napus, a close relative of mustard (Grove et al., 1979).

According to Zhou-Yushu et al. (2003), berry size of Kyoho grapes was increased with the application of homobrassinolide at 2-3 days before flowering, at full bloom and 14 days after full bloom. Symons et al. (2006) showed that the application of BR to grape berries evidently enhanced skin coloration and the final sugar level of the flesh, and significantly promoted ripening.

An increase in crop yield and quality has been observed when plants were treated with exogenous BR at appropriate stages of their development (Bartwal et al., 2013). Harindra Champa et al. (2014) reported the clusters treated with 1 ppm brassinosteroid significantly increased cluster and berry weight, berry length and breadth. It also increased TSS content when vines were sprayed with brassinosteroid at 0.5 and 1.0 ppm.

Combined effect of gibberellic acid and CPPU on yield and quality in grape

In applications of GA₃ and CPPU in the cultivar Thompson Seedless, there was 28% increase in the mass of clusters compared to single applications of GA₃ (Schuck, 1994). According to Wolf et al. (1994) showed promising results with improvement in quality of the clusters with treatments GA₃ associated with CPPU for the cultivars Sultanina, Flame Seedless and Muscat Seedless.

Miele et al. (2000) evaluated the effects of CPPU (0, 3, 4, 5, 6, 8 or 12 ppm) and GA₃ (40 ppm) and found that their combinations increased berry size in grape cv. Italia. There was also a linear increase in the weight of bunches with the addition of CPPU.

Mervet et al. (2001) obtained best results with the application of CPPU (5 ppm) applied to berries 6 mm in diameter, in combination with GA₃ (40 ppm) in cv. Thompson Seedless. There was increase in yield per vine due to the increase of bunch weight, size in length and width of bunches but delayed maturation, reduced soluble solids and increased acidity. In Chile, Navarro et al. (2001) observed increased berry size, weight and production of bunches per plant, when associated with combined application of GA₃ and CPPU in grape cv. Sultanina. Tao-Jianmin et al. (2001) reported that the application of CPPU and GA₃ had no obvious effect on the berry soluble solid content in grape cv. Venus.

According to Feitosa (2002), the cluster of Italia grapes of export quality can be produced with combined treatments of CPPU and GA₃. However, the combined effect of CPPU and GA₃ delayed harvest by 8 days. Enlarged berries over 20 g in Fujiminori cultivar were harvested in Japan when fruits were sprayed with 25 ppm GA₃ at full bloom, followed by mixture of 500 to 100 ppm GA₃ and 10 ppm CPPU 11 days later. Treated fruits did not exhibit pale skin colour, less sweetness and less acidity (Ishikawa et al., 2003). Pires et al. (2003) found that, applications of CPPU and GA₃ at 5 ppm to the clusters of ‘Centennial Seedless’ grapes increased berry weight by 59.0% and 78.7% and led to the formation of very large and excessively compact clusters with very thick pedicels. Ribeiro and Son (2003) in Porto Feliz, Brazil observed an increase in berry length and improved total soluble solids in the berries in cultivars Centennial Seedless, Flame Seedless and Thompson Seedless, when GA₃ at doses of 0, 25, 50 and 100 ppm used in combination with CPPU at 10 ppm applied at 15 days after flowering.

Dong-QuiHong et al. (2004) reported the highest soluble solids content was obtained after treatment with 50 ppm GA₃ + 5 ppm CPPU. According to Han and Lee (2004) the application of CPPU (10 ppm) and GA₃ (25 ppm) 10 days after bloom increased the quality parameters of seven years old Kyoho grape. In five years old Fujiminitori grapevine, TSS was increased by the application of 10 ppm CPPU in combination with 25 ppm GA₃ (Wang-ShiPing et al., 2004).

Natchigal et al. (2005) observed a synergistic effect in diameter of berries in grape cv. BRS Clara, grown in SP-Jales, when applied with a spray of GA₃ 20 ppm with CPPU 4 ppm, to clusters with fruit measuring 7 mm in diameter, improved the quality but higher concentrations decreased the TSS content. Best quality Thompson Seedless grape was produced by spraying 2 ppm CPPU + 35 ppm GA₃ at 2-3 mm berry size (Ramteke and Somkuwar, 2005). Avenant and Avenant (2006) reported in grape cultivar ‘Red Globe’, the combination of GA₃
(20 ppm) and CPPU (5 ppm) applied at 12 mm berry size, delayed the accumulation of sugars.

In cv. Red Globe, berry size and firmness were increased by combined application of (20 ppm) GA<sub>3</sub> and (3 ppm) CPPU at 10 mm berry stage (Quxley and Raath, 2010). According to Rumpai <i>et al.</i> (2010), treatment of 12.5 ppm GA<sub>3</sub> and 10 ppm CPPU, applied 12 days after full bloom followed by 25 ppm GA<sub>3</sub>, 25 days after full bloom increased 75% berry weight in ‘Kyoho’ and 56% in ‘Honey Red’ seedless grapes. Sung-Min Park (2010) noticed that significant increase in berry size was in Triploid grapes treated with 2.5 ppm of CPPU in combination with 100 ppm of GA<sub>3</sub>.

Among the combinations of different concentrations of GA<sub>3</sub> (20 and 30 ppm) and CPPU (0.25, 0.50 and 1 ppm) used at 3-4 mm and again at 6-7 mm berry size stage in grape cultivar Red Globe, application of CPPU (1 ppm) and GA<sub>3</sub> (20 and 30 ppm) showed significant differences in bunch weight, berry size and acidity (Anon, 2011). Rodrigues <i>et al.</i> (2011) reported foliar spray with the mixture of GA<sub>3</sub> (20 ppm) and CPPU (10 ppm) in the pea berry stage promoted the increase of the length and diameter of berries without prejudice to the mass of the clusters in grape cv. Italia.

According to Ahmed Ola <i>et al.</i> (2012) combination of GA<sub>3</sub> at 40 ppm and CPPU at 3 ppm resulted in improved cluster weight, berry traits and TSS, but decreased acidity in cv. Thompson Seedless. Rafaat <i>et al.</i> (2012) found that spraying GA<sub>3</sub> at 40 ppm and CPPU at 5 ppm had significantly increased weight, size, length, diameter and berry index shape of berries of Thompson Seedless. According to Eyal Raban <i>et al.</i> (2013), three seedless table grape cultivars, ‘Mystery’, ‘Superior’, and ‘Crimson Seedless’ treated with gibberellin (GA<sub>3</sub>), cytokinin (CPPU) responded to the combined treatment of GA<sub>3</sub> and CPPU with increased berry weight and diameter.

**Combined effect of gibberellic acid, CPPU and brassinosteroid on yield and quality in grape**

Vivency (1995) observed, the application of 25 ppm GA<sub>3</sub> with 1 ppm of BR to Sonaka Seedless and Thompson Seedless bunches gave heavier bunch weight.

Velu (2001) opined that, application of 25 ppm of GA<sub>3</sub> with 0.5 ppm of BR at flowering and fruit set stage improved yield and quality of Muscat grapes than control. Application of GA<sub>3</sub> in combination with Brassinosteroid (1 ppm) was found effective for increasing the yield of Thompson Seedless grapes (Tambe, 2002).

Warusavitharana <i>et al.</i> (2008) reported that the vines treated with GA<sub>3</sub> at 10 ppm at pre-bloom stage, 15 ppm at initiation of flowering, 25 ppm at 3-4 mm berry diameter stage in combination with 1 ppm brassinosteroid recorded the maximum for bunch characters in three year old Thompson Seedless grapes trained under bower system.

Habibi <i>et al.</i> (2010) reported that, 50 ppm GA<sub>3</sub> + 1 ppm brassinosteroid increased the berry weight and diameter significantly in Bangalore Blue grapes. Padashetti <i>et al.</i> (2010) found that GA<sub>3</sub> (50 ppm) + BR (1 ppm) applied twice at fruit set stage increased bunch weight, berry weight and reducing sugar (%) in Arka Neelamani and TSS in Thompson seedless.

**Combined effect of gibberellic acid, CPPU and brassinosteroid on yield and quality in grape**

Among the growth regulators like GA<sub>3</sub>, brassinosteroid, CPPU and BA, 2 ppm CPPU + 0.4 ppm brassinosteroid + 20 ppm BA gave the highest mean brix: acid ratio (60.23) and average brix yield (73-86 g) when fruits of Flame Seedless were dipped in growth regulators at 7 days after fruit set, whereas 3 ppm of CPPU gave the lowest mean brix: acid ratio (58.9) and average brix yield of 55.13 g (Bhat <i>et al.</i>, 2004).

According to Warusavitharana (2008), after October pruning vines and bunches at specific stage of development were treated with respective plant growth regulators like GA<sub>3</sub>, brassinosteroid, CPPU, and benzyladenine. The results revealed that the application of GA<sub>3</sub> in combination with brassinosteroid and BA was found effective for cell elongation and cell division, which lead to increase berry size, yield and quality of Thompson Seedless grapes.

Bhat <i>et al.</i> (2012) evaluated the effects of GA<sub>3</sub>, brassinosteroid and CPPU on seedless grape variety ‘Tas-A-Ganesh’. He applied brassinosteroid and CPPU either alone or in combination with benzyladenine by dipping the bunches at either 7 or 15, or both 7 and 15 days after fruit set. The treatments having a combination of either higher or lower concentration of both BR (0.4 ppm) and CPPU (4 ppm) along with benzyladenine 20 ppm produced maximum bunch weight (371.13 g), berry weight (4.90 g), berry volume (4.22 cm<sup>3</sup>), and number of berries per bunch (90.88).

**Conclusion**

GA<sub>3</sub> application has revolutionized the grape cultivation and other growth regulators like brassinolides and CPPU had also been tried with success for improving the quality. Although various research outcomes authenticated the effects of several bioregulators in grape over a period of time, their usage at the right stage with optimized concentration is essential for the improvement
of yield and quality.

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