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Impact of Spraying 'Early Sweet' Grapevines with Gibberellic Acid and Urea for Reducing Shot Berries Percentage and Improving Yield and Cluster Quality

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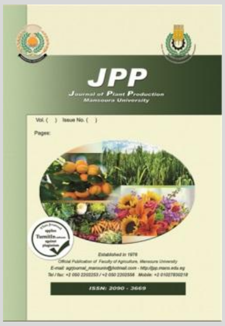

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ABSTRACT

The presence of shot berries in the Early Sweet grapevine cultivar poses a considerable challenge that negatively affects grapevine productivity and fruit quality, making it crucial to find certain treatments to minimize their prevalence and increase grapevine yield. Field experiments were conducted at Horticulture Research Institute experimental farm, Mansoura, Egypt, using a completely randomized block design with three replicates during 2021 and 2022 successive seasons. The experiment includes five treatments i.e., T1) control, spraying only with tap water; T2) spraying with 1 ppm gibberellic acid (GA_3) and 0.5 g/L low biuret urea twice during full bloom and at 25% fruit set; T3) same as T2 plus spraying with 10 ppm GA_3 at 7-8 mm berries diameter; T4) same as T2 plus spraying with 10 ppm GA_3 and 20 ppm GA_3 at 7-8 mm and 10-12 mm berries diameter respectively, and T5) same as T2 plus spraying with 20 ppm GA_3 at 10-12 mm berries diameter. The findings showed that spraying GA_3 along with urea during different growth stages significantly boosted both yield and quality of berries compared to control treatment. However, treatments of GA_3 and urea, particularly (1–10 ppm and 1–20 ppm), resulted in higher acidity levels and a slight reduction in soluble solid content (SSC) and SSC/acid ratios. Among the treatments, T4 showed the lowest percentages of shot berries, accompanied by a significant increase in yield, cluster weight, berry weight, diameter, and total chlorophyll concentration in berry skin, while reducing total carotenoid concentration in berry skin.

Keywords: Gibberellic acid (GA_3), Low-biuret urea, 'Early Sweet' grapevines, Shot berries.

INTRODUCTION

Grapes (*Vitis vinifera* L.) rank among the world's most important fruit crops, with substantial economic and export value. In Egypt, grape production covers approximately 79,092 hectares, yielding about 1.57 million tons annually, making it the second most important fruit crop after citrus (FAO, 2022). Among cultivars grown in warm climates, the 'Early Sweet' stenospermocarpic grape is an early-ripening table grape variety that is highly prone to shot berry formation (Or *et al*., 2020). Shot berries; tiny, underdeveloped berries within a cluster that do not reach the size of typical berries; they often have lower sweetness and visually reduce the uniformity and market value of the bunch. Shot berries occur due to postponed pollination and fertilization in certain flowers or insufficient carbohydrate supply for the developing berries. Contributing factors include boron deficiency, improper timing of gibberellin application, and the practice of girdling (Ramteke, 2012). To overcome these challenges, sophisticated agrotechnical approaches have been developed, utilizing the external application of gibberellic acid (GA_3) to improve the quality of seedless grapes (Nampila *et al*., 2010; Dimovska *et al*., 2014).

In stenospermocarpic cultivars like 'Early Sweet', seeds act as the main source of GA_3 only until they abort, so these berries stay small due to their restricted levels of bioactive gibberellin (Iwahori *et al*., 1968; Conde *et al*., 2007). Subsequently, to encourage proper berry development to achieve marketable size, these varieties are typically treated with external applications of GA_3. Gibberellic acid plays a key role in various developmental stages, including stem elongation, flowering, and fruit formation (Taiz and Zeiger, 2006). In grapes, it influences flower cluster formation, promoting berry setting and enlargement, bunch elongation, berry thinning within the bunch, and protecting berries from cracking (Korkutal *et al*., 2008). In table grape cultivation, GA_3 is frequently applied, particularly to increase the size of berries of seedless cultivars (Rusjan, 2010; Meneses *et al*., 2020). Applying GA_3 at important stages of the development of the fruit plays a crucial role in seedless grape cultivation due to its role in enlarging berries as it stimulates pericarp cell elongation, leading to increased berry size (Casanova *et al*., 2009; Rademacher, 2016). Alternatively, applying GA_3 to 'Early Sweet' cultivar can boost fruit set and trigger shot berry formation, depending on its timing and concentration. Therefore, precise management is essential to maintain a balance between fruit set and berry development (Or *et al*., 2020).

Urea is the most widely utilized nitrogen source in the production of synthetic fertilizers globally. It is a non-electrically charged nitrogen molecule, which is ideal for foliar application as it's an uncharged molecule, highly soluble in water, and quickly and effectively absorbed by leaves since it easily diffuses through the leaf's epicuticular layer (Lasa *et al.* 2012; Gutiérrez-Gamboa *et al*., 2022). Recently, urea has been applied at the pre-bloom or full-bloom stages to decrease berry set percentage, thereby promoting natural berry thinning (El-Salhy *et al*., 2009; Fawzi *et al*., 2014).

The presence of shot berries in 'Early Sweet' grape clusters poses a challenge since it lowers the marketable

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value, incurs high costs, and is time intensive when using manual thinning. Therefore, the study was conducted to assess the role of GA_3 levels and urea on the yield and berry quality of 'Early Sweet' grapevines, with the additional goal of reducing the shot berries in the clusters.

MATERIALS AND METHODS

This study was carried out during 2021 and 2022 growing seasons using six-year-old "Early Sweet" seedless grapevines grafted onto Freedom rootstock. The experiments were conducted at the Horticulture Research Institute's experimental farm, Mansoura, Egypt (31.1195° N, 31.4487° E). Forty-five vines, uniform in vigor and health, were selected and maintained according to the standard agricultural practices followed in the vineyard. The vines were grown in clay soil, spaced at 2 × 3 meters, irrigated through a surface irrigation system, supported by the Spanish Baron trellis system, and trained using a mixed pruning method, keeping nearly 76 eyes/vine (based on 12 fruiting spurs/vine × 5 eyes/spur + 8 renewal spurs with 2 eyes/spur). The crop load for all vines was standardized to 25 clusters per vine following berry set. Pruning operations were performed in the last week of December in both growing seasons of the study.

The experiment involved five treatments within a completely randomized block design with three replicates for every treatment, and three vines per replicate. The treatments were as follows: T1) control, spraying only tap water; T2) spraying with 1 ppm GA_3 and 0.5g/L low biuret urea twice during full bloom and at 25% fruit set; T3) same as T2 plus spraying with 10 ppm GA_3 at 7-8 mm berries diameter; T4) same as T2 plus spraying with 10 ppm GA_3 and 20 ppm GA_3 at 7-8 mm and 10-12 mm berries diameter respectively; T5) same as T2 plus spraying with 20 ppm GA_3 at 10-12 mm berries diameter.

At harvesting time (when soluble solids content 'SSC' in berry juice reached 15-16 %), the cluster samples were harvested and transferred to the Pomology Department laboratory at Mansoura University for assessment of the following parameters:

1. The yield and cluster characteristics

Yield/vine (kg): was calculated by multiplying the total number of clusters on each vine by the average cluster weight.

Average cluster weight (g): was determined using a precision electronic balance to ensure accurate measurement.

Yield increase (%): was calculated in comparison to the control treatment using the formula:

$$\text{Yield increase} = \frac{\textit{total yield of each treatment} - \textit{total yield of control treatment}}{\textit{total yield of control treatment}}\ x\ 100$$

2. Physical properties of berries:

The average weight (gram)

Berry diameter on average (mm): estimated with a digital caliper.

$$\text{The shot berries \%} = \frac{\text{number of shot berries per bunch}}{\text{total berries per bunch}}\ x\ 100$$

3.Chemical properties of berries:

The soluble solids content (SSC%) of fresh berry juice was measured using a Carlsize handheld refractometer.

Total acidity (%) was determined by titrating 5 mL of berry juice with 0.1 N sodium hydroxide (NaOH) until reaching a phenolphthalein endpoint and expressed as tartaric acid equivalent (AOAC, 1984).

The ratio of soluble solids to acidity was also determined

4.Total chlorophyll and carotenoid concentrations (mg/g FW):

The concentrations of total chlorophyll and carotenoids in the berry skin were assessed based on the protocol of Lichtenthaler and Wellburn (1985), with slight modifications. A 0.1-gram sample of fresh berry skin was extracted with 10 mL of methanol and kept in a refrigerator for 48 hours; subsequently, its optical density was measured at 470, 653, and 666 nm.

Statistical analysis:

The collected data were analyzed using the analysis of variance (ANOVA) method within a completely randomized blocks design via CoStat Version 6.0. Means of treatment were compared using Duncan's Multiple Range Test at a probability level of 5% (Waller and Duncan, 1969)

RESULTS AND DISCUSSION

This study was conducted to evaluate the impact of spraying 'Early Sweet' grapevines with GA_3 and urea on yield, cluster, and berry quality during both seasons 2021 and 2022. The results obtained are presented as follows:

Effect on yield and cluster characteristics:

Data presented in Table 1 clearly demonstrate that applying GA_3 in combination with urea significantly enhanced yield per vine, average cluster weight, and yield increase percentage in 'Early Sweet' grapevines compared to the untreated control. The treatment with GA_3 at 1–10–20 ppm plus urea significantly produced the highest values in both seasons when compared with all treatments, achieving a yield increase of more than 40%, a cluster weight close to 600 g, and almost 15 kg yield per vine. In contrast, the control consistently recorded the lowest values for all measured traits. Moderate improvements were also observed with the GA_3 at 1–10 ppm plus urea treatment, while the GA_3 at 1 ppm plus urea treatment revealed the least enhancement among the GA_3 plus urea combinations, indicating that the sequence and timing of GA_3 concentrations play a crucial role in maximizing productivity.

Table 1. Effect of GA_3 and urea on yield per vine, average weight of cluster, and yield increase of 'Early Sweet' vines during seasons of 2021 and 2022.

Treatments	yield/vine (Kg)		Weight of cluster (g)		Yield increase (%)	
	2021	2022	2021	2022	2021	2022
T1	10.30^{e}	10.67^{d}	410.90^{e}	427.00^{d}	0.00^{e}	0.00^{d}
T2	11.23^{d}	12.07^{c}	450.00^{d}	481.90^{c}	9.07^{d}	13.19^{c}
T3	14.10^{b}	14.13^{b}	563.00^{b}	564.33^{b}	36.89^{b}	32.57^{b}
T4	14.90^{a}	14.97^{a}	595.33^{a}	598.43^{a}	44.67^{a}	40.34^{a}
T5	12.77^{c}	11.83^{c}	510.23^{c}	473.20^{c}	23.94^{c}	11.01^{c}

Values in the same column sharing identical letters are not significantly different using Duncan's Multiple Range Test at 5% probability. T1) control, spraying only with tap water; T2) spraying with 1 ppm gibberellic acid (GA_3) and 0.5g/L low biuret urea twice during full bloom and at 25% fruit set; T3) same as T2 plus spraying with 10 ppm GA_3 at 7-8 mm berries diameter; T4) same as T2 plus spraying with 10 ppm GA_3 and 20 ppm GA_3 at 7-8 mm and 10-12 mm berries diameter respectively; T5) same as T2 plus spraying with 20 ppm GA_3 at 10-12 mm berries diameter.

The promoting effects of GA_3 on the yield and cluster weight of grapevine as recorded in the current study was supported by Kaplan *et al.* (2017) on "Einset Seedless" grapevines, which observed that foliar application of GA_3 at concentrations of 100, 200, and 300 mg/L, applied 7, 14, and 21 days after full-bloom, enhanced yield per vine which increased slightly as the concentration of gibberellin increased, and grapevines sprayed three times produced greater yield compared to vines treated once or twice, with comparable trends also noted in cluster weight. Mohamed *et al.* (2019) studied the influence of abscisic acid and GA_3 spraying on three major grape cultivars, "Flame Seedless, Ruby Seedless, and Thompson Seedless", and found that applying abscisic acid at 400 ppm in combination with GA_3 at 10 ppm led to a significant enhancement in yield per vine. Recently, Pahi *et al.* (2020) recorded that the application of GA_3 in several grape cultivars at various developmental stages, including flowering and fruiting, significantly enhanced yield while preserving fruit quality in comparison to the control treatment. Furthermore, Abdel Hameed *et al.* (2023) mentioned that sprayed "Superior" grapevines with GA_3 at 0, 10, 20, or 40 ppm at the pea stage '6mm' led to an increase in vine productivity and weight of bunch.

The positive effects of urea on enhancing yield and cluster weight across various grapevine cultivars have been confirmed by several researchers, including El-Halaby *et al.* (2015) on 'Flame Seedless' and El-Salhy *et al.* (2019) on 'Early sweet Seedless', and Abd El-Khalek *et al.* (2024) on 'Prime Seedless'.

Effect on berry physical characteristics:

Data in Table 2 revealed that combined applications of GA_3 and urea significantly enhance berry development in 'Early Sweet' grapevines compared to the control treatment, indicating the positive impact of GA_3 and urea on berry enlargement. The highest average berry weight was recorded with the treatment GA_3 (1–10–20 ppm) + urea (0.5 g/L), over the control. This treatment also maintained consistent performance across both seasons, 6.30 g and 6.03 g, respectively. Similarly, berry diameter peaked under the same treatment, significantly outperforming other treatments in both years. Concerning the effect of spraying 'Early Sweet' vines on the average number of berries per bunch, it remained unaffected by the applied treatments, and non-significant differences were observed between all treatments in the first season of study.

Table 2. Impact of GA_3 and urea on average weight of berries, average diameter of berries, and number of berries/clusters of 'Early Sweet' vines during 2021 and 2022 seasons.

Treatments	Average weight of berries (g)		Average diameter of berries (mm)		Average number of berries /clusters	
	2021	2022	2021	2022	2021	2022
T1	4.27^{e}	4.30^{c}	17.47^{e}	17.70^{d}	96.33^{a}	99.33^{a}
T2	4.63^{d}	4.97^{b}	18.70^{d}	19.00^{c}	96.67^{a}	96.33^{ab}
T3	5.97^{b}	5.93^{a}	20.37^{b}	20.50^{b}	94.33^{a}	95.33^{b}
T4	6.30^{a}	6.03^{a}	20.73^{a}	21.00^{a}	94.67^{a}	99.33^{a}
T5	5.17^{c}	4.83^{b}	19.00^{c}	19.10^{c}	98.00^{a}	97.33^{ab}

Values in the same column sharing identical letters are not significantly different using Duncan's Multiple Range Test at 5% probability. T1) control, spraying only with tap water; T2) spraying with 1 ppm gibberellic acid (GA_3) and 0.5g/L low biuret urea twice during full bloom and at 25% fruit set; T3) same as T2 plus spraying with 10 ppm GA_3 at 7-8 mm berries diameter; T4) same as T2 plus spraying with 10 ppm GA_3 and 20 ppm GA_3 at 7-8 mm and 10-12 mm berries diameter respectively; T5) same as T2 plus spraying with 20 ppm GA_3 at 10-12 mm berries diameter.

These findings are consistent with those reported by Özer *et al.* (2008), who noted that spraying GA_3 ten days after berry set led to an increase in berry size for 'Reçel Üzümü' grapes. The most substantial berry weights were achieved with GA_3 treatments of 10 plus 20 plus 20 ppm and 20 plus 40 plus 40 ppm, administered sequentially at full bloom, berry set, and 10 days post-set. Spraying 'Tekirdağ Misketi' grapevines with 10 or 20 ppm GA_3 during both the full-bloom and berry set phases led to noticeable improvements in berry and cluster size (Ergönül *et al.*, 2015). Research carried out by Kaplan *et al.* (2017) on the 'Einset Seedless' grapevine cultivar revealed that foliar application of GA_3 at 300 mg/L three times significantly affected berry weight compared to treatments performed once and twice, and the number of GA_3 sprays influenced berry weight only when the highest concentration was used. Özer and Ergönül (2021) mentioned that applying GA_3 alone could effectively enhance the berry size of 'Özer Beyazı' grapevines.

The application of GA_3 significantly decreases the number of cells (cell density) per unit area while markedly increasing both the transverse and longitudinal diameters of cells (Meneses *et al.,* 2020; Chen *et al*., 2025). Furthermore, Chai *et al.* (2014) reported that external application of GA_3 increases tryptophan levels in grapes by promoting protein degradation, which in turn stimulates auxin production through the enzymatic action of tryptophan aminotransferase. Transcriptome analysis indicated that externally applied GA_3 primarily influences the development of the cell wall, primary growth, and phenylpropane biosynthesis, thereby regulating key physiological functions. In addition, fruit volume and cell length increased when GA_3 was sprayed during the early expansion period of grape berries, suggesting that externally applied GA_3 significantly enhances berry size and promotes cell enlargement (Li *et al*., 2024 a) as they demonstrated that the rates of auxin and cytokinin in 'Red Globe' grape cultivar treated with exogenous GA_3 gradually rose throughout the early phases of grape growth. Thus, exogenous GA_3 promoted the growth of grape berries by enhancing the concentration of naturally occurring hormones (Upadhyay *et al*., 2018).

Urea offers a readily accessible nitrogen source, critical for protein assimilation and plant growth, aiding in the formation of more substantial clusters and berries (Taiz and Zeiger, 2006). Canopy net photosynthesis in grapevines is influenced by nitrogen availability and the carbohydrate demand from both vegetative and reproductive sinks (Keller 2020; Stefanello *et al.* 2020). Consequently, adjusting the source–sink balance through foliar nitrogen application may impact grapevine physiology and development. Ahmed *et al.* (2004) found that spraying "Perlette" grapes with low biuret urea at the concentrations of 3% at the pre-bloom and fruit set stage induced a significant increase in average berry weight when compared to the control treatment.

The data presented in Figure 1 clearly demonstrate the impact of combined GA_3 and urea treatments on reducing the rate of shot berry formation in the 'Early Sweet' cultivar across two growing seasons. Treatment T1 (Control) consistently showed the highest percentage of shot berries in both 2021 and 2022, over other treatments. All treatments alongside foliar urea significantly reduced shot berry formation, indicating the positive impact of hormonal and nitrogen interventions on berry development. Notably, T4, which involved a sequential application of GA_3 at 1, 10, and

20 ppm along with urea, achieved the lowest shot berry percentages and was statistically marked from other treatments, particularly in the 2022 season.

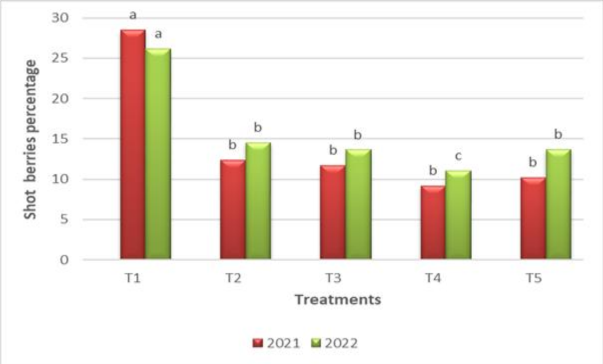

Fig. 1. Effect of GA_3 and urea on shot berries percentage of 'Early Sweet' grapevines during 2021 and 2022 seasons. Means in the same column that have different lower-case letters are significantly different according to the Duncan's multiple range test (P≤0.05)

T1) control, spraying only with tap water; T2) spraying with 1 ppm gibberellic acid (GA_3) and 0.5g/L low biuret urea twice during full bloom and at 25% fruit set; T3) same as T2 plus spraying with 10 ppm GA_3 at 7-8 mm berries diameter; T4) same as T2 plus spraying with 10 ppm GA_3 and 20 ppm GA_3 at 7-8 mm and 10-12 mm berries diameter respectively; T5) same as T2 plus spraying with 20 ppm GA_3 at 10-12 mm berries diameter.

The physiological mechanism responsible for these effects with GA_3 came from stimulating both cell division and elongation while also adjusting hormonal balance during the early phases of berry development. Meanwhile, applying urea has probably enhanced the nitrogen status in the plant that is closely tied to canopy photosynthesis and carbohydrate production, which are crucial for fruit development. These findings align with previous research on different grapevine cultivars, suggesting that foliar nutrition and hormone treatments can improve fruit uniformity and reduce developmental anomalies. Ahmed *et al*. (2004) worked on "Perlette" grapes and proved that using 3% urea at pre-bloom and fruit set stages gave the lowest percentage of shot berries (14.66 %). Abd El-Khalek *et al*. (2024) mentioned that exclusive use of basal leaf removal, whether alone or in combination with low-biuret urea and/or cyanocobalamin, led to a reduction in the percentage of shot berries on 'Prime Seedless' clusters.

Moreover, earlier studies on 'Early Sweet' grape cultivar reported that applying GA_3 at concentrations ranging from 10 to 40 ppm or Sitofex between 2.5 to 10 ppm resulted in a significant reduction in shot berry percentage when compared to vines without treatment, and using GA_3 proved to be more effective than Sitofex in minimizing shot berry percentage (Abada *et al*., 2015). Also, application of GA_3 spray resulted in an approximate 77.26% reduction in shot berries of 'Early Sweet' grape clusters (El-Salhy *et al*., 2019). Applying plant growth regulators along with cluster-tipping proved to be an effective method for improving 'Early Sweet' cluster uniformity by reducing the proportion of shot berries per cluster (Bedrech and Farag, 2022). Additionally, Abdel Hameed *et al*. (2023) found that shot berries percentage in the clusters of "Superior" grapevines sprayed with GA_3 at concentrations (10, 20, and 40 ppm) at the pea stage, "6 mm" was decreased, and the 40-ppm concentration had the lowest shot berry values.

Contrary to the findings, Or *et al*. (2020) highlighted the influence of GA_3 application to 'Early Sweet' clusters on the formation of shot berries. The results show that applying GA_3 to Early Sweet clusters either two weeks before anthesis or at anthesis leads to intense formation of shot berries. The severity of this effect is concentration-dependent, with 30 ppm GA_3 producing significantly more shot berries than 10 ppm. Notably, the higher concentration also resulted in smaller-sized shot berries. Additionally, they observed that inflorescences with fewer flowers exhibited significantly lower shot berry formation compared to those with a higher flower load, even under identical GA_3 treatments, as the initial flower load increased, so did the percentage of shot berries in clusters treated with GA_3.

Effect on berry chemical characteristics:

Data presented in Table 3 indicate that both GA_3 and urea applications affected SSC, acidity, and SSC/acid ratio in the berry juice of 'Early Sweet' grapevines during the 2021 and 2022 seasons. The untreated control exhibited the highest SSC/acid ratio and SSC values and the lowest acidity across both seasons, while combined GA_3 and urea treatments generally resulted in slightly lower SSC/acid ratios due to a moderate increase in juice acidity. Among the treatments, GA_3 applied at multiple concentrations (1–10–20 ppm) with urea (0.5 g/L) produced balanced SSC and acidity values, whereas high concentrations of GA_3 tend to increase acidity and reduce SSC/acid ratio.

Table 3. Effect of GA_3 and urea on soluble solid content (SSC), Acidity, and SSC/acid ratio in berry juice of 'Early Sweet' grapevines during 2021 and 2022 seasons.

Treatments	SSC (%)		Acidity (%)		SSC/acid ratio	
	2021	2022	2021	2022	2021	2022
T1	16.50^{a}	15.50^{a}	0.387^{d}	0.393^{b}	42.67^{a}	39.47^{a}
T2	15.07^{c}	15.37^{a}	0.398^{c}	0.393^{b}	38.27^{b}	39.47^{a}
T3	15.10^{c}	15.30^{ab}	0.425^{a}	0.417^{a}	35.53^{c}	36.77^{b}
T4	16.07^{b}	15.23^{ab}	0.411^{b}	0.416^{a}	39.07^{b}	36.63^{b}
T5	15.97^{b}	14.97^{b}	0.424^{a}	0.419^{a}	37.60^{b}	35.70^{b}

Values in the same column sharing identical letters are not significantly different using Duncan's Multiple Range Test at 5% probability. T1) control, spraying only with tap water; T2) spraying with 1 ppm gibberellic acid (GA_3) and 0.5g/L low biuret urea twice during full bloom and at 25% fruit set; T3) same as T2 plus spraying with 10 ppm GA_3 at 7-8 mm berries diameter; T4) same as T2 plus spraying with 10 ppm GA_3 and 20 ppm GA_3 at 7-8 mm and 10-12 mm berries diameter respectively; T5) same as T2 plus spraying with 20 ppm GA_3 at 10-12 mm berries diameter.

There was agreement between these results and those of Elatafi *et al.* (2022) on Sultana 'H4 strain'; Abdel Hameed *et al.* (2023) on 'Superior' and Li *et al*. (2024 b) on 'Shine Muscat' grapes, they reported that GA_3 significantly increased both berry weight and volume, suggesting that the concentrations of compounds like sugars and acids may have been influenced by a dilution effect resulting from berry enlargement. Contrarily, Elgendy *et al*. (2012) observed that applying GA_3 at a concentration of 40 ppm enhanced the quality of 'Thompson Seedless' grape berries by raising SSC and the SSC/acid ratio and decreasing acidity. It can be said that GA_3 effects depend strongly on cultivar, phenological timing of application, number of sprays, and application method.

Chlorophyll and carotenoids significantly influence the coloration of white grape berries. The data presented in

Figure 2 clearly demonstrate that the application of GA_3 and urea significantly influenced the total chlorophyll and total carotenoid concentrations in the berry skin of 'Early Sweet' vines during the seasons of 2021 and 2022. The highest chlorophyll concentration was observed in treatment T_4 (GA_3 at 1–10–20 ppm + urea at 0.5 g/L), which differed significantly from the other treatments. This indicates that sequential GA_3 applications in combination with urea effectively enhanced chlorophyll biosynthesis or delayed chlorophyll degradation in berry skin. Conversely, the control treatment (T_1) exhibited the lowest chlorophyll concentration, while intermediate levels were recorded in T_2, T_3, and T_5. The highest carotenoid levels were observed in the control treatment (T_1), which differed significantly from all GA_3-treated vines. Increasing GA_3 concentration, particularly in treatments T_4 (1–10–20 ppm + urea) and T_5 (1–20 ppm + urea), led to a marked decline in carotenoid concentration. This reduction may be attributed to GA_3-induced delays in berry ripening or pigment degradation processes that alter carotenoid accumulation.

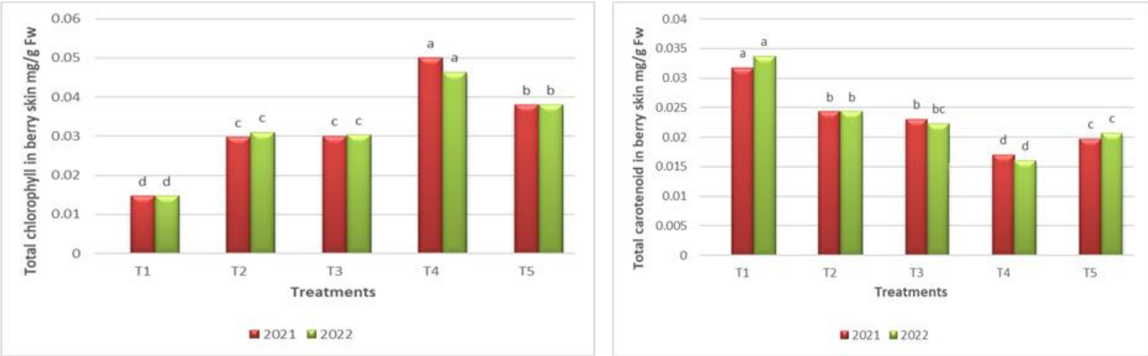

Fig. 2. Effect of GA_3 and urea on total chlorophyll and total carotenoid in berry skin (mg/g FW) of 'Early Sweet' grapevines during 2021 and 2022 seasons. Means in the same column that have different lower-case letters are significantly different according to the Duncan's multiple range test ($P \leq 0.05$).

T1) control, spraying only with tap water; T2) spraying with 1 ppm gibberellic acid (GA_3) and 0.5g/L low biuret urea twice during full bloom and at 25% fruit set; T3) same as T2 plus spraying with 10 ppm GA_3 at 7-8 mm berries diameter; T4) same as T2 plus spraying with 10 ppm GA_3 and 20 ppm GA_3 at 7-8 mm and 10-12 mm berries diameter respectively; T5) same as T2 plus spraying with 20 ppm GA_3 at 10-12 mm berries diameter.

In general, the coloration of plant tissues is dependent on the concentrations of chlorophyll and carotenoid pigments. For grapes with yellow-green skin, chlorophyll and carotenoids are the primary factors that affect the color of the berry skin, with chlorophyll exerting a more dominant effect than carotenoids (Lancaster *et al*., 1997). As the ripening process advances, the skin of white grape berries clearly changes colour from green to yellow. The amounts and relative ratios of carotenoids and chlorophylls, along with melanin-like pigments and the byproducts of their breakdown, significantly influence the final colour (Rustioni *et al*., 2015). Additionally, carotenoid levels declined throughout berry development (Rocchi *et al*., 2016). Results agree with the previous studies of Suehiro *et al*. (2019), as they showed that GA_3 and cytokinin treatments both led to an increase in chlorophyll concentration in the berry skin of 'Shine Muscat' grapes, as chlorophyll was less decomposed. Consequently, the berry skin retained a greenish color throughout the maturation phase.

CONCLUSION

From this study, application of GA_3 along with urea positively enhanced yield, cluster weight, as well as berry weight and diameter of 'Early Sweet' grape cultivar, while simultaneously decreasing the percentage of shot berries compared to the untreated control. The most significant reduction occurred in T4 (1–10–20 ppm + urea at 0.5 g/L), where GA_3 was applied at three critical phenological stages: full bloom, early fruit set, and berry sizing. However, while GA_3 and urea improve physical berry traits, they often lower SSC and increase acidity, leading to a lowered SSC/acid ratio. Among the treatments, GA_3 applied at multiple concentrations (1–10–20 ppm) together with urea (0.5 g/L) significantly recorded the highest chlorophyll concentration in berry skin, which coincided with a significant reduction in carotenoid level, possibly enhancing berry color development and postponing senescence. Overall, the data highlight that multiple applications of GA_3 concentrations, alongside urea, can effectively minimize shot berry formation and improve vine performance and yield components in 'Early Sweet' grapevines.

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تأثير رش كروم العنب صنف "إيرلي سويت" بحمض الجبريليك واليوريا في تقليل نسبة الحبات الصغيرة وتحسين المحصول وجودة العناقيد

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الملخص

يُعَدّ ظهور الحبات الصغيرة (Shot berries) في صنف العنب "إيرلي سويت" من أهم المشاكل التي تؤثر سلبًا على إنتاجية الكرمة وجودة العناقيد، مما يجعل من الضروري إيجاد معاملات فعالة لتقليل انتشار هذه الظاهرة وزيادة المحصول. أجريت هذه الدراسة في المزرعة البحثية التابعة لمعهد بحوث البساتين، المنصورة، مصر باستخدام تصميم القطاعات الكاملة العشوائية بثلاث مكررات خلال موسمي 2021 و ٢٠٢٢ المتتاليين. شملت التجربة خمس معاملات كما يلي: المعاملة T1 الكنترول :(الرش بالماء فقط)، المعاملة :T2 الرش بمحلول يحتوي على ١ جزء في المليون من الجبريللين (GA_3) و٠,٥ جم/لتر يوريا منخفضة البيوريت مرتين، الأولى عند التزهير الكامل والثانية عند مرحلة عقد الثمار بنسبة ٢٥% ، المعاملة :T3مثل المعاملة T2 بالإضافة إلى الرش بـ١٠ جزء في المليون جبريللين عند وصول قطر الحبة إلى ٧–٨ مم ، المعاملة :T4 مثل المعاملة T2 بالإضافة إلى الرش بـ١٠ جزء في المليون جبريللين عند قطر ٧–٨ مم و٢٠ جزء في المليون جبريللين عند قطر ١٠–١٢ مم ، المعاملة :T5 مثل المعاملة T2 بالإضافة إلى الرش بـ٢٠ جزء في المليون جبريللين عند قطر ١٠–١٢ مم. أظهرت النتائج أن الرش بالجبريللين مع اليوريا في مراحل النمو المختلفة أدى إلى تحسين معنوي في محصول العنب وجودة الحبات مقارنةً بمعاملة الكنترول، ومع ذلك، فإن معاملات الجبريللين واليوريا خصوصاً عند التركيزات (10–1) جزء في المليون و (20–1) جزء في المليون أدت إلى زيادة في الحموضة وانخفاض طفيف في محتوى المواد الصلبة الذائبة (SSC)ونسبة SSC /الحموضة. ومن بين جميع المعاملات تميزت المعاملة T4 بأنها حققت أقل نسبة حبات صغيرة في العناقيد إلى جانب زيادة معنوية في المحصول، ووزن العنقود، ووزن الحبة، وقطرها، وتركيز الكلوروفيل الكلي في قشرة الحبة، مع انخفاض في تركيز الكاروتينات الكلية في القشرة.