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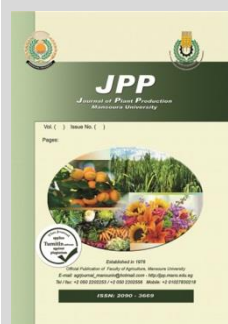
Early Marketable Yield and Better Berry Skin Color of 'Redglobe' Grapevines Cultivar Grown under Warm Climate by Application of Sulis®

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ABSTRACT

Coloration of red grapes under high temperature and narrow day/night temperature range conditions is a great challenge. The aim of the investigation was to test the effect of Sulis® fertilizer which has recently commercially released in Egypt on the color of 'Redglobe' grapes. In 2018, the treatments were water (control), 1 ml L⁻¹ Sulis®, or 2 ml L⁻¹ Sulis®. 'Redglobe' berries were darker red color due to Sulis® treatments, with no different effect between both Sulis® concentration. While, The 2019 treatments were water (control), 150 mg l⁻¹ ABA + 250 mg l⁻¹ Ethephone, 1 ml L⁻¹ Sulis®+ 250 mg l⁻¹ Ethephone, or 1 ml L⁻¹ Sulis®. During both seasons, the treatments gave the same effect on physical berry characteristics. The bunches sprayed with ABA or Sulis®+ethephone were harvested 10 days earlier than those treated with Sulis® alone, and 20 days earlier than the control clusters. The treatments gave higher packable yield percentages at first pick harvest and SSC/TA ratio than the control. *L**, *a**, *b**, *C** and *h°* of berry color traits were decreased due to the treatment applications. Sulis®+ethephone and Sulis® treatments increased the red color index and anthocyanin content in berry skin than the control treatments. Sulis® fertilizers is promising as a coloring agent in grapevines cultivation.

Keywords: Redglobe, Grapes color, Ethephon, Sulis®, Berry Skin

INTRODUCTION

Grapevines (*Vitis vinifera* L.) are the second major fruit crop in Egypt, after citrus. Red colored grapes are not only desired because of their attractive color, but also they have anthocyanins, which have potential effects on human health (He *et al.*, 2010; Miao *et al.*, 2016). Coloration of red grapes, however, is facing challenges which affect its color uniformity in within berries and cluster (Gargin and Altindisli, 2015). One of the biggest challenges is regional weather conditions, including high temperature, and narrow day/night temperature range (Spayd *et al.*, 2002; Ferrara *et al.*, 2013). Temperature of 30°C inhibits anthocyanin accumulation (Spayd *et al.*, 2002). Lack of coloration for red tables grapes due to high temperature during harvest time has been noticed in several countries, Australia, USA, Italy, Brazil, and China (Cameron, 2001; Brar *et al.*, 2008; Ferrara *et al.* 2013; Lo'ay 2017; Scavroni *et al.*, 2018; Shahab *et al.*, 2019; Deng *et al.* 2019). Under these conditions, Total soluble Solid percentage in berries might reach to commercial level (14-16 Brix) without suitable color appearance (Lurie *et al.*, 2009). The same climate patterns are in Egypt (Omran 2011; Lo'ay 2017). Temperature rising (global warming) is likely to continue (Agrawala *et al.*, 2004), making proper coloration of red grapes is more difficult. In Minia governorate region, where the study has taken place, has similar properties of continental climate during summer times, the weather is very hot where the temperature could reach 37.7 °C (Attia, 1974).

'Redglobe' grapevines are widely planted due to their favorite berry characteristics; large size, firm texture, and uniform red color (Peppi *et al.* 2007a). Harvest of 'Redglobe' grapes in Minia governorate is earlier than the northern part of Egypt. This situation gave a great opportunity to the grower to earn better money. But, fulfillment of commercial standard

coloration, under recently recorded high temperature, is a big challenge (Omran 2011).

Anthocyanins are plant pigments responsible for red color of table grapes (Roberto *et al.*, 2013). High temperature negatively affects anthocyanin accumulation in grape berry skin (Spayd *et al.*, 2002). Subsequently, economic values of table grapes are dramatically decreased (Peppi *et al.* 2006; Cantín *et al.*, 2007).

Exogenous application of Plant growth regulators, in particular ethephone (2-Chloroethylphosphonic acid) and Abscissic (ABA), are greatly responsible to obtain higher anthocyanin content in berry skin of red grapes as suggested by Several studies (El-Kereamy *et al.*, 2003; Mailhac and Chervin 2006; Peppi *et al.*, 2006, 2007a,b; Cantín *et al.*, 2007; Lauri *et al.*, 2009; Ferrara *et al.*, 2013;; Roberto *et al.*, 2013; Leão *et al.*, 2015; Yamamoto *et al.*, 2015; Olivares *et al.*, 2017; Scavroni *et al.*, 2018; Deng *et al.*, 2019). But, Application of ethephone results in berry softening which is not desirable trait (Szyjewicz *et al.*, 1984; Peppi *et al.*, 2007a; Peppi and Fidelibus 2008; Roberto *et al.*, 2013). In addition, the high cost of ABA is un-acceptable practice (Peppi *et al.* 2006). Therefore, Alternative applications for both PGRs have been suggested, like brassinosteroids (Luan *et al.* 2013), methyl jasmonate (Ju *et al.* 2016), 2,4-epibrassinolide (Liu *et al.*, 2016), pectin-derived oligosaccharides (Villegas *et al.*, 2016), Sugars (Olivares *et al.*, 2017) and cyanocobalmin (Lo'ay 2017). Moreover, stimulant Fertilizers which have the influence in enhancement berry coloration, were recently gaining favor like Potassium sources (Strydom 2014), Kaolin foliar fertilizer (Conde *et al.* 2016), and algae extract (Deng *et al.* 2019).

The goal of this study was to evaluate the effect of Sulis®, a recently introduced fertilizer in Egypt, on

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marketable yield at first pick, berry physical, chemical, and color characteristics, and anthocyanin content in berry skin of 'Redglobe' grapes.

MATERIALS AND METHODS

Plant Material and Experimental Design

The study was carried out on uniformed Six-years-old 'Redglobe' grapevines (*Vitis vinifera* L.) grafted onto 'Freedom' rootstock, in a commercial table grape vineyard located at Abu Qorqas district on the western desert road ((27°57'32" N; 30°33'39" E, Minya, Egypt), typically subtropical zone. The vineyard production was annually devoted for exportation, where the soil was classified as sandy soil, drip irrigated with two drip lines, drippers were 0.5 m apart with volume of 4l/h, and water EC was 500 ppm. Vines were spaced 2 X 3 m, trained with short cane (6 eyes) pruning on barron's supporting system. The vineyard was performed standard practices in the area, GA₃ was applied at concentration of 1 ppm for berry thinning (full bloom), and 12 ppm for berry sizing at 6-8 mm, cluster thinning was carried out by removing of 40 % of cluster tip skeleton at berry size 2-3 mm and number of clusters/vine was adjusted to 30 ± 2 clusters. All local recommended vineyard practices were done including fertilizer additions, pest control, canopy management, and other operations.

2018 Experiment

A complete randomized block design was used with three blocks and three treatments, three grapevines were used per each replicate. The treatments were as follow: water (control), 1 ml L⁻¹ Sulis®, or 2 ml L⁻¹ Sulis®. All treatments were applied two times with 7 days interval, starting at the beginning of *véraison* (15% of berries on at least 50% of the experimental clusters had begun to soften, Peppi *et al.*, 2007a) at the first week of June in 2018. The treatments were directly applied to clusters with a handled sprayer until runoff, after adding Surfactant (250 mg L⁻¹, Triton B) to all sprays. Sulis® is a proprietary mixture containing Molybdenum (Mo) 50 g L⁻¹ and Boron (B) 8 g L⁻¹ (Levity Crop Science, Preston, PR3 0RY, UK) (<https://news.levitycropscience.com/sulis/>).

Only commercial acceptable bunches were harvested when soluble solids content SSC ≥ 14° Brix. Five bunches from each replicates were picked to evaluate the quality parameters. The three replicates of 20 berries were randomly chosen for measuring physical, color, and chemical characteristics. The physical properties of berries (weight (g), length (mm), and diameter (mm), were measured (Jensen *et al.*, 1975). The berry color was analyzed using a colorimeter (ColorTec-PCM™, Inc. Pittsford, New York, USA) from berry equator; the values of L*(luminosity), a*, and b* were obtained by direct detection, all berries were washed by clean cotton before testing. The values of C* (chroma) and h° (hue angle) were calculated; $C^* = [a^{*2} + b^{*2}]^{1/2}$, and $h^\circ = \arctan(b^*/a^*)$. Then, the color index of red grapes (CIRG) was determined according to a formula: $CIRG = [(180 - h^\circ)/(L^* + C^*)]$ (Carreño *et al.*, 1995).

2019 Experiment

According to the 2018 results, the lower concentration of Sulis® (1 ml L⁻¹) was used for further investigation. A complete randomized blocks design was used with four blocks and four treatments, five grapevines were used per each replicate. The 2019 experiment was conducted in the

same vineyard, and consisted four treatments; water (control), 150 mg l⁻¹ ABA + 250 mg l⁻¹ Ethephone (the recommended farm application), 1 ml L⁻¹ Sulis® + 250 mg l⁻¹ Ethephone, or 1 ml L⁻¹ Sulis®. the treatments were applied as the same way done in 2018.

ABA source was ProTon® (10g L⁻¹ S-ABA, Valent BioSciences Corporation, Libertyville, IL, USA). Ethephone was from Ethrel® (480 g L⁻¹ Ethephone, Bayer Crop Science, Research Triangle Park, NC).

All characteristics detected in 2018, were measured in 2019 in the same way. The yield/vine, cluster number, and cluster weight were recorded. Marketable yield percentages at first pick were calculated according [(yield (kg) per vine at first harvest time divided to total yield (kg) per vine, and then multiplied by 100], Marketable yield was characterized with commercial standard SSC% > 14 % and acceptable skin color (Berry size is not changed since the berry SSC % reached the commercial standard level). For chemical properties of berries testing, the juice of 10 berries were extracted by hand with cheesecloth. Soluble solids contents (SSC) was measured and expressed as °Brix, using a digital table refractometer, titratable acidity (TA) was determined by titration with 0.13N NaOH, using 5 ml of diluted juice and expressed as g tartaric acid 100 mL⁻¹ juice. Then, the relationship between SSC and TA ratio was calculated. For measuring total anthocyanin, 5 berries from each cluster randomly selected, 10 mm-diameter skin disk from each berry was removed carefully without any pulp. The samples were rinsed with tap water, then with deionised water. The skin disks were dried with paper towels. The samples were incubated with 99% methanol [10% (v/w) skin fresh weight (FW)] and extracted in the dark at room temperature for 48 h. After removing the samples from dark, they were mixed for 5 s, then a 2 ml aliquot was acidified with 1% (v/v) HCl to adjust the pH to 1.5 for maximum anthocyanin absorption (Peppi *et al.* 2006). The sample absorption was measured at 520 nm using a spectrophotometer (Perkin-Elmer, LAMBDA 2). Total anthocyanins were expressed as mg cm⁻² of skin (Peppi 2004).

Statistical analysis: the differences between the treatment means in 2018 and 2019 seasons were evaluated by the analysis of variance (ANOVA), and significant differences were subjected to Duncan's multiple range test at P < 0.05 (according to Mead *et al.*, 1993). All the data analysis was performed with MSTATC software.

RESULTS AND DISCUSSION

2018 Experiment

2018 experiment was designed to stand out the effect Sulis® on 'Redglobe' grapes quality with preliminary results. The clusters in season 2018 were harvested when SSC reached to marketable level; Sulis® treatments gave higher SSC values than the control (Data not shown). Table 1 presents two different characteristic groups of 'Redglobe' berries, physical and coloration in 2018. All berry physical characteristics including weight, length, and diameter values were not significantly differed among the treatments. Data shown in Table (1) declare that treatments of Sulis® at 1 ml L⁻¹ had similar effects in all chromatic parameters, comparing with treatment of Sulis® at 2 ml L⁻¹. On the other hand, Sulis® treatments did significant effect in berry skin color parameters (a*, b*, L*, C*, h° and CIRG) compared with

control treatment (Table 1). The values of C* and h° of berry color parameters (7.77 and 18.77, respectively) were lower than clusters treated with Sulis® 1 ml L⁻¹ than those treated with control (8.39 and 21.80, respectively). Thereby, the color of cluster berries that received Sulis® 1 ml L⁻¹ application were darker red-color than those received the control treatment. Sulis® 1 ml L⁻¹ application increased CIRG value

(3.81) with remarkable effect than the CIRG value (3.42) obtained from control treatment. These results confirmed that the treated grapes with Sulis® were darker red-color than untreated. The same treatments were applied to ten-year-old own-rooted ‘Redglobe’ grapevines grown in clay loam soil in 2018 season. The results had the same trends as data represented in this article (data not shown).

Table 1. The effect of Sulis® concentrations on berry physical and color characteristics of ‘Redglobe’ grapes in 2018.

Treatments	Berry physical			Berry color					
	weight (g)	length (mm)	diameter (mm)	a*	b*	L*	C*	h°	CIRG
Control	12.1 ^a	2.7 ^a	2.5 ^a	7.8 ^a	3.1 ^a	37.85 ^a	8.40 ^a	21.82 ^a	3.42 ^b
Sulis® 1 ml L ⁻¹	11.9 ^a	2.7 ^a	2.5 ^a	7.3 ^b	2.5 ^b	34.60 ^b	7.73 ^b	18.78 ^b	3.81 ^a
Sulis® 2 ml L ⁻¹	12.2 ^a	2.6 ^a	2.4 ^a	7.2 ^b	2.4 ^b	34.70 ^b	7.60 ^b	18.27 ^b	3.82 ^a

Means followed by different higher-case letters within a column are significantly different according to Duncan’s multiple range test ($P \leq 0.05$).

Table 2. Effect of the treatments on the yield properties and berry physical characteristics of ‘Redglobe’ grapes in 2019.

Treatments	yield/vine (kg)	Yield properties			Berry physical characteristics		
		cluster weight (g)	marketable yield at first pick (Kg)	marketable yield at first pick (%)	weight (g)	length cm	diameter cm
Control	30.50 ^a	984 ^a	3.1 ^c	10 ^c	12.3 ^a	2.9 ^a	2.7 ^a
ABA+ethephone	30.60 ^a	1020 ^a	7.4 ^a	24 ^a	12.0 ^a	2.8 ^a	2.6 ^a
Sulis®+ethephone	30.89 ^a	936 ^a	6.8 ^a	22 ^a	11.7 ^a	2.6 ^a	2.5 ^a
Sulis®	29.52 ^a	984 ^a	4.8 ^b	16 ^b	12.0 ^a	2.8 ^a	2.6 ^a

Means followed by different higher-case letters within a column are significantly different according to Duncan’s multiple range test ($P \leq 0.05$).

2019 Experiment

The clusters were sprayed with a mixture of ABA or Sulis® +ethephone reached to the marketable quality at 8 of June 2019. The mixture treatments clusters were harvested 10 days earlier than those treated with Sulis® alone (18 of June 2019), and 20 days earlier than the control clusters (28 of June 2019). It means that clusters sprayed with Sulis® 1 ml L⁻¹ were harvested in 10 days earlier than those sprayed with the check treatment. Data shown in Table (2) declared that all treatments gave similar results in yield/vine and individual cluster weight in comparison with the control.

Marketable yield was weighted at the first pick time for each treatment and later after finishing the harvest, then the percentages of marketable yield at first harvest time was calculated. All treatments showed significant differences in percentages of packable yield except between ABA+ethephone and Sulis®+ethephone treatments. The highest percentage of packable clusters at first pick was 24% (7.4kg) obtained from grapevines received ABA+ethephone, followed by 22% (6.8kg), and 16% (4.8kg) obtained from those received Sulis®+ethephone and Sulis®, respectively. While the lowest percentage of packable clusters was 10% (3.1kg) for grapevines treated with control.

On the other hand, Treatments did not significantly affect the berry physical characteristic, including berry weight, berry length, and berry diameters in 2019, although slightly decreases in their values comparing with the control (Table 2).

Table 3. Effect of the treatments on berry chemical characteristics of ‘Redglobe’ grapes in 2019.

Treatments	SSC	TA	SSC/TA
Control	15.5 ^c	0.559 ^a	27.73 ^c
ABA+ethephone	17.0 ^a	0.437 ^c	38.90 ^a
Sulis®+ethephone	16.8 ^a	0.445 ^c	37.75 ^a
Sulis®	15.9 ^b	0.516 ^b	30.81 ^b

Means followed by different higher-case letters within a column are significantly different according to Duncan’s multiple range test ($P \leq 0.05$).

SSC, TA, and SSC/TA were affected by treatments as shown in Table 3. The highest values of SSC % and SSC/TA (17.0 and 38.90), respectively, were recorded with application of ABA+ethephone, the similar effect was obtained from Sulis®+ethephone application. Sulis® spray had a significantly higher effect on SSC and SSC/TA than the control. On the other hand, the highest TA values were obtained from control treatment, followed in order by Sulis®, Sulis®+ethephone, and ABA+ethephone (Table 3).

Table 4. Effect of the treatments on berry color characteristics and Anthocyanins content of ‘Redglobe’ grapes in 2019.

Treatments	Berry color characteristics						Anthocyanins mg cm ² skin
	L*	a*	b*	C*	h°	CIRG	
Control	37.93 ^a	8.2 ^a	3.2 ^a	8.81 ^a	21.33 ^a	3.40 ^c	0.0075 ^b
ABA+ethephone	35.44 ^c	6.7 ^c	1.9 ^c	6.97 ^c	15.87 ^c	3.87 ^a	0.0186 ^a
Sulis®+ethephone	34.95 ^c	6.9 ^c	2.0 ^c	7.18 ^c	15.82 ^c	3.90 ^a	0.0172 ^a
Sulis®	36.06 ^b	7.3 ^b	2.3 ^b	7.68 ^b	17.49 ^b	3.72 ^b	0.0113 ^b

Means followed by different higher-case letters within a column are significantly different according to Duncan’s multiple range test ($P \leq 0.05$).

L* , a* , b* , C* , and h° of berry color traits were significantly decreased due to the treatment applications, compared with those recorded from control berries as represented in table 4. Both mixture treatments

ABA+ethephone and Sulis®+ ethephone showed the same effect on those traits, and had lower values than those of Sulis® and control treated berries. Sulis® treated berries had significant less lightness (L*); means darker, and less hue

angle h° (more redness), than control treated berries as found in 2018 season. The color index of red grapes (CIRG) is used to show the effect of treatments the color of full ripe grapes. There were significant differences among the treatments in CIRG, confirming that ABA or Sulis® +ethephone resulted in larger values (3.87 and 3.0, respectively) than Sulis® (3.72) and control (3.40). Sulis® application increased CIRG values significantly than the control. These results (Table 4) declared that berries treated with ABA+ethephone and Sulis®+ethephone were darker red-color than other treatments. While, Sulis® treatment resulted in darker red-color berries than the control.

The data in table 4 showed the effect of the treatments on berries anthocyanin contents. Grapes treated with ABA or Sulis® +ethephone had the highest values of anthocyanins content (0.0186 and 0.172 mg cm² skin, respectively), with no significant effects between both treatments. The lowest value of total anthocyanins (0.0075 mg cm² skin) was obtained from bunches treated in control vines, surpassed significantly with those treated with Sulis® (0.0113 mg cm² skin).

Discussion

Sulis® has been recently introduced in Egypt as a fertilizer which enhances fruit colors with registration number of 8743 in Nov., 2017, via United Group for Agricultural Import, Export, Trading and development Co. (Tokh ElKhal, 61-725 Minia, Egypt).

The trial in 2018 was a pre-experiment to stand out the effects of Sulis® on 'Redglobe' grape berries. Sulis® application did not affect berry physical parameters studied in 2018 season. On the other hand, Sulis® application resulted in darker red-color in berries than control. In all investigated traits in 2018, there were no significant differences between both concentration of Sulis® at 1 ml L⁻¹ or 2 ml L⁻¹, thereby, concentration of Sulis® at 1 ml L⁻¹ was selected for a further study in 2019.

The special formulation in Sulis® (5 % Mo, 0.8 % B) helps fruit build better levels of colour and brix to allow earlier picking (<https://news.levitycropscience.com/sulis/>). Effect of Mo and B studies was previously focused on their effects on berry sitting and yield of grapevines, and they were applied before *véraison* (Williams *et al.*, 2004; Longbottom *et al.*, 2010; Masi and Bosli 2011; Batukaev *et al.*, 2016; Ekbic *et al.*, 2018). Sulis® activates the plant's natural process of maturity, whilst ensuring these key nutrients in the process are available. It promotes the processes of maturation that are normally triggered by the hormone ABA (<https://news.levitycropscience.com/sulis/>). Thereby, Sulis® increases the effects of endogenous S-ABA and acts as a plant growth regulator (<https://news.levitycropscience.com/sulis/>). The hormone ABA might be responsible to anthocyanin accumulation in grape berry skin (Lee *et al.*, 1979; Tomana *et al.*, 1979).

In 2019, the experiment design contained four treatments, of which S-ABA+ethephone treatment is the vineyard recommended application. Since Sulis® encourages the effects of endogenous ABA, one of the treatments designed from Sulis®+ethephone in order to compare its effect with the vineyard recommended application.

Yield, cluster weight, berry physical (weight, length, and diameter), in 2019 season, were not significantly different between the PGRs treatments and control. Yield and cluster

weight is mainly depending on berry weight. The results of berry weight were in similar to noticed by Peppi *et al.* (2007a), Omran (2011) and Deng *et al.* (2019) for 'Redglobe', Peppi *et al.* (2007b), Peppi and Fidelibus (2008), Lurie *et al.* (2009) and Ferrara *et al.* (2013) for 'Crimson Seedless' grapes, and Kishino and Roberto (2007) for 'Rubi' grape, when they applied PGRs. These results, however, were in disagreement with those reported by Peppi *et al.* 2006 in 'Flame Seedless', Koyama *et al.* (2014) for 'Isabel' and Neto *et al.* (2017) for 'Rubi'. These results might be related to ABA may regulate berry composition rather than fruit growth (Düring *et al.*, 1978; Kataoka *et al.* 1982; Matsushima *et al.*, 1989).

Starting harvest, however, was earlier with Spraying PGRs than control, and increased the ratio of marketable yield at the first harvest date. In Egypt, the exportation for Redglobe grapes is so narrow, The applications which result in an earlier harvesting with a bigger amount of marketable yield increase the outcomes for the growers who dedicated their yield for exportation. There were similar results detected from ABA+ethephone or Sulis®+ethephone. These results were similar to obtained from application of PGRs (Düring *et al.*, 1978; Lee *et al.* 1997; Peppi *et al.* 2006, 2007b; Cantín *et al.* 2007; Lauri *et al.* 2009; Ferrara *et al.*, 2013, 2015).

The marketable of SSC and SSC/TA ratio were accomplished earlier in vines treated with Sulis®, ABA and ethephone. SSC and SSC/TA ratio were higher due to the application of PGRs. TA, however, was less in treated vines than control. The lowest results were obtained from application ABA+ethephone and Sulis®+ethephone. Increasing SSC and SSC/TA and reducing TA of table grapes due to application of ethephone plus ABA were previously reported by Peppi *et al.* (2006). Higher sugar accumulation for 'Cabernet Sauvignon' grapes with application of ethephon, due to released ethylene leads to the expression of genes encoding sucrose transporters, resulting in higher sucrose translocation from biosynthesis sites to the berry vacuole, in which sucrose is enzymatically converted into glucose and fructose (Chevrin *et al.* 2006). In addition, Sulis® at 1 ml L⁻¹ application was accompanied with higher level of SSC and Lower TA. These results might be due to Sulis® is responsible for increasing the endogenous ABA in berries. Increasing ABA level in berries during ripening stages was recorded by Coobe and Hale, (1973), Coombe (1976) and Düring *et al.* (1978).

L^* , a^* , and b^* values of PGRs treated-berries were less than the control. The conversion of these L^* , a^* , and b^* to lightness, chroma, and hue shows into lower lightness and hue values and in general. Reductions of L^* , C^* and h° in grape skin, due to application of ABA, ethephone or both together, were previously observed by Kim *et al.* (1998), Peppi *et al.* (2006); Lurie *et al.* (2009), Omran (2011), Ferrara *et al.* (2013), and Olivares *et al.* (2017) . But, Cantín *et al.* (2007) found that h° and L^* values were not differed than the control when ABA or ethephone were applied. A reduction of both lightness and purity of color and the reduction of h° indicates on promotion of a more red-color development of berry skin (Peppi *et al.*, 2007a).

Color index for classifying red grape berries (CIRG) were confidential applied (Carreño *et al.*, 1995; Fernández-Lopez *et al.*, 1998). CIRG values in this trail were increased with the treatments, weather the treatment included Sulis®

alone or with ethephone, or ABA with ethephone. The same results were obtained when ABA was sprayed (Kim *et al.*, 1998; Omran 2011; Olivares *et al.*, 2017). On the other hand, ABA application did not affect CIRG as reported by Cantín *et al.* (2007); Roberto *et al.* (2013). Any way the berries considered as pink-colored between 2 and 4 CIRG (Carreño *et al.* 1995), all previously reported values of CIRG for 'Redglobe' grapes were within this range (Peppi *et al.*, 2007a; Omran 2011; Mekawy and Ahmed 2018; Deng *et al.*, 2019).

Anthocyanin is the most important natural colorants in grapes (He *et al.* 2010). Skin anthocyanin concentrations had a pronounced effect on L^* and h° of the berries, especially at low pigment concentration. Application of ethephone plus ABA or Sulis® increased the red-color in berries, as well as anthocyanin content. It was well confirmed that ethephone increases the anthocyanin content in berries skin (Chervin *et al.* 2006; Peppi *et al.*, 2006; Cantín *et al.*, 2007; Scavroni *et al.* 2017). The increase of anthocyanin content in berry-treated ethephone is thought to be related to the higher ethephone-induced endogenous ethylene production which leads to the transcription of genes encoding important enzymes from the biosynthetic pathway involving these pigments such as PAL, CHS, UDP, GST (Sudha and Ravishankar 2003; Chervin *et al.* 2006; Scavroni *et al.* 2017). Exogenous ABA improved grape coloration in respect of increasing anthocyanin content (Peppi *et al.*, 2007a and Deng *et al.*, 2019 on 'Redglobe'; Reberto *et al.*, 2013 on 'Rubi'; Cantín *et al.* 2007 and Peppi *et al.* 2008 'Crimson Seedless'). Peppi *et al.*, 2006 reported that Application of ABA plus ethephone resulted in darker red-color of 'Flame Seedless' grapes. This effect might be related that the exogenous ABA involved with the relative expressions levels of genes in the anthocyanin biosynthesis, either at particular stages or throughout the fruit ripening process (Gagné *et al.*, 2011; Koyama *et al.*, 2018; Deng *et al.*, 2019). Sulis® fertilizer with its special formulation increases the endogenous ABA level in berries during ripening period; this might be the same effect like exogenous application of ABA as reported by Ferrara *et al.* (2013) who found that the exogenous ABA increases the level of endogenous ABA level. This could explain why ABA+ethephone treatment did the same effect as Sulis®+ethephone.

Ethephone plus ABA or Sulis® had similar effects in all studied traits. Exogenous ABA application per acre costs about 500 \$, while Sulis® application per acre costs 35 \$. It is a great difference related to the cost of exogenous ABA and Sulis® applications per acre.

CONCLUSION

Sulis® fertilizer has recently commercially released in Egypt. Sulis® did generally significant enhancement color of 'Redglobe' grapes grown in Minia governorate which was classified a warm region, and resulted in earlier harvest date with great marketable yield at first harvest date. These effects were better when Sulis® applied along with ethephone. Further studies will be needed to understand physiological effects of Sulis®.

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