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SUGAR ALCOHOL EFFECT ON GRAPES YIELD AND QUALITY

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SUMMARY

The presented experiment on grape (*Vitis vinifera* L.), carried out in the growing season of 2022, transpired in the orchard of the Department of Horticulture and Garden Engineering, College of Agriculture, Tikrit University, Tikrit, Iraq. Two factors comprised the study. The first factor was two grape cultivars, i.e., Halwani and Kamali, while the second involved foliar application of sugar alcohol (mannitol) with three levels (0, 4, and 8 ml L^{-1}). The study aimed to evaluate the grape cultivars, impact of sugar alcohol, and their interaction on the yield characteristics and qualitative traits. The vine plants planting had dimensions of 2 m × 4 m, with the experiment having the split-plot design. The trial included six treatments, randomly distributed into three replicates, with two vines per experimental unit, totaling 36 vine plants. The results showed adding sugar alcohol solution (8 ml L^{-1}) led to a significant enhancement in the number of clusters, cluster weight, total suspended solids, total sugars, total acidity, and anthocyanin content. The grape cultivar Halwani outperformed the other cultivar Kamali for cluster weight, total yield, total sugars, and anthocyanin content, while cultivar Kamali excelled in the number of clusters and total acidity.

Keywords: Grape (*Vitis vinifera* L.), grape cultivars, sugar alcohol, yield quantity, qualitative traits, sugars and anthocyanin content

Key findings: Superiority of the sweet grape (*Vitis vinifera* L.) cultivar Halwani over the non-sweet cultivar Kamali was evident in cluster weight, total sugars, and anthocyanin content. Conversely, the non-sweet cultivar Kamali outperformed the sweet cultivar Halwani for cluster number and total acidity. However, both grape cultivars revealed nonsignificant differences in total suspended solids and yield quantity.

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INTRODUCTION

Grapes (*Vitis vinifera* L.) have become one of the notable horticultural crops, both in Iraq and worldwide. Their cultivation has a very ancient history in Iraq, dating back to the early settlements of the Mesopotamian region (Mustafa *et al.,* 2019). This might be due to the favorable environmental conditions for grape cultivation. The recent years saw grape cultivation developed significantly in Iraq. Grapes hold a prominent position among fruit trees in the world in both acreage and production (Abdullah *et al.,* 2015). The total global grape production reaches 75 million tons, while the estimated grape cultivated area is 75,866 kilometers worldwide (Vander and Chan, 2019).

In Iraq, the area cultivated with grapes is approximately 22,500 hectares, and the estimated grape crop production is around 421.868 ton. In summer fruits production, the grape crop accounts for 49.16% of the total production in Iraq (CSO, 2021). Sugar alcohols, considered carbohydrates, also bore the name alcohol due to their chemical composition. In 1996, grapes reached identified identity as naturally carrying boron. Additional elements within the bark attained the term as Polyols, which form complexes with boron and other elements like Di-sorbitol and sorbitol-boron and borate ester, with a unique technology based on Polyols complexes and nutritional elements as leaf nutrients (Brown and Hu, 1996).

Grapes applied foliarly with mannitol at the concentrations of 0.05% and 0.09%, manifested a significant increase in the total suspended solids and sugars, especially at the concentration of 0.09% (Trinetta *et al.*, 2007). Past studies also revealed spraying with the sugar alcohol (mannitol) at concentrations of 0 and 0.05% resulted in a significant increase in fruit size, the sugar, and acidity content of the grapes (Giorgetti *et al.*, 2013; Al-Obaidat *et al.,* 2016).

Rai *et al.* (2018) concluded in their study using liquid organic fertilizer and spraying with sugar alcohol (mannitol) on grapevines resulted in a remarkable increase in yield, sugar content, fruit acidity, the number of clusters, and cluster weight. In a study conducted by Al-Hasnawi *et al.* (2018) on the effect of spraying grapes with sugar alcohol at a concentration of 0.05%, revealed a notable rise in the yield and quality, as well as some chemical attributes associated with fruit quality. Chung *et al.* (2019) reported the impact of the foliar application of the sugar alcohol on the yield, quality, and chemical properties of table grapes (*V. vinifera*) and observed a substantial escalation in the production, sugar content, and fruit acidity. Ali-Ibrahim *et al.* (2021) investigated the effects of spraying with sorbitol on the strawberry (*Fragaria* x *ananassa* Duch.), and the concentration of 50 g L^{1} provided a significant increase in fruit weight. The presented study aimed to evaluate the grape (*V. vinifera*) cultivars, impact of sugar alcohol, and their interaction on the yield characteristics and qualitative traits.

MATERIALS AND METHODS

The latest grape (*Vitis vinifera* L.) experiment commenced during the growing season of 2022 in the orchard of the Department of Horticulture and Garden Engineering, College of Agriculture, Tikrit University, Tikrit, Iraq. The experiment included two main factors, with the first factor as two grape cultivars, i.e., Halwani and Kamali. Meanwhile, the second factor involved foliar application of sugar alcohol (mannitol) with three levels (0, 4, and 8 mL L^{-1}). The experiment layout followed a split-plot design involving two grapevine cultivars and three levels of ethanol. The grapevines' spraying occurred early in the morning with the addition of a spreading agent. The second spraying ensued one month after the first one, with three factors for each cultivar and three repetitions for each experimental unit for grape cultivars Halwani and Kamali. In the experiment, the total number of grapevines was 36 (2 × 3 × 2 × 3). The physical and chemical characteristics of the soil in the grapevine orchard during the season of 2022 are available in Table 1.

Table 1. Physical and chemical characteristics of the soil in the grapevine orchard.

Principal character	Elements	Unit	Quantity
Sand		%	25.8
Clay		%	26.0
Gray		%	48.2
Ph		-	7.45
Ec		(ds m^{-1})	4.20
Soluble cations and anions (m L^{-1})	CA^{+}	g L^{-1}	266
	MG^{+}	g L^{-1}	121
	NA	g L^{-1}	324
	K	g L^{-1}	17
	CL	g L^{-1}	602
	SO_4	g L^{-1}	570
	HCO_3	g L^{-1}	260
	CO_3	g L^{-1}	12
	NO_3	g L^{-1}	15
	PO_4	g L^{-1}	0.46
Sodium absorption rate		-	4.10
Available nitrogen		g L^{-1}	49
Available phosphorus		g L^{-1}	6.8
Available potassium		g L^{-1}	123
Organic matter M. O		%	1.10
Calcium carbonate (lime)		%	29.7
Cation exchange capacity (CEC)		Centmol (soil kg^{-1})	11.6

Data recorded

Yield characteristics

The data recorded consisted of the number of clusters per each grapevine. Average cluster weight (g) used the following formula:

$$\text{Average weight grape} = \frac{\text{Total weight of grape}}{\text{Number of clusters per plant}}$$

The calculation of total yield of grapes continued by weighing the yield of each grapevine when the percentage of total suspended solids (TSS) in the berries of control treatment reaches 15%–16% using a digital scale (Al-Douri, 2014).

Quality characteristics

The total suspended solids (TSS %) reached measuring by squeezing the number of berries randomly using a refractometer, and taking the average of four readings (Al-Tahafy, 2004). The estimation of total acidity (%) in fruit juice followed the method according to AOAC (2005). Measuring the total sugars in the berries juice (%) ensued by taking one ml of juice and placed in a 50 ml glass beaker, then, added with one ml of 5% phenol solution, distilled water, and 5 ml of concentrated sulfuric acid with continuous shaking. Afterward, leaving the mixture to cool. The absorbance measurement used an Apel PD-303 spectrophotometer at the wavelength of 490 nm (Joslyn, 1970). The anthocyanin pigment (mg 100 g $juice^{-1}$) estimation followed the equation based on the optical density (OD) (Spayd and Morris, 1978).

$$\text{Anthocyanin pigment} = \text{Device reading} \times \text{Total solution volume} \times \text{Sample volume} \times 98.2 \times \text{Dilution} \times 10$$

RESULTS AND DISCUSSION

In agriculture, the primary focuses of research on low-molecular-weight organic compounds in their nutritional values served in enhancing crop quality and growth. However, a dearth of information exists on low-molecular organic compounds and their effects on plant availability, absorption, and use of nutrients, particularly on microelement absorption and utilization. Since, the shoots quickly absorb sugar alcohols and relieve the symptoms of nutrient deficiency while also providing the plant with sugar alcohols directly entering the metabolic cycles within plant tissues. Al-Obaidat *et al.* (2016) also studied the effects of low molecular weight organic compounds in grape cultivars, Halwani and Kamali, for fruit quality traits, focusing on the said issues.

Clusters per plant

The grape cultivars revealed significant differences for the said trait, while the cultivar Kamali yielded the highest number of cluster per plant (27.67 clusters plant^{-1}), and the cultivar Halwani gave the lowest (21.89 clusters plant^{-1}) (Table 2). The alcohol-sugar levels indicated considerable differences for the said trait. The sugar alcohol (8 mL L^{-1}) showed the topmost substantial variance, with a value of 25.56 clusters plant^{-1}, compared with the control treatment (24.11 clusters plant^{-1}). Regarding the interaction between the two grape cultivars and mannitol, a significant difference was evident. Cultivar Kamali, with sugar alcohol (8 mL L^{-1}), yielded the most number of clusters (28.89 clusters plant^{-1}), while the control treatment produced the lowest value (21.67 clusters plant^{-1}). The superiority of the Kamali cultivar over Halwani in the number of clusters was due to the genetic characters of the cultivar and the type and intensity of pruning. A positive relationship occurred between the clusters and fertile branches, leaf area, and the increase in cluster weight of the cultivar Halwani. It refers to the increase in the cluster's share of nutrients manufactured in the leaves. Likewise, the decrease in competition between the clusters because the clusters were the largest consumers of photosynthesis process products and the hormones manufactured in the leaves (Ali-Ibrahim *et al.,* 2021).

Cluster weight

For cluster weight, the grape cultivars revealed notable disparities, and the cultivar Halwani gave the highest value (642 g) compared with the cultivar Kamali, which yielded the lowest value (504 g) (Table 2). The results indicated a significant effect of sugar alcohol, and the sugar alcohol 8 mL L^{-1} enunciated the topmost value (601 g) versus the control treatment (542 g) for cluster weight. The interaction between the two cultivars and sugar alcohol revealed a substantial increase in the cultivar Halwani with sugar alcohol 8 ml L^{-1} and yielded the highest value (673 g), compared with the control treatment, producing the lowest value (474 g) in cluster weight. The maximum level of sugar alcohol also achieved a significant increase in all the studied characteristics, except for total dissolved solids and total acidity. This may be due to the easy permeability of sugar alcohol through cell membranes with its small size molecules, contributing to the basic building blocks of the carbohydrates. It also helped facilitate the movement of dissolved sugars produced in the leaves to their places of consumption, improving fruits' weight, and increasing total sugars, reflected positively in these characteristics (Vanden-Heuvel, 2022).

Grape yield

Grape cultivars exhibited nonsignificant difference for yield (Table 2). However, the sugar alcohol 8 ml L^{s} showed a significant increase with the highest yield (15,361.56 g vine^{-1}), while the control treatment gave the lowest value (13,067.62 g vine^{-1}). Regarding interaction between the grape cultivars and sugar alcohol, a significant increase was visible in the cultivar Kamali with sugar alcohol 8 ml L^{-1} (18,543.38 g vine^{-1}), while the control treatment had the lowest value (13,197.03 g vine^{-1}). This may be due to the ease of permeation of sugar alcohols through cell membranes due to its small size molecules, contributing to the basic structure of carbohydrates. Past studies also reported its contribution to facilitating the movement of dissolved sugars produced in the leaves to other plant parts, and thus, increasing the dry matter, positively affecting the fruit yield (Lebon *et al.,* 2008).

Table 2. Effect of grape cultivars, sugar alcohols, and their interactions on the number of clusters, cluster weight, and total yield of grapes.

Type	Sugar alcohols	Clusters plant^{-1}	Cluster weight (g)	Total yield (g vine^{-1})
Halwani	0 ml L^{-1}	21.67	609	13197
	4 ml L^{-1}	21.78	643	14004
	8 ml L^{-1}	22.22	673	14954
Kamali	0 ml L^{-1}	28.56	474	13537
	4 ml L^{-1}	27.56	508	14000
	8 ml L^{-1}	28.89	530	15311
Type	Halwani	21.89	642	14053
	Kamali	28.33	504	14278
Sugar alcohols	0 ml L^{-1}	24.11	542	13067
	4 ml L^{-1}	24.67	575	14185
	8 ml L^{-1}	25.56	601	15361
$LSD_{0.05}$ Cultivars		0.934	47.3	N.S.
$LSD_{0.05}$ Sugar alcohols		1.144	57.9	1515.9
$LSD_{0.05}$ Interaction (C x SA)		1.617	81.9	2143.8

Table 3. Effect of cultivars, sugar alcohols, and their interaction on the qualitative traits of grapes.

Type	Sugar alcohols	Total suspended solids TSS (%)	Total sugars (%)	Total acidity (%)	Anthocyanin (mg 100 g^{-1})
Halwani	0 ml L^{-1}	14.17	11.90	0.61	40.33
	4 ml L^{-1}	14.74	12.80	0.57	43.40
	8 ml L^{-1}	14.76	12.80	0.54	45.31
Kamali	0 ml L^{-1}	13.81	11.33	0.62	38.83
	4 ml L^{-1}	14.14	11.95	0.58	42.00
	8 ml L^{-1}	14.14	12.80	0.55	43.56
Type	Halwani	14.55	12.50	0.57	43.01
	Kamali	14.03	11.78	0.59	41.46
Sugar alcohols	0 ml L^{-1}	13.99	11.57	0.62	41.46
	4 ml L^{-1}	14.44	12.41	0.58	42.70
	8 ml L^{-1}	14.45	12.44	0.55	44.44
$LSD_{0.05}$ Cultivars		N.S.	0.3374	0.01	0.81
$LSD_{0.05}$ Sugar alcohols		N.S.	0.4133	0.02	0.10
$LSD_{0.05}$ Interaction (C x SA)		0.17	0.5845	0.02	0.41

Total suspended solids (TSS)

The outcomes revealed no significant differences between the grape cultivars and among the sugar alcohol levels for total suspended solids (Table 3). However, concerning the interaction between cultivars and the sugar alcohol levels, grape cultivars displayed a noteworthy increase with sugar alcohol compared with the control. Grape cultivar Kamali with sugar alcohol 8 ml L^{-1} showed considerably a higher value of TSS (14.76%), surpassing other interaction treatments, while the control treatment yielded the lowest TSS value (13.81%). The accumulation of dissolved solids may relate to the genetic makeup of the grape cultivars in the production of sugars during maturity and the increased activity of the photosynthesis process. This leads to boosting the absorption of nutrients and other minerals from the soil. The said processes resulted in the increased accumulation of dissolved solids, and probably, some special genes controlling these traits, as well as environmental conditions (Ali-Ibrahim *et al*., 2021).

Total sugars

The results indicated significant difference between the grape cultivars for total sugars (Table 3). The sweet cultivar showed superiority and yielded the highest value of total sugars (12.50%), compared with the non-sweet cultivar, showing a lower value (11.78%). The effect of sugar alcohol was evident, and the sugar alcohol 8 ml L^{-1} demonstrated superiority by giving the utmost value (12.44%), versus the control treatment revealing a lower value (11.57%) for total sugars. Regarding the interaction between the cultivars and sugar alcohol, the cultivar Halwani and Kamali with sugar alcohol 4 and 8 ml L^{-1}, respectively, yielded the highest value (12.80%) and outperformed the control treatment (11.23%) in total sugars.

The shoots quickly absorbed sugar alcohol and treated the symptoms of nutrient deficiency, and at the same time, supplied the plant with the sugar alcohol, entering directly into the cycle. Metabolism within the plant tissue and the efficiency of the plant with increased production resulted in the improvement of the studied traits (Al-Tahafy *et al.,* 2004). According to Al-Obaidat *et al.* (2016), sugar alcohols' rapid absorption by the plants alleviate nutrient shortage symptoms. Additionally, these sugar alcohols also directly participate in the metabolic processes inside the plant tissues (Godshaw *et al.,* 2019).

Total acidity

The findings illustrated a remarkable difference between the grape cultivars for total acidity (Table 3). The non-sweet grape cultivar Kamali showed the superiority by yielding a higher value (0.59%) than the sweet cultivar Halwani, which gave a lower value (0.57%) of total acidity. As for the effect of sugar alcohol indicating a significant impact, the control treatment outperformed by giving the highest value (0.62%) versus the sugar alcohol 8 ml L^{-1}, which yielded a lower value (0.55%). Regarding the interaction of cultivars and sugar alcohol, the cultivar Kamali with no sugar alcohol performed well by yielding the maximum value of total acidity (0.62%) compared with the cultivar Halwani at sugar alcohol (8 m L^{-1}), which showed the lowest value (0.54%).

The total acidity formation of the cultivar Kamali fruit grains was due to the production of organic acids, especially tartaric and malic acids. Moreover, the anthocyanin pigment for some cultivars possesses a special gene that can induce the formation of a special enzyme, allowing the assimilation of anthocyanin (Rai *et al.,* 2018). The reason for differences between the two grape cultivars may be genetically, by growing specific plants under the same environmental conditions. The differences appearing between the cultivars will be due to the genetic make-up, which control all those traits (Geng *et al.,* 2022).

Anthocyanin pigment

For anthocyanin pigment, the grape cultivars exhibited significant differences (Table 3). The sweet grape cultivar Halwani showed superiority and yielded the highest value for the anthocyanin pigment (43.01 mg per 100 g), while the non-sweet cultivar Kamali gave a lower value for the said trait (41.46 mg per 100 g). As for the effect of sugar alcohol, the sugar alcohol 8 ml L^{-1} revealed superiority over all other interaction treatments, by giving the maximum value of anthocyanin content (44.44 mg 100 g^{-1}). Regarding interaction between the cultivars and sugar alcohol, cultivar Halwani with sugar alcohol 8 ml L^{-1} displayed dominance by yielding the utmost value (45.31 mg per 100 g), compared with the control treatment, which gave a lower value of anthocyanin (38.83 mg per 100 g). The anthocyanin pigment may depend upon the nature of the genetic makeup of the cultivars, as the said trait is often hereditary. Additionally, the role of leaf nutrients, including sugar, also increased the efficiency of photosynthesis, and thus, eventually enhanced the growth and development of the chlorophyll and auxiliary pigments, including the anthocyanin (Dai *et al.,* 2013; Osman *et al*., 2023; Huseynov and Aghayev, 2024).

CONCLUSIONS

The results revealed foliar application of sugar alcohol (Mannitol) had a considerable role in improving the quality and yield of grapes. With sugar alcohol, the non-sweet grape cultivar Kamali showed an increased total yield of the clusters, while in the sweet cultivar Halwani, it had a favorable effect in showing improved physiological characteristics, such as, higher anthocyanin and acidity content.

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