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Synergistic Effects of Foliar Application of Potassium Sulfate and Amino Acids on Yield and Quality of 'Superior' Grapevines

Mohamed A. El-Sayed, Heba F. S. Ibrahim and Islam E. H. Mohamed*

Hort. Dept. Fac. of Agric. Minia Univ., Egypt.

***Corresponding author:** iehab9080@gmail.com

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Abstract: This study investigates the impact of foliar application of potassium sulfate and selected amino acids (tryptophan, methionine, and cystine) on the yield and quality attributes of 'Superior' grapevines in Minia Governorate, Egypt, across the 2023 and 2024 growing seasons. Thirty uniform grapevines were subjected to ten treatments with 3 replicates in Complete Randomize Bloch Design, including varying concentrations (0.05, 0.1 and 0.2%) each of potassium sulfate, amino acids, and their combinations, applied thrice during growth stages. Results demonstrated that both potassium sulfate and amino acid treatments significantly enhanced cluster and berry characteristics, yield per vine, and berry quality compared to untreated control. The combination of 0.1% potassium sulfate and amino acids, applied three times during the season, was identified as the most cost-effective treatment, resulting in substantial increases in cluster number, berry size, weight, juice percentage, total soluble solids, and reducing sugar content, while reducing berry acidity and shot berry percentage. Higher concentrations (0.2%) yielded similar improvements, but without significant differences from the 0.1% treatment. The findings underscore the synergistic benefits of integrating potassium sulfate and amino acids as foliar sprays to optimize grapevine productivity and fruit quality, offering a practical strategy for sustainable viticulture under semi-arid Egyptian conditions.

Key words: Potassium sulphate, amino acids, yield, quality and Superior grapevines.

1. Introduction

The grapevine (*Vitis vinifera* L.) is a globally significant fruit crop, widely grown for both fresh eating and raisin production. It covers more cultivation area worldwide than any other fruit and accounts for about half of the total fruit consumption globally. In Egypt, grapes rank as the third most cultivated fruit after mangoes and citrus (**Mostafa *et al.*, 2023**). The total grape-growing area in Egypt is 186735 feddans, with 175245 feddans being productive, resulting in an annual production of approximately 1715410 tons. Specifically, in the Minia Governorate, grape cultivation spans 21098 feddans, of which 20852 feddans are productive, producing around 205244 tons of grapes (**MALR, 2023**).

Climate change is exerting unprecedented pressure on viticulture, with rising temperatures, altered precipitation patterns, and increased frequency of extreme weather events threatening both grapevine productivity worldwide. The adaptability of grapevine has historically enabled its cultivation across diverse climates, but current and projected climate trends necessitate the rapid development and deployment of adaptation strategies to ensure the sustainability of grape production (**Pastore *et al.*, 2022**). Agronomic methods are central to short- and medium-term adaptation in viticulture. These strategies can be flexibly implemented and adjusted at the vineyard level to mitigate the immediate impacts of climate variability (**Naulleau *et al.*, 2021**).

Biostimulants comprise a wide array of natural substances and microorganisms that are applied in agriculture to improve plant growth and productivity beyond what is achieved with conventional fertilization alone. These products, including amino acids, act by modulating various physiological and metabolic pathways within plants, thereby enhancing nutrient uptake, stress tolerance, and overall crop performance (**du Jardin, 2015; Rouphael and Colla, 2020**). Tryptophan, cysteine, and methionine are amino acids that are indispensable in the metabolism of plants. They function as precursors for essential secondary metabolites in plant cells and as transporters of organic nitrogen within the plant's organelles (**Dinkeloo *et al.*, 2018**). Numerous studies on grapevines have shown that the foliar spray of amino acids to the foliage is essential for the promotion of development, the enhancement of the nutritional state of the vines, the production of more fruit, and the enhancement of the quality of the berries (**Hussein, 2017; Mohamed, 2017 and Ali *et al.*, 2025 a & b**).

Tryptophan, an aromatic amino acid synthesized via the shikimate pathway beginning with chorismate, plays a pivotal role in plant physiology (**Tzin and Galili, 2010**). Recent studies have reinforced the importance of tryptophan as a precursor for indole-3-acetic acid (IAA), a principal auxin that regulates plant growth and development (**Zhao, 2010**). Foliar application of tryptophan has been shown to stimulate vegetative growth, enhance chlorophyll and carotenoid content, and increase overall productivity in several crops **(Fouad *et al.*, 2022 and Mira *et al.*, 2024**). Moreover, tryptophan application helps prevent premature flower and fruit drop by supporting the enzymatic pathways involved in auxin biosynthesis, thereby improving fruit set and retention (**Saburi *et al.*, 2014 and Fouad *et al.*, 2022**).

Methionine is a fundamental sulfur-containing amino acid that serves as a cornerstone in various plant metabolic processes. It is essential for protein assembly and central carbon metabolism, acting as the initiating amino acid during protein synthesis and linking amino acid biosynthesis to broader metabolic pathways (**Watanabe *et al.*, 2021**). Methionine’s methyl group is transferred to S-adenosylmethionine (SAM), a key methyl donor involved in numerous biological reactions, including DNA and histone methylation, which are critical for gene regulation and epigenetic control (**Niedziela *et al.*, 2025**). Additionally, methionine is indispensable for the biosynthesis of chlorophyll, polyamines, glucosinolates, and several secondary metabolites, all of which contribute to plant growth, stress tolerance, and defense mechanisms (**Shahid *et al.*, 2023**). The involvement of methionine in cell wall formation and cellular energy production further highlights its central role in plant development and adaptation (**Watanabe *et al.*, 2021**).

Cysteine is amino acid, distinguished by its thiol, amino, and carboxylic acid groups, which make it highly reactive and central to numerous plant metabolic processes. Its thiol group enables cysteine to function as a strong antioxidant, efficiently neutralizing reactive oxygen species (ROS) and thereby protecting plant tissues from oxidative stress caused by environmental challenges (**Carballal and Banerjee, 2022**). Beyond its antioxidant role, cysteine is fundamental for the biosynthesis of critical molecules such as glutathione, metallothioneins, thionins, phytoalexins, glucosinolates, and phytochelatins, all of which contribute to plant defense, detoxification, and stress adaptation (**Künstler *et al.*, 2020**). Additionally, cysteine is a central intermediate in sulfur metabolism, serving as a precursor for methionine synthesis. This relationship is important because methionine and its derivative S-adenosylmethionine are essential for the production of major phytohormones, including ethylene and polyamines, which regulate plant growth and developmental processes (**Wawrzyńska and Sirko, 2024**). Thus, cysteine not only supports antioxidant defense but also plays an indispensable role in plant metabolism, stress resilience, and developmental regulation.

Potassium sulfate (K_2SO_4) has emerged as an essential nutrient source for grapevines, owing to its multifaceted role in enhancing yield, improving fruit quality, and supporting plant health under stress conditions. Recent studies have demonstrated that the foliar application of potassium sulfate during critical stages of fruit development significantly increases sugar accumulation and total soluble solids (TSS) in grape berries, which are key determinants of both table grape and wine quality (**Singh *et al.*, 2024**). Notably, repeated foliar sprays of K_2SO_4 have been shown to not only boost sugar content but also optimize yield by stimulating chlorophyll production and enhancing photosynthetic efficiency, thereby promoting carbohydrate synthesis and fruit development (**Fekry and Aboel-Anin, 2020**). Furthermore, potassium sulfate contributes to robust vegetative growth and improved stress tolerance, as it stabilizes photosynthetic pigments, reduces ion leakage, and increases the uptake of essential nutrients such as nitrogen, magnesium, and calcium, even under salinity stress (**Minazadeh *et al.*, 2018**). Collectively, these findings underscore the indispensable role of potassium sulfate in modern viticulture, making it a recommended practice for achieving sustainable yield improvements and superior fruit quality in grape production.

The primary goal of this study is to evaluate the effects of foliar applying of different amino acids—specifically methionine, cystine, and tryptophan—as well as potassium sulfate on the physiological and quality attributes of Superior grapevines

2. Materials and Methods

2.1. Experimental location

This study used the ‘Superior' variety of grapevines, cultivated in a private vineyard located at Samalut center- Minia Governorate, to study the impact of potassium sulfate and different amino acids as foliar applications on grapevine vegetative and productivity across 2023 and 2024 season.

Thirty healthy grapevines exhibiting similar growth vigor were selected for the experiment. Cane pruning was performed, leaving a total of 84 buds per vine, achieved by retaining 6 canes with 12 buds each and 6 renewal spurs with 2 buds each. All vines received standard vineyard management practices, including irrigation and pest control. The planting layout consisted of 2 meters between vines and 3 meters between rows, established on clay soil. Soil physical and chemical characteristics are detailed in Table A, following the methodology of **Wilde *et al.* (1985**). Surface irrigation was carried out using Nile water.

2.2. Experimental treatments and design:

The study employed a complete randomized block design with three repeats and one vine/treatment. The following is how the treatments were set up:

1) Control (spay with tap water).
2) Amino acids 0.05%
3) Amino acids 0.1%
4) Amino acids 0.2%
5) Potassium sulfate 0.05%
6) Potassium sulfate 0.1%
7) Potassium sulfate 0.2%
8) Amino acids 0.05%+ Potassium sulfate 0.05%
9) Amino acids 0.1%+ Potassium sulfate 0.1%
10) Amino acids 0.2%+ Potassium sulfate 0.2%

At three specific stages—namely, the beginning of growth, directly after berry set, and one month later—each treatment was applied spraying foliarly using the tested rates of potassium sulfate as well as various amino acids, including tryptophan, cystine, and methionine.

Table (A): Characteristics of the investigated soil

Soil characters		2023/2024
Particle size distribution (%)	**Sand**	3.11
	Silt	33.65
	Clay	63.24
	Texture class	Clay
EC ppm (1:2.5 extract)		286
pH (1:2.5 extract)		7.92
Organic matter %		2.13
$CaCO_3$ %		2.61
Soil nutrients	**Total N (%)**	0.18
	Available P (ppm)	5.11
	Available K (ppm)	486.0
	Zn (ppm)	1.9
	Fe (ppm)	2.8
	Mn (ppm)	3.26
	Cu (ppm)	0.08

2.3. Plant measurements

- Yield and physical attributes of clusters: Ten clusters per vine were selected as representative random samples, and the subsequent parameters were ascertained; clusters number/vine**,** weight (g), yield (kg)/vine was assessed in kg for each tree/replicate by multiply the previous parameters**,** cluster dimensions (length and shoulder in (cm)) and berry setting (%) was computed as the following: packed 5 flower clusters per vine in perforated paper bags before bloom, which are discharged during berry set which computed as follows:

$$\text{Fruit berry Setting\%} = \frac{\text{Number of berries /cluster}}{\text{Total number of flower /cluster}}$$

- Physical characteristics of berries: To determine the shot berry proportion, percentage of berries in each cluster /the aggregate number of berries in all clusters X 100, berry weight (g) and dimensions (longitudinal and equatorial).

- Chemical characteristics of berries according to (**A.O.A.C, 2000**): TSS% in berry juice measured with a handheld refractometer, titrating 5 ml of berry juice against 0.1 N NaOH with phenolphthalein determined the titratable acidity percentage, TSS/acidity ratio of berry juice was calculated, reducing sugar% and juice%

2.4. Analysis of data

The new LSD technique was utilized to examine the data at a significance of 5%, as outlined by **Mead *et al.* (1993).**

3. Results and Discussion

3.1. Yield and cluster characteristic

The data presented in Table 1 clearly illustrates the average number of clusters per vine, weight, yield in kg per vine, berry setting percentage, cluster length, and shoulder dimensions as affected by all interventions. Yield and cluster parameters increases across all treatments in both seasons. The application of K-sulfate at concentrations of 0.1% and 0.2% resulted in the largest berries yielding the highest output with high cluster parameters, with the lower concentration of amino acids following closely, and the control group yielding the least. No notable variations were detected between the maximum concentrations of both compounds regarding the average yield and cluster traits across both seasons. The treatment that demonstrated the highest cost-effectiveness yielded 10.7-11.1 for berry setting, 24.0-20.3 for cluster length, 14.3 for cluster shoulder in two seasons, 23-37 for cluster number/vine, 371.0-385.0 for cluster weight (g) and 8.53 - 14.25 kg yield per vine with a concentration of 0.1% for both K-sulfate and amino acids, respectively in 2024 compared to the 2023 season. In contrast, the peak mean values observed for the combination of 0.2% for each of K-sulfate and amino acids. The untreated vines exhibited the lowest values, recorded at (8.3-8.0%), (20.1-21.0 cm), (11.9-12.2 cm), (23.0-23.0), (345.0-350.0 g) and (7.94 - 8.05 kg/vine) for berry setting, cluster length, shoulder, number, weight and yield, respectively.

Foliar application of potassium sulfate (K_2SO_4) is a widely adopted practice in viticulture to enhance grapevine yield and improve cluster and berry characteristics. This method delivers potassium directly to the leaves, supporting key physiological processes that drive fruit development and quality. Foliar K_2SO_4 application significantly raises the yield per vine compared to untreated controls. Studies report that repeated foliar sprays at moderate to high concentrations (e.g., 1–3%) result in higher yields, with the most pronounced effects at the highest application rates (**Zlámalová *et al.*, 2015; Ben Yahmed and Ben Mimoun, 2019**). Application of K_2SO_4 increases both berry weight and diameter, contributing to more uniform and marketable fruit. This is linked to improved water and nutrient transport, as well as enhanced sugar accumulation in the berries (**Zareei *et al.*, 2018; Karimi *et al.*, 2021**).

Application of amino acids, especially at concentrations around 0.1–0.2%, leads to a notable increase in yield per vine compared to untreated controls. For example, spraying grapevines with a mixture containing methionine, tryptophan, and cystine three times per season resulted in yield increases of 18–41% over two consecutive years as well as maximize cluster number compared to individual treatments or controls (**Abd El- Baset and Khiamy, 2022 and Abada *et al.*, 2023**). Tryptophan at 200 ppm and methionine at 50–100 mg/L have been particularly effective, with tryptophan often producing the highest yield, 100-berry weight and cluster weight among tested amino acids (**Mekawy, 2019 and El-Kenawy, 2022**). Tryptophan is a precursor for auxin (IAA), which promotes fruit set and berry development. Methionine is involved in ethylene synthesis, influencing fruit ripening and cluster formation. While, Cystine, as a sulfur-containing amino acid, contributes to antioxidant defense, helping vines maintain productivity under stress conditions.

3.2. Berry physical characteristics

The treatments investigated in both seasons had a substantial impact on the berry shot%, weight, longitudinal, equatorial, as evidenced by the data presented in Table 2. In 2023, the berry shot%, weight, longitudinal, equatorial of Superior grapevines ranged from 5.6 to 9.2%, 3.33 to 3.81 g, 1.81 to 2.11 cm and 1.70 to 1.88 cm, while in 2024, they ranged from 5.2 to 9.0%, 3.50 to 4.03 g, 1.85 to 2.16 cm and 1.73 to 1.71 cm, respectively. The individual treatment of 0.2% K-sulfate resulted in the highest berry weight, longitudinal, equatorial measurement, and lowest berry shot%. This result did not exhibit any significant differences when compared to vines that used 0.1% of K-sulfate. The tiniest berry weight, longitudinal, equatorial measurements and highest berry shot% were found in the control vines, which did not receive any foliar sprays. When K-sulfate and amino acids were applied together at higher concentrations, there was a noticeable increase in the average berry weight, longitudinal, equatorial. And lowest berry shot%. The foliar application of 0.2% K-sulfate combined with amino acids resulted in the highest average berry weight, longitudinal, equatorial and lowest berry shot% closely followed by the 0.1% combination, with no significant difference between these two treatments. Compared to the control, the increases in berry weight, longitudinal, equatorial and decrease in berry shot% for the highest concentration were 14.41-15.14%, 16.57-16.75%, 10.59-10.40% and 39.13-42.22% in the two seasons, respectively, while the medium concentration led to increases of 12.91-13.14%, 14.36-14.05%, 9.41-9.83% and 33.69-36.67%, respectively. Other treatments produced intermediate berry equatorial measurements.

Table (1). Superior grapevines cluster number/vine, cluster weight (g) and yield (kg)/vine response to foliar application with potassium sulfate and amino across 2022 and 2023 seasons

Characteristics / Treatments	Berry setting %		Cluster length (cm)		Cluster shoulder (cm)		Cluster number/vine		Cluster weight (g)		Yield/vine (kg)	
	2023	2024	2023	2024	2023	2024	2023	2024	2023	2024	2023	2024
Control	8.3	8.0	20.1	21.0	11.9	12.2	23	23	345.0	350.0	7.94	8.05
A.A. 0.05%	9.2	9.3	21.5	22.5	12.6	12.8	23	27	353.0	364.0	8.12	9.83
A.A. 0.1%	9.7	10.0	22.2	23.1	13.2	13.4	23	31	359.0	371.0	8.26	11.50
A.A 0.2%	10.0	10.3	11.6	23.5	13.6	13.7	23	33	363.0	376.0	8.35	12.41
K-sulfate 0.05%	9.7	9.9	22.1	23.2	13.1	13.2	23	30	360.0	370.0	8.28	11.10
K-sulfate 0.1%	10.2	10.5	22.8	23.5	13.7	13.8	23	35	366.0	377.0	8.42	13.20
K-sulfate 0.2%	10.4	10.8	23.1	24.1	14.1	14.1	23	37	370.0	382.0	8.51	14.13
A.A 0.05%+ K-sulfate 0.05%	10.1	10.5	23.5	25.7	13.8	13.8	23	33	365.0	377.0	8.43	12.44
A.A 0.1%+ K-sulfate 0.1%	10.7	11.1	24.0	26.3	14.3	14.3	23	37	371.0	385.0	8.53	14.25
A.A 0.2%+ K-sulfate 0.2%	11.0	11.4	24.4	26.6	14.6	14.6	23	38	374.0	390.0	8.60	14.82
New LSD at 5%	**0.4**	**0.4**	**0.5**	**0.5**	**0.5**	**0.4**	**N.S**	**3.0**	**5.0**	**6.0**	**1.0**	**1.0**

Table (2). Superior grapevines berries physical quality response to foliar application with potassium sulfate and amino across 2022 and 2023 seasons

Characteristics / Treatments	Shot berries %		Average berry weight (g)		Average berry longitudinal (cm)		Average berry equatorial (cm)	
	2023	2024	2023	2024	2023	2024	2023	2024
Control	9.2	9.0	3.33	3.50	1.81	1.85	1.70	1.73
A.A. 0.05%	8.2	8.1	3.45	3.65	1.88	1.93	1.75	1.79
A.A. 0.1%	7.4	7.3	3.53	3.75	1.94	2.00	1.79	1.82
A.A 0.2%	6.9	6.7	3.59	3.82	1.98	2.05	1.80	1.84
K-sulfate 0.05%	7.5	7.3	3.56	3.76	1.95	1.99	1.80	1.83
K-sulfate 0.1%	6.9	6.5	3.64	3.85	2.00	2.06	1.84	1.86
K-sulfate 0.2%	6.4	5.9	3.70	3.92	2.03	2.11	1.86	1.88
A.A 0.05%+ K-sulfate 0.05%	6.7	6.4	3.68	3.87	2.01	2.05	1.83	1.86
A.A 0.1%+ K-sulfate 0.1%	6.1	5.7	3.76	3.96	2.07	2.11	1.86	1.90
A.A 0.2%+ K-sulfate 0.2%	5.6	5.2	3.81	4.03	2.11	2.16	1.88	1.91
New LSD at 5%	**0.6**	**0.7**	**0.07**	**0.08**	**0.05**	**0.06**	**0.03**	**0.03**

Improvements in the physical quality of grapevine berries—specifically reductions in shot berry percentage and increases in berry weight, length, and width—are closely interconnected and have a substantial impact on both yield and marketability. Foliar application of potassium sulfate (K_2SO_4) has become an increasingly popular strategy in viticulture for optimizing the physical quality of grapevine berries. Unlike soil application, foliar feeding allows for more immediate uptake and utilization of potassium, especially during critical periods of berry development. This approach directly influences several interrelated physical parameters of the berries, including size, weight, and compositional quality. Lower shot berry percentages, often achieved through optimal foliar nutrition such as potassium sulfate and amino acid applications, lead to more uniform clusters and reduce postharvest losses (**Mpelasoka *et al.*, 2003 and Mansour *et al.*, 2024**). At the same time, these treatments enhance berry weight by promoting cell expansion and water uptake, which typically results in larger berries with greater length and width (**Ben Yahmed and Ben Mimoun, 2019 and Keller, 2020**). The increase in berry size parameters is not only visually appealing but also contributes to higher consumer acceptance and economic returns, as heavier and larger berries are preferred in both fresh and processing markets (**Abd El-Rahim *et al.*, 2022**). Thus, strategies that simultaneously lower shot berry incidence and boost berry size parameters create a synergistic improvement in grape quality, demonstrating the importance of integrated nutrient management in viticulture.

Foliar application of tryptophan, particularly at higher concentrations, significantly boosts berry weight, length, and width, while also improving berry set and thereby reducing shot berry percentage; these enhancements are attributed to tryptophan's role in stimulating cell division, chlorophyll synthesis, and overall vine nutritional status, leading to larger, heavier, and more uniform berries within clusters (**Hussein, 2017; Mekawy, 2019 and El-Kenawy, 2022**). Methionine similarly enhances berry weight and dimensions, and its involvement in ethylene biosynthesis and protein formation supports improved berry development and reduced shot berry incidence; methionine treatments also promote berry firmness and quality, further linking increased size and weight with better cluster uniformity and reduced losses (**Mekawy, 2019 and Abada *et al.*, 2023**). Cysteine, though less frequently studied in grapevines, is recognized for its antioxidant properties and its contribution to berry quality through improved stress tolerance and maintenance of berry integrity, which can indirectly support greater berry size and reduced shot berry rates, thereby complementing the effects of the other amino acids (**Elias *et al.*, 2005; Ali *et al.* 2025 a**). Collectively, these amino acids, when applied foliarly, reinforce each other's positive effects, resulting in a synergistic improvement of berry weight, size, and uniformity, while minimizing the proportion of shot berries and enhancing the overall marketability and quality of grapevine yields as indicated by (**Ali *et al.* 2025 a & b**) on Superior grapevines.

3.3. Berry chemical quality characteristics

The information shown in Table 3 demonstrates that the application of K-sulfate and/or various amino acids at different dosages, administered three times to the 'Superior' grapevine, led to a notable increase in juice%, TSS%, TSS/total acidity ratio, reducing sugar% and decrease in total acidity when compared to the control treatment (untreated vines) throughout both experimental seasons. The observed increase in juice%, TSS%, TSS/total acidity ratio, reducing sugar% and decrease in total acidity were correlated with the elevated concentrations of K-sulfate and/or amino acids. There were no significant differences berries parameters levels between the two higher concentrations across the two experimental seasons. The application of K-sulfate spray showed significant efficacy, especially at a concentration of 0.2%. The examination of the treatments indicated significant differences in berries chemical quality across the two seasons. The highest values for juice%, TSS%, TSS/total acidity ratio, reducing sugar% and lowest for total acidity were recorded at 0.2% for both K-sulfate and amino acids, with 0.1% closely following for each. The treatments exhibited no notable differences during the 2023 and 2024 seasons.

Potassium sulfate (K_2SO_4) is directly influencing the chemical composition and quality of grape berries. Its application, particularly as a foliar spray, has been shown to enhance several important chemical parameters: total soluble solids (TSS), acidity, juice percentage, and reducing sugar content. These parameters are closely linked, and improvements in one often coincide with enhancements in others, collectively contributing to superior fruit quality. Potassium sulfate application significantly increases the TSS and reducing sugar content in grape berries, which is a primary indicator of sugar accumulation and fruit ripeness. Recent studies have shown that foliar applied potassium sulfate can raise TSS by up to 3.5 percentage points compared to untreated controls, with the most pronounced effects observed at higher application rates (**Wang *et al.*, 2024 and Hittalamani *et al.*, 2025**). Potassium facilitates the translocation of sugars from leaves to berries, promoting carbohydrate accumulation and improving the sweetness and flavor profile of the fruit (**Ben Yahmed and Ben Mimoun, 2019**), its role in activating sugar metabolism enzymes and facilitating the conversion of starches to simple sugars during berry development. Potassium sulfate treatments consistently lead to a decrease in berry acidity. This reduction is attributed to potassium's role in organic acid metabolism and its ability to promote the conversion of acids into sugars during berry ripening (**El-Badawy, 2019; Ben Yahmed and Ben Mimoun, 2019**). The combined effect of increased TSS and reduced acidity results in a higher TSS/acid ratio, which is a critical determinant of grape flavor and consumer preference. The highest TSS/acid ratios are typically observed in vines treated with higher concentrations of potassium sulfate (**Ali *et al.*, 2024 and Hittalamani *et al.*, 2025**), also, potassium sulfate application improves the juice percentage in grape berries by enhancing water uptake and maintaining cell turgor. This leads to juicier berries and higher must yield, which is beneficial for table grape. The increase in juice content is often accompanied by improvements in TSS and reducing sugar, as potassium optimizes nutrient flow and water balance within the berry (**Hittalamani *et al.*, 2025**)

Table (3). Superior grapevines berries chemical quality response to foliar application with potassium sulfate and amino across 2022 and 2023 seasons

Characteristics / Treatments	Juice%		TSS%		Total acidity%		TSS/acidity ratio		Reducing sugar%	
	2023	**2024**	**2023**	**2024**	**2023**	**2024**	**2023**	**2024**	**2023**	**2024**
Control	75.5	75.8	17.7	17.9	0.655	0.648	27.02	27.62	15.5	16.0
A.A. 0.05%	76.2	76.5	18.2	18.3	0.639	0.629	28.48	29.09	16.6	17.2
A.A. 0.1%	76.7	76.9	18.6	18.7	0.621	0.610	29.95	30.66	17.1	17.6
A.A 0.2%	77.0	77.1	18.7	18.9	0.607	0.595	30.81	31.76	17.3	17.8
K-sulfate 0.05%	76.6	77.0	18.6	18.7	0.609	0.600	30.54	31.17	17.0	17.6
K-sulfate 0.1%	77.1	77.4	18.9	19.1	0.587	0.580	32.20	32.93	17.3	18.0
K-sulfate 0.2%	77.3	77.7	19.1	19.3	0.572	0.565	33.39	34.16	17.4	18.1
A.A 0.05%+ K-sulfate 0.05%	77.1	77.4	20.0	20.1	0.582	0.579	34.25	34.72	17.4	17.9
A.A 0.1%+ K-sulfate 0.1%	77.5	77.8	20.3	20.4	0.564	0.560	35.99	36.43	17.7	18.2
A.A 0.2%+ K-sulfate 0.2%	77.8	80.0	20.4	20.6	0.550	0.544	37.09	37.87	17.9	18.4
New LSD at 5%	**0.4**	**0.4**	**0.3**	**0.3**	**0.016**	**0.017**	**1.20**	**1.45**	**0.3**	**0.3**

Foliar application of tryptophan significantly increases TSS and reducing sugar content in grape berries. This is attributed to tryptophan's role in stimulating auxin synthesis, which enhances carbohydrate metabolism and sugar accumulation in the fruit (**Mekawy, 2019 and El-Kenawy, 2022**), aslo, associated with a reduction in berry acidity, leading to a higher TSS/acid ratio and improved flavor profile. By promoting better fruit set and berry development, tryptophan can indirectly increase juice yield, as larger and healthier berries tend to have higher juice content (**El-Kenawy, 2022**). As for, methionine, as a precursor in ethylene biosynthesis, supports fruit ripening and sugar accumulation, leading to higher TSS and reducing sugar levels in grape berries as well as decreasing acidity (**Masoud *et al.*, 2025**). By enhancing berry development and ripening, methionine can contribute to increased juice yield, as more mature berries typically contain more juice. While direct studies on cysteine's effect in grapevines are limited, cysteine is known for its role in antioxidant defense and stress tolerance, which can support better sugar accumulation and higher TSS, TSS/acidity, juice and reducing sugar content with decrease in acidity in berries under optimal conditions (**Ali *et al.*, 2025 a**)

The chemical quality parameters—TSS, acidity, juice percentage, and reducing sugar—are strongly interrelated. Potassium sulfate and amino acids application not only increases TSS and reducing sugar but also reduces acidity and enhances juice yield. These improvements are synergistic: higher sugar content and lower acidity improve flavor, while increased juice percentage and reducing sugar contribute to better processing quality and consumer appeal. The overall effect is a marked enhancement in grape berry quality, making potassium sulfate and amino acids a vital input for modern viticulture.

4. Conclusion

The use of potassium sulfate in combination with amino acids leads to notable improvements in both the yield and quality of 'Superior' grapevines, as reflected in increased productivity, larger berry size, and enhanced quality traits. Based on the findings of this study, it can be concluded that applying foliar sprays 0.1% each of potassium sulfate and amino acid—tryptophan, methionine, and cystine—three times during the growing season is the most cost-effective approach for maximizing economic yield of 'Superior' grapevines under the conditions of El-Minia Governorate.

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التاثيرات التآزريه للرش الورقى بسلفات البوتاسيوم و الأحماض الأمينيه على إنتاجية و جوجة كروم عنب "سوبيريور"

محمد أحمد السيد - هبه فوزى سيد إبراهيم - إسلام إيهاب حلمى محمد

قسم البساتين – كلية الزراعة – جامعة المنيا – مصر

الموجز

يهدف البحث إلى دراسة تأثير الرش الورقى بسلفات البوتاسيوم و بعض الأحماض الأمينيه (تريبتوفان، ميثيونين و سيستين) على صفات المحصول و جوده الحبات لعنب سوبيريور المزروع فى مركز سمالوط بمحافظة المنيا خلال موسمى النمو ٢٠٢٣ و ٢٠٢٤. حيث خضعت ٣٠ كرمه متجانسة للرش ثلاث مرات خلال موسم النمو لعشر معاملات فى ٣ مكررات خلال تصميم كامل العشوائية لتركيزات ٠,٠٥، ٠,١ و٠,٢% لكل من سلفات البوتاسيوم و / أو الاحماض الامينيه و التفاعلات المشتركه بينهم. أظهرت النتائج أن إستخدام كل من سلفات البوتاسيوم و الاحماض الامينيه حسن بشكل ملحوظ خصائص العناقيد و الثمار و محصول الكرمه و جوده الحبات مقارنه بالكرمه الغير معالجة. ووجد أن الرش الورقى بتركيز ٠,١% لكل من سلفات البوتاسيوم و الاحماض الامينيه كان الاكثر فعاليه من حيث التكلفه و الذى أدى إلى زياده ملحوظة فى عدد العناقيد، حجم الثمار ووزنها و نسبة العصير و إجمالى المواد الصلبة الذائبة الكلية و السكر المختزل مع إنخفاض الحموضه و نسبة الحبات الصغيره للعناقيد، مع ملاحظة أن التركيز ٠,٢% لكل منهما أسفر عن تحسينات أعلى مماثله و لكن دون إختلافات جوهريه و تؤكد هذه النتائج عن الفوائد التآزريه من دمج سلفات البوتاسيوم و الاحماض الامينيه على تحسين إنتاجية و جودة ثمار العنب صنف سوبيريور ، مم يقدم إستراتيجيه عمليه لزراعة العنب المستدامة فى ظل ظروف الأراضى المصريه شبة القاحله.

الكلمات المفتاحيه: سلفات البوتاسيوم، أحماض امينيه، محصول، جوده و عنب سوبيريور