



Response of Some Vegetative Growth, Yield and Cluster Quality of Grapevine Taifi to Foliar Application of Salicylic Acid, Fulvic Acid and Bio-Fertilizers

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ABSTRACT

This study was conducted during the growing season (2024) on ten-year-old grapevine cv. Taifi a private vineyard located in Dukok Government, Bare-Buhar Village, Kurdistan region-Iraq. The vines were trained on T-Trills, These vines, which were ten years old, were planted at 2.5×2.5 m distances between rows to indicate the response of some vegetative growth, yield and cluster quality of grapevine (*Vitis Vinifera* L.) to foliar application of salicylic acid at concentrations (0, 200 and 400 mgL⁻¹), Fulvic acid at concentrations (0, 3 and 6 g L⁻¹) and soil application of Bio-fertilizers (Mycorrhizae) at levels (0, 50 and 100 g per vine⁻¹), and their interaction effect on the studied traits. The data were analyzed using a Randomized Complete Block Design (RCBD). The results showed that every measured parameter was considerably improved by all three treatments. The highest application rates (400 mg L⁻¹SA, 6 g L⁻¹FA, and 100 g vine mycorrhizae) consistently yielded the best results individually. Their combined application showed a strong synergistic effect. In terms of carbohydrate content (15.81%), total sugar (24.3%), anthocyanin (1.53 mg/100g FW), cluster weight (691.2 g), and number of berries per cluster (256.3), the triple interaction of 400 mg L⁻¹ SA + 6 g L⁻¹ FA + 100 g vine⁻¹ mycorrhizae produced the most noticeable effects. The highest petiole contents of N (1.431%), P (0.508%), and K (1.410%) were also obtained with this treatment.

Keywords: foliage spray, Salicylic acid, Fulvic acid mycorrhizae, quality, *Vitis vinifera* L., Taifi.

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INTRODUCTION

The grape (*Vitis vinifera* L.) is a member of the Vitaceae family. Grapevines are cultivated in a range of climates and environments across the globe. One of the indigenous varieties that is widely cultivated in the Dohuk/Kurdistan region/Iraq is Taifi, a table grape that produces hermaphrodite blossoms. Within a specific region, conventional and organic growers share several considerations and techniques in grape cultivation. Both conventional and organic grape cultures, for example, use comparable methods for site selection, pruning, training, and planting [1 and 2]. An estimated 5,869 hectares of grapevines are grown in Iraq, with an annual production of 95,725 tons (about 16.3 tons per hectare). However, the output of production has declined by 11%. In the prior five years [3]. It was cultivated between latitudes 20° and 50° north and 20° and 40° south [4] The grape is one of the most delectable, refreshing and nutritious subtropical fruits minerals and vitamins (B1, B2, and C) are abundant in the berries. About 27% of the grapes produced worldwide are used for fresh fruit, 2% for dried fruit, and 71% are used for wine. Producing grape juice to be reconstituted for fruits that are canned "with no added sugar" and "100% natural" uses a percentage of the grape crop [5, 6 and 7].

Salicylic acid and its derivatives are plant hormones that belong to the phenolic acid group. They consist of a ring bonded to hydroxyl and carboxyl groups, with cinnamic acid serving as the first element (8, 9 and 10). The mechanism that leads to adaptation to varying environments is mostly mediated by salicylic acid (SA) molecules. For a long time, SA has been recognized as a signal molecule that stimulates defensive mechanisms in plants [11 and 12]. By decreasing the activation of cell wall-degrading enzymes such as cellulose, xylanase, and poly galactouronase during storage, salicylic acid treatments improved cluster weight loss, decay incidence, and berry softening rate of "Thompson seedless" grapes [13 and 14]. It is a nutritional supplement that lowers the danger of stomach, intestinal, and urinary system disorders and acts as a stimulant for the liver and kidneys as well as a stimulant for brain cells and

heart muscles [15, 16 and 17]. Fulvic acid (FA) is a crucial organic and natural physical molecule in hydrous arrangements that is also of interest to plants and soil. As a chelating agent, it increases microbiological activity, promotes nutrient transportation, and enhances vegetative traits, nutritional status, and leaf colors [18 and 19]. Compared to humic acid, fulvic acid has twice as much oxygen and a greater number of carboxyl and hydroxyl groups [20 and 21]. The average size, weight, and shape index (length/diameter) of table grape fruit were all markedly enhanced by fulvic acid spraying [22 and 23]

Mycorrhizal bio fertilizers play a key role in the ecosystem's nutrient cycle through symbiosis, which also protects plants from external stressors and increases their tolerance to disease and pests [24 and 25]. Mycorrhizal bio-fertilizers Fungi and microbes have a mutually advantageous relationship [26 and 27]. To complete growing and developing, a fungus needs the host plant's nutrients, or organic carbon. In addition, it enhances the plant stress tolerance and helps in its absorption of water and nutrients (phosphate and nitrate). These kinds of reciprocal relationships have existed for 400 million years [28 and 29]. Despite the known benefits of SA, FA, and mycorrhizal bio-fertilizers individually, there is a lack of comprehensive research on their combined application for table grape production, particularly for the indigenous Taifi cultivar in the Duhok region of Iraq. The optimal concentrations of SA and FA for foliar application, when integrated with soil-applied mycorrhizal bio-fertilizers under drip irrigation systems, remain undetermined. Furthermore, it is unclear how these treatments interact to influence the growth, yield, and berry quality of grapevines in this specific agro-climatic context. This knowledge gap is critical to address, given the recent 11% decline in national productivity. The aim of this study to determine concentrations of salicylic acid and fulvic acid suitable to the vineyard and its effect on growth, yield as well as quality of berries of grapevines grown under drip irrigated condition. Also to study the effect of adding proper bio-fertilizer as soil fertilization on growth, yield as well as quality of berries of grapevines.

Materials and methods

The study was conducted during the growing season (2024) at a private vineyard in Duhok Governorate, Bare-Buhar village, Kurdistan region, Iraq, to look into the response of vegetative growth, yield, and chemical properties of grapevine cv. Taifi, irrigated with a drip system, The soil in the vineyard had a clay loam texture, average of temperature and humidity of region were (27.69C°) and (48.41%) respectively three concentrations of salicylic acid (0, 200, and 400 mg.L⁻¹), three concentrations of fulvic acid (0, 3, and 6 g.L⁻¹), and three levels of bio-fertilizer (mycorrhizae) applied to the soil (0, 50, and 100 g per vine⁻¹). Every vine was foliar sprayed twice a season, on April 25 and 27, 2023 (two weeks prior to full bloom) and May 25 and 27, 2023 (when the berries were swelling or the cluster had started to hang) with a solution containing salicylic acid and fulvic acid, respectively, to drip point (run off). Using a 16-liter sprayer, a detergent powder was added to all of the spraying solution as a wetting agent at a rate of 1-2 g.L⁻¹. Soil was treated with bio-fertilizer (Mycorrhizae Fungi) once a season (prior to bud burst). In the second week of March, the vines under investigation were pruned to leave 8 fruiting canes with 7 eyes each and 4 renewal spurs with 2 eyes each (a total of 64 eyes remaining on each vine). The vines were trained on T-Trills. The experimental vines were selected to have comparable sizes and bloom densities, as well as uniform vigor as is possible (measured by trunk diameter at 30 cm above the surface of the ground). These vines, which were ten years old, were planted at 2.5 × 2.5 m distances between rows. The 13th of May marked the full blossom. There were 81 grapevines used in this study overall because the experiment had 27 treatments with three replications. This study exposed every vine to the standard horticultural and agricultural techniques commonly used in commercial vineyards. After the berries' TSS achieved 16% and their color turned rose or purple, the harvest date was recorded. The data were analyzed using SAS software, and the treatment means were compared at the 5% significance level using Duncan's multiple range tests (DMRT) [30]. Possible response of grapevine to foliar application of salicylic acid, fulvic acid and soil application of mycorrhizae were evaluated in terms of change in carbohydrate content in canes, nutrients state in leaves petiole, cluster weight, number of berries per cluster, in addition to the chemical characteristic's anthocyanin and total sugar in berry juice.

Results

Carbohydrate content in cane (%):

Table (1) shows that the impact of foliar application of SA at concentrations (400 mg. L⁻¹) significantly increased the carbohydrate content in cane which recorded the highest (14.77 %) as compared with the control which produced the lowest (11.89 %). The same Table indicates that the increasing concentration of fulvic acid from (0 to 6 g.L⁻¹) significantly increased Carbohydrate content in cane while control produced minimum Carbohydrate content in cane (13.71 %).

Table 1. Impact of salicylic acid, fulvic acid, mycorrhizae and their integrations on carbohydrates content (%) in annual canes of grapevine cv. Taifi.

Salicylic acid mg. L ⁻¹	FA g.L ⁻¹	Mycorrhiza (g. vine ⁻¹)			SA * FA	Mean of SA
		0	50	100		
0	0	10.84 p	11.24op	11.45no	11.18 h	11.89 c
	3	11.61no	12.21lm	12.42j-i	12.08 g	
	6	11.87mn	12.57j-l	12.78jk	12.41 f	
200	0	12.32k-m	12.87i-k	12.94ij	12.71 e	13.15 b
	3	12.92ij	13.34hi	13.49gh	13.25 d	
	6	12.61j-l	13.87fg	14.04fe	13.51 d	
400	0	13.57f-h	14.52de	14.74cd	14.28 c	14.77 a
	3	14.46de	14.96b-d	15.06 bc	14.82 b	
	6	14.51 de	15.29 b	15.81 a	15.20 a	
Mean of Mycorrhiza		12.74 c	13.43 b	13.64 a	Mean of FA	
SA * Mycorrhiza	0	11.44 g	12.01 f	12.22 f		
	200	12.61 e	13.36 d	13.49 d		
	400	14.18 c	14.92 b	15.20 a		
FA * Mycorrhiza	0	12.24 e	12.88 d	13.04 d	0	12.72 c
	3	12.99 d	13.50 c	13.65 bc	3	13.38 b
	6	13.00 d	13.91 b	14.21 a	6	13.71 a

Means within a column, row and their interactions followed with the same letters are not significantly different from each other according to Duncan multiple ranges test 5% level

Carbohydrate content in canes significantly increased with higher Mycorrhizae levels, the highest content (13.64%) resulted from soil application of mycorrhizae (100 g.L⁻¹) compared to other treatments which produced (13.43 and 12.74%) respectively. For the interaction data in Table (1) showed that SA+ FA and FA + Myco differed significantly, with the highest values (15.20 and 14.21 %) obtained by the interaction of 400 mg. L⁻¹SA + 6 mg. L⁻¹ FA and 6 g.L⁻¹ FA + 100 g. vine⁻¹ Mycorrhiza compared with the lowest value of Carbohydrate content in cane (11.18 and 12.24 %) respectively from control. While by the interaction 400 mg. L⁻¹ SA and 100 g. vine⁻¹ Mycorrhiza compared with the lowest value (11.44 %) interaction between SA and Mycorrhiza was significantly increased, the highest value (15.20 %) was obtained from the control. As for the interaction between SA, FA and Mycorrhiza data in the same Table revealed that the highest value (15.81 %) was obtained by the interaction 400 mg. L⁻¹SA + 6 g.L⁻¹ FA + 100 g. vine⁻¹ Mycorrhiza compared with the lowest value (10.84 %) from the untreated

Nitrogen % in leaves petioles:

Data in table (2) shows that there were notable differences between treatments as compared with the control. Increasing levels of SA, FA and Mycorrhiza significantly increased Nitrogen percent in leaves petiole, the highest Nitrogen present was registered in the vine sprayed with 400 mg. L⁻¹ SA, 6 g.L⁻¹ FA and soil application of 100 g. vine⁻¹ Mycorrhiza, which were (1.291, 1.287 and 1.347 %) respectively. For the interaction the data in Table (2) illustrates that the combination of 400 mg.L⁻¹ SA + 6 g.L⁻¹ FA, 400 mg.L⁻¹ SA + 100 g. vine⁻¹ Mycorrhiza and 6 g.L⁻¹ FA + 100 g. vine⁻¹ Mycorrhiza significantly increased Nitrogen percent, the highest values (1.368, 1.343 and 1.347 %) respectively were obtained as compared with lowest values of Nitrogen percent (1.090, 1.048 and 1.028 %) respectively from control.

While the interaction between SA, FA and Mycorrhiza in the same table cleared that the highest value of Nitrogen percent (1.431 %) was obtained by the interaction of sprayed with 400 mg. L⁻¹ SA, 6 g. L⁻¹ FA and soil application of 100 g. vine⁻¹ Mycorrhiza compared with lowest value (0.807 %) from control.

Table 2. Impact of salicylic acid, fulvic acid, mycorrhizae and their integrations on Nitrogen (%) in petioles of grapevine cv. Taifi.

Salicylic acid mg. L ⁻¹	FA g.L ⁻¹	Mycorrhiza (g. vine ⁻¹)			SA * FA	Mean of SA
		0	50	100		
0	0	0.807 d	1.217 a-c	1.247 a-c	1.090 c	1.184 b
	3	1.114 c	1.235 a-c	1.274 a-c	1.208 bc	
	6	1.223 a-c	1.241 a-c	1.293 a-c	1.252ab	
200	0	1.106 a-c	1.207 a-c	1.239 a-c	1.184 bc	1.210 b
	3	1.142 c	1.218 a-c	1.253 a-c	1.204 bc	

	6	1.186 a-c	1.216 a-c	1.318 a-c	1.240 b	
400	0	1.169 bc	1.208 a-c	1.256 a-c	1.211 bc	1.291 a
	3	1.244 a-c	1.292 a-c	1.341 a-c	1.292 ab	
	6	1.280 a-c	1.394 ab	1.431 a	1.368 a	
Mean of Mycorrhiza		1.141 b	1.248 a	1.295 a		Mean of FA
SA * Mycorrhiza	0	1.048 c	1.231 bc	1.272 bc		
	200	1.145 bc	1.214 bc	1.270 ab		
	400	1.231 bc	1.298 a	1.343 a		
FA * Mycorrhiza	0	1.028 c	1.211 bc	1.247 bc	0	1.162 b
	3	1.167 b	1.248 bc	1.290 bc	3	1.235 a
	6	1.230 bc	1.284 bc	1.347 a	6	1.287 a

Means within a column, row and their interactions followed with the same letters are not significantly different from each other according to Duncan multiple ranges test 5% level

Phosphorus content in petioles (%): All three treatments had a considerable impact on the phosphorus concentration, as indicated in Table (3). The highest mean phosphorus content was obtained with the maximum SA rates of application (400 mg. L⁻¹). Similarly, the maximum mean values for each factor were obtained by increasing mycorrhizae from (0 and 200 g. vine⁻¹) to (100 g. vine⁻¹) and fulvic acid from (0 and 3 g. L⁻¹) to (6 g. L⁻¹). There was a very significant interaction between these variables. 400 mg. L⁻¹ SA + 6 g. L⁻¹ FA + 100 g. vine⁻¹ Mycorrhiza was the most successful combination, achieving the highest phosphorus content (0.508%). This number was significantly greater than the lowest value (0.199%) found in the vines that were not treated.

Table 3. Impact of salicylic acid, fulvic acid, mycorrhizae and their integrations on phosphor (%) in petioles of grapevine cv. Taifi.

Salicylic acid mg. L ⁻¹	FA g.L ⁻¹	Mycorrhiza (g. vine ⁻¹)			SA * FA	Mean of SA
		0	50	100		
0	0	0.199 g	0.323 d-f	0.342 c-f	0.288 e	0.327 c
	3	0.273 e-g	0.338 c-f	0.349 b-f	0.320 de	
	6	0.342 c-f	0.389 b-e	0.390 b-e	0.374 cd	
200	0	0.262 fg	0.358 b-f	0.378 b-f	0.333 de	0.370 b
	3	0.348 b-f	0.378 b-f	0.410 a-c	0.378 cd	
	6	0.384 b-e	0.392 a-e	0.421 a-c	0.399 bc	
400	0	0.313 d-f	0.381 b-e	0.395 a-c	0.363 cd	0.423 a
	3	0.409 a-c	0.448 a-c	0.464 ab	0.440 ab	
	6	0.428 a-d	0.458 a-c	0.508 a	0.465 a	
Mean of Mycorrhiza		0.329 c	0.385 a	0.406 a		Mean of FA
SA * Mycorrhiza	0	0.271 e	0.350 cd	0.360 cd		
	200	0.331 d	0.376 b-d	0.403 a-c		
	400	0.383 b-d	0.429 ab	0.456 a		
FA * Mycorrhiza	0	0.258 d	0.354 bc	0.372 bc	0	0.328 c
	3	0.343 c	0.388 ab	0.408 ab	3	0.380 b
	6	0.385 a-c	0.413 ab	0.440 a	6	0.413 a

Means within a column, row and their interactions followed with the same letters are not significantly different from each other according to Duncan multiple ranges test 5% level

Potassium % in leaves petioles:

The potassium concentration increased significantly with higher SA concentrations. The mean K content for vines treated with 0 mg. L⁻¹ SA (1.062%) was significantly lower than those treated with 200 mg. L⁻¹ (1.201%) and 400 mg. L⁻¹ (1.280%), with the highest dose yielding the best result.

A similar positive trend was observed for FA. The highest mean K content (1.251%) was achieved with the 6 g. L⁻¹ FA application, which was significantly greater than the control (0 g.L⁻¹, 1.118%).

Mycorrhizal application also significantly enhanced K uptake. The mean K percentage increased from 0.852% in the control (0 g.vine⁻¹) to 1.104% with 50 g.vine⁻¹, and reached its peak of 1.228% with the 100 g.vine⁻¹ application. The two-way and three-way interactions between the factors were significant. The highest potassium levels were consistently achieved by combining the highest doses of all three treatments. Specifically, the combination of 400 mg.L⁻¹ SA, 6 g.L⁻¹ FA, and 100 g.vine⁻¹ mycorrhiza produced the single highest K value (1.410%), which was statistically on par with several other high-dose combinations but significantly superior to all low-dose and control treatments.

Table 4. Impact of salicylic acid, fulvic acid, mycorrhizae and their integrations on potassium (%) in petioles of grapevine cv. Taifi.

Salicylic acid mg. L ⁻¹	FA g.L ⁻¹	Mycorrhiza (g. vine ⁻¹)			SA * FA	Mean of SA
		0	50	100		
0	0	0.611 c	1.084 ab	1.205 ab	0.967 c	1.062 b
	3	0.821 bc	1.064 ab	1.229 ab	1.038 bc	
	6	1.124 ab	1.165 ab	1.251 ab	1.180 a-c	
200	0	1.037 ab	1.211 ab	1.211 ab	1.153 a-c	1.201 a
	3	1.163 ab	1.256 a	1.230 ab	1.216 ab	
	6	1.209 ab	1.230 ab	1.263 a	1.234 ab	
400	0	1.161 ab	1.241 ab	1.301 a	1.234 ab	1.280 a
	3	1.191 ab	1.259 a	1.346 a	1.265 ab	
	6	1.222 ab	1.388 a	1.410 a	1.340 a	
Mean of Mycorrhiza		1.060 b	1.211 a	1.272 a	Mean of FA	
SA * Mycorrhiza	0	0.852 c	1.104 b	1.228 ab		
	200	1.136 ab	1.232 ab	1.235 ab		
	400	1.191 ab	1.296 ab	1.352 a		
FA * Mycorrhiza	0	0.936 c	1.179 ab	1.239 ab	0	1.118 b
	3	1.058 bc	1.193 ab	1.268 ab	3	1.173 ab
	6	1.185 ab	1.261 ab	1.308 a	6	1.251 a

Means within a column, row and their interactions followed with the same letters are not significantly different from each other according to Duncan multiple ranges test 5% level

Number of berries per cluster:

The number of berries per cluster was positively impacted by all administered treatments, as shown in Table (5). 400 mg. L⁻¹ SA (207.1), 6 g. L⁻¹ FA (198.5), and 100 g. vine⁻¹ Mycorrhiza (203.9) had the highest number. There were notable interactions among the parameters.

Table 5. Impact of salicylic acid, fulvic acid, mycorrhizae and their integrations on number of berries per cluster of grapevine cv. Taifi.

Salicylic acid mg. L ⁻¹	FA g.L ⁻¹	Mycorrhiza (g. vine ⁻¹)			SA * FA	Mean of SA
		0	50	100		
0	0	129.3 i	155.3 e-i	178.2 c-h	154.3 e	163.7 c
	3	138.2 hi	159.9 e-i	184.4 c-h	160.8 de	
	6	149.1 f-i	180.5 c-h	198.1 b-e	175.9 c-e	
200	0	145.7 g-i	177.8 c-g	195.7 b-f	173.1 c-e	180.4 b
	3	163.2 d-i	174.2 c-i	191.3 b-g	176.2 c-e	
	6	184.1 c-h	190.0 b-g	202.0 b-e	192.0 bc	
400	0	167.8 d-i	180.1 c-h	196.2 b-e	181.4 cd	207.1 a
	3	194.8 b-f	209.0 b-d	233.1 ab	212.3 ab	
	6	209.1 b-d	217.1 a-c	256.3 a	227.5 a	
Mean of Mycorrhiza		164.6 c	182.7 b	203.9 a	Mean of FA	
SA * Mycorrhiza	0	138.8 d	165.2 c	186.9 bc		
	200	164.3 c	180.7 bc	196.3 b		
	400	190.6 b	202.1 b	228.5 a		
FA * Mycorrhiza	0	147.6 d	171.1 c	190.0 bc	0	169.6 c
	3	165.4 cd	181.0 bc	202.9 ab	3	183.1 b
	6	180.8 bc	195.9 ab	218.8 a	6	198.5 a

Means within a column, row and their interactions followed with the same letters are not significantly different from each other according to Duncan multiple ranges test 5% level

The combination of 400 mg. L⁻¹ SA and 100 g. vine⁻¹ Mycorrhiza had the strongest impact also the combination between 400 mg. L⁻¹ SA and 6 g. L⁻¹ FA gave the highest number of berries per clusters (227.5) as compared with the lowest value (154.3). The greatest number of berries per cluster (256.3) was produced by the combined treatment of 400 mg. L⁻¹ SA + 6 g. L⁻¹ FA + 100 g. vine⁻¹ Mycorrhiza. This figure was noticeably higher than the lowest value (129.3) from the untreated vines.

Cluster weight (g):

The data in table (6) demonstrated that both soil application of mycorrhizae and the foliar application of SA and FA considerably increased cluster weight (545.3 g), (584.0 g) and (550.9 g) respectively when vine treatments with 100 g. vine⁻¹ Mycorrhiza, 400 mg L⁻¹ SA and 6 g. L⁻¹ FA. The impacts of the interactions were very important. The integration of 400 mg L⁻¹ SA and 6 g. L⁻¹ FA produced the largest cluster weight (629.9 g) and lowest cluster weight (438.7g). The interaction between 400 mgL⁻¹ SA and 100 g vine⁻¹ obtained the highest value (617g) as compared with the lowest value (431.5g) while the interaction between 400 mgL⁻¹ SA + 6 g. L⁻¹ FA and 100 g. vine⁻¹ Mycorrhiza. The minimum cluster weight (386.1 g) found in the control plants was significantly smaller than the highest value (691g).

Table 6. Impact of salicylic acid, fulvic acid, mycorrhizae and their integrations on cluster weight (g) of grapevine cv. Taifi.

Salicylic acid mg. L ⁻¹	FA g.L ⁻¹	Mycorrhiza (g. vine ⁻¹)			SA * FA	Mean of SA
		0	50	100		
0	0	386.1 i	447.9 g-i	482.2 e-h	438.7 d	464.2 c
	3	435.3 hi	464.3 f-i	487.0 e-h	462.2 cd	
	6	473.0 e-h	490.2 e-h	511.8 c-g	491.7 bc	
200	0	438.5 hi	484.0 e-h	520.7 c-h	481.1 cd	499.9 b
	3	468.6 e-i	493.9 e-h	499.6 d-h	487.3 bc	
	6	515.9 c-h	522.9 c-g	554.8 b-f	531.2 b	
400	0	514.1 c-h	536.1 b-g	541.6 b-f	530.6 b	584.0 a
	3	558.9 b-e	596.2 bc	619.2 ab	591.4 a	
	6	588.2 bc	610.4 b	691.2 a	629.9 a	
Mean of Mycorrhiza		486.5 c	516.2 b	545.3 a	Mean of FA	
SA * Mycorrhiza	0	431.5f	467.5 ef	493.7 de		
	200	474.3 ef	500.3 de	525.1 cd		
	400	553.7 bc	580.9 ab	617.3 a		
FA * Mycorrhiza	0	446.2 d	489.4 cd	514.8 bc	0	483.5 c
	3	487.6 cd	518.1 bc	535.3 bc	3	513.7 b
	6	525.7 bc	541.2 b	585.9 a	6	550.9 a

Means within a column, row and their interactions followed with the same letters are not significantly different from each other according to Duncan multiple ranges test 5% level

Anthocyanin content (mg/100g F.W.):

Data in table (7) mentioned that foliar application of SA at concentration (200 and 400 mg. L⁻¹) was enhanced anthocyanin concentration in berry juice. The application of 6 g.L⁻¹ FA significantly improved anthocyanin content in berries juice (1.24 mg/100g F.W) as compared with the lowest mean values (0.83 mg/100g F.W).The interaction of 400 mg SA and 6 g.L⁻¹ FA caused to increase anthocyanin content in berries juice the greater value (1.30 mg/100g F.W) and the lowest value (0.79 mg/100g F.W). For the interaction between FA at 6 g. L⁻¹ and mycorrhizae at 100 g. vine⁻¹ were yielded the highest mean anthocyanin content (1.41 mg/100g F.W) as compared with the lowest anthocyanin content (0.72 mg/100g F.W). while the triple combination between 400 mg. L⁻¹ SA + 6 g. L⁻¹ FA + 100 g. vine⁻¹ Mycorrhiza were significantly enhanced anthocyanin content in berries juice producing the highest value (1.53 mg/100g F.W) when compared to the lowest value (0.60 mg/100g F.W) in the control.

Table 7. Impact of salicylic acid, fulvic acid, mycorrhizae and their integrations on anthocyanin (mg/ 100g F. W) in berries juice of grapevine cv. Taifi.

Salicylic acid mg. L ⁻¹	FA g.L ⁻¹	Mycorrhiza (g. vine ⁻¹)			SA * FA	Mean of SA
		0	50	100		
0	0	0.60 d	0.83 c-d	0.94 b-d	0.79 c	0.97 a
	3	0.78 c-d	0.90 b-d	1.26 a-c	0.98 bc	
	6	0.96 b-d	1.20 a-c	1.28 a-c	1.15 a-c	
200	0	0.75 c-d	0.88 b-d	0.91 b-d	0.85 c	1.06 a
	3	0.94 b-d	1.11 a-d	1.16 a-c	1.07 a-c	
	6	1.13 a-d	1.28 a-c	1.42 ab	1.27 a	
400	0	0.81 c-d	0.83 c-d	0.89 b-d	0.84 c	1.06 a
	3	0.95 b-d	1.03 a-d	1.19 a-c	1.05 ab	

	6	1.14 a-d	1.22 a-c	1.53 a	1.30 a	
Mean of Mycorrhiza		0.89 b	1.03 ab	1.17 a		Mean of FA
SA * Mycorrhiza	0	0.78 b	0.97 ab	1.16 a		
	200	0.94 ab	1.09 a	1.16 a		
	400	0.96 ab	1.03 ab	1.20 a		
FA * Mycorrhiza	0	0.72 d	0.85 cd	0.91 cd	0	0.83 c
	3	0.89 cd	1.01 bc	1.20 ab	3	1.03 b
	6	1.07 bc	1.23 ab	1.41 a	6	1.24 a

Means within a column, row and their interactions followed with the same letters are not significantly different from each other according to Duncan multiple ranges test 5% level

Total sugar content (%):

Data in table (8) illustrated that all treatment parameters considerably increased the amount of total sugar percentage in berry juice. 400 mg. L⁻¹ SA (21.7%), 6 g. L⁻¹ FA (19.4%), and 100 g. vine⁻¹ Mycorrhiza (19.1%) produced the highest mean sugar content.

The interactions between 400 mg.L⁻¹SA and 6 g.L⁻¹FA produced the highest value of total sugar in berries juice (23.0 %) as compared with the lowest value (13.5 %) and the interaction of 400 mg.L⁻¹ SA and 100 g.vine⁻¹ Mycorrhiza gave the highest value (23.1 %) as compared with lowest value (13.2.), while the interaction of 6 g.L⁻¹ FA and 100 g.vine⁻¹ Mycorrhiza were highly significant increase in sugar present the greater value (20.3 %) and lowest value (15.4 %). The most effective combination was 400 mg. L⁻¹ SA + 6 g. L⁻¹ FA + 100 g. vine⁻¹ Mycorrhiza, which yielded the maximum total sugar content (24.3 %). This optimal value was dramatically higher than the minimum value (12.2 %) found in the untreated control vines.

Table 8. Impact of salicylic acid, fulvic acid, mycorrhizae and their integrations on total sugar (%) in berries juice of grapevine cv. Taifi.

Salicylic acid mg. L ⁻¹	FA g.L ⁻¹	Mycorrhiza (g. vine ⁻¹)			SA * FA	Mean of SA
		0	50	100		
0	0	12.2 m	13.7 k-m	14.4 j-l	13.5 g	14.3 c
	3	13.0 lm	14.3 j-l	15.1 ij	14.1 g	
	6	14.3 j-l	15.3 ij	16.3 hi	15.3 f	
200	0	15.6 ij	16.3 hi	17.5 gh	16.4 e	18.2 b
	3	17.5gh	18.3 fg	19.2 e-g	18.3 d	
	6	19.4 ef	20.1 de	20.2 de	19.9 c	
400	0	18.3 fg	20.9 c-e	22.0 bc	20.4 c	21.7 a
	3	20.6 c-e	21.8 b-d	23.0 ab	21.8 b	
	6	21.8 b-d	22.7 ab	24.3 a	23.0 a	
Mean of Mycorrhiza		17.0 c	18.2 b	19.1 a		Mean of FA
SA * Mycorrhiza	0	13.2 g	14.5 f	15.3 f		
	200	17.5 e	18.2 de	18.9 d		
	400	20.2 c	21.8 b	23.1 a		
FA * Mycorrhiza	0	15.4 f	16.9 cd	18.0 d	0	16.8 c
	3	17.0 e	18.1 cd	19.1 bc	3	18.1 b
	6	18.5 b-d	19.4 ab	20.3 a	6	19.4 a

Means within a column, row and their interactions followed with the same letters are not significantly different from each other according to Duncan multiple ranges test 5% level

Discussion

The study's findings clearly demonstrate that the physiological, nutritional, and yield parameters of grapevines cv. Taifi were significantly enhanced by the foliar application of salicylic acid (SA) and fulvic acid (FA), either in isolation or in combination with mycorrhizal soil application. The steady increase in every variable that was analyzed, from berry quality to petiole nutrient content, demonstrates the significant beneficial effects of the treatments on grapevine productivity [31 and 19].

One important finding is that the application of SA, FA, and mycorrhizae significantly increased the amount of carbohydrates in canes (Table 1). The main source of energy and the building elements for the growth and development of plants are carbohydrates. One widespread signaling molecule that can improve photosynthetic efficiency and photo assimilates' source-to-sink translocation is SA agree with [32 and 33]. Fulvic acid has the ability to increase photosynthetic rates by improving membrane permeability and facilitating nutrient absorption. By extending the root system, mycorrhizae greatly increase the plant's ability to acquire nutrients and water, which can lower energy costs

associated with root development and increase the amount of carbon stored above ground, such as in cane's carbohydrates. This energy store is essential for the early growth and fruit set of the following season.

The modes of action of the treatments are directly related to the improved nutrient status shown in the petioles (potassium in Table 4, phosphorus in Table 3, and nitrogen in Table 2). A chelating substance called fulvic acid can change soil nutrients into forms that are bioavailable and being fixed, increasing their accessibility for plant uptake agree with [17 and 34]. The root systems of mycorrhizal fungi, which coexist symbiotically with plant roots, are very efficient at scavenging immobile nutrients like zinc and phosphorus and enhancing the uptake of nitrogen and potassium agree with [35]. By promoting root growth and raising the plant's general metabolic activity, SA may have an indirect impact in increasing nutrient content by improving the plant's ability to use the nutrients that FA and mycorrhizae make available. The synergistic effect highlights the complementing processes of these bio stimulants, as the triple interaction (SA+FA+Myco) consistently recorded the highest nutrient levels. The enhanced nutritional and carbohydrate status of the vines directly leads to improvements in yield components, including cluster weight (Table 6) and the number of berries per cluster (Table 5). An excellent environment for flowering, fruit set, and berry development is produced by a higher reserve of carbohydrates and an abundant supply of vital nutrients such as potassium (for sugar transport and enzyme activation) and nitrogen (for vegetative growth and protein synthesis). The higher berry weight most likely comes from improved cell division and expansion during berry development, driven by the improved photo assimilate supply, while the greater number of berries indicates improved fruit set and less flower abortion.

Finally, it is essential for grape production that fruit quality indices such as anthocyanin (Table 7) and total sugar content (Table 8) significantly improve. One of the main sources for the carbohydrates the vine produces is the buildup of sugar in berries. This mechanism is directly strengthened by improved nutrient absorption, specifically potassium, which is essential to sugar translocation, and increased reserves of carbohydrates. Secondary metabolites, anthocyanins, are responsible for the reddish-blue coloration of berries. Their synthesis is influenced by genetic, environmental, and nutritional factors. Given that SA is a phenolic molecule and an important hormone that activates protective and secondary metabolic pathways, as well as having the ability to stimulate the genes involved in anthocyanin production, its use is especially pertinent in this context agree with the results [36 and 37]. Greater plant health and nutrient status (from FA and mycorrhizae) supplied the substrate and energy, and SA served as a signal to direct these resources toward high-quality chemical synthesis therefore, the combination treatment most likely produced a synergistic impact.

Conclusion

The best way to increase the growth, yield, and fruit quality of 'Taifi' grapevines was to apply fulvic acid (6 g. L⁻¹), salicylic acid (400 mg. L⁻¹), and mycorrhizae (100 g. vine⁻¹) all at once. This strategy effectively made use of the separate but complementary functions of each treatment: mycorrhizae as a nutrient collector and root system enhancer, FA as a nutrient solubilize and transporter, and SA as a physiological stimulant and signaling chemical. This study offers strong evidence that employing these sustainable bio stimulants is a practical way to improve fruit quality and vineyard productivity but it need for further studies or broader experiments to obtain validate results.

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استجابة بعض النموات الخضرية، الحاصل ونوعية العناقيد لعنب صنف الطائفي لرش الورقي لحمض ساليسيليك اسيد، حامض فولفيك اسيد و السماد الحيوي

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الخلاصة

أجريت هذه الدراسة خلال موسم النمو (2024) على كرم العنب بعمره عشر سنوات صنف تايفي في مزرعة خاصة تقع في محافظة دهوك، قرية بير بوهار، إقليم كردستان العراق، تم تربية الكروم بتقنية *T-Trills*، زرعت هذه الكروم التي يبلغ عمرها عشر سنوات، على مسافات 2.5×2.5 متر بين الصفوف. استجابة بعض النموات الخضري والمحصول وجودة العناقيد في العنب (*Vitis Vinifera L.*) الرش الورقي بحمض الساليسيليك بتركيز (0، 200 و 400 ملغم/لتر)، وحمض الفولفيك بتركيز (0، 3 و 6 جم/لتر) وإضافة الأسمدة الحيوية (الفطريات الجذرية) على التربة بمستويات (0، 50 و 100 جم/كرمة)، وتأثير التداخل بينها على الصفات المدروسة. خللت البيانات باستخدام تصميم القطاعات العشوائية الكاملة، باستخدام برنامج *SAS*، وقورنت المتوسطات عند مستوى احتمالية 5% باستخدام اختبار دنكان متعدد الحدود (*DMRT*) أظهرت النتائج تحسناً ملحوظاً في جميع المعاملات الثلاث. وبشكل فردي، تم الحصول على أفضل النتائج باستمرار مع أعلى معدلات الاستخدام (400 ملغ لتر⁻¹ *SA*، و 6 غ لتر⁻¹ *FA*، و 100 غ من فطريات الكرمة الجذرية). وقد أظهر استخدامها المشترك تأثيراً تآزرياً قوياً. من حيث محتوى الكربوهيدرات (15.81%)، والسكر الكلي (24.3%)، والأنتوسيانين (1.53 ملغ/100 غرام من الوزن الذري)، ووزن العنقود (691.2 غرام)، وعدد الثمار في العنقود (256.3)، فإن التفاعل الثلاثي المكون من 400 ملغ من حمض الستريك (*6* + *SA*) L^{-7} غرام من حمض الفوليك (*100* + *FA*) L^{-7} غرام من فطريات الجذريات الكرمة (*7* *Cream*) قد أحدث تأثيرات ملحوظة. كما تم الحصول على أعلى محتوى من النيتروجين (1.431%) والفوسفور (0.508%) والبوتاسيوم (1.410%) في أعناق الأوراق باستخدام هذه المعالجة.

الكلمات المفتاحية: الرش الورقي، حامض ساليسيليك، حامض فولفيك، مايكورابزا، نوعية العنب الطائفي.