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Foliar Sprays of Potassium Dihydrogen Phosphate and Their Impact on Yield, Fruit Quality and Controlling Powdery Mildew Disease of Thompson Seedless Grapevines

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Abstract: This investigation was carried out during two successive seasons (2005 and 2006) and included two experiments, the first one (field experiment) was carried out to improve yield and fruit quality of Thompson seedless grape grown under sandy soil condition through foliar sprays of potassium dihydrogen phosphate (KH_2PO_4) at 1 and 1.5% concentrations which sprayed at different periods (every 10, 20 or 30 days). The second experiment (pathological trails) was carried out to study the effect of different potassium dihydrogen phosphate concentrations on spore germination, germ tube length of grape powdery mildew fungi and their diseases infection. Results indicated that, using potassium dihydrogen phosphate as a foliar sprays had a positive effect on leaf mineral content, yield weight and fruit quality of Thompson seedless grapevines specially when sprayed at 1% concentration every 10 days or 1.5% every 20 days from the beginning of April till end of July, such treatments considered the promising under field conditions. On the other hand, a complete inhibition (100%) was recorded with 2.5% concentration of KH_2PO_4 as a tested salt against fungi. Spraying detached leaves with KH_2PO_4 (2.5%) 24 h. before inoculation was more effective than those of 24 h. after inoculation in decreasing values of infection parameters (disease incidence and severity) for powdery mildew, therefore, it was as effective as the fungicide Afugan.

Key words: Thompson seedless grapevines · potassium dihydrogen phosphate · yield · fruit quality · mineral contents · powdery mildew disease

INTRODUCTION

It is well known that most of the new reclaimed area in Egypt are planted with fruit trees especially grapes which considered the second fruit crop in Egypt. The area of the vineyards has increased rapidly through the last few years and reached about 160,005 feddans (one feddan = 4200m^2) (according to the statistics book of Ministry of Agriculture and Land Reclamation, 2005). In Egypt, Thompson seedless grape (*Vitis vinifera,* L.) is considered the leader of grape cultivars and consumed mainly fresh as table grape, so improving fruit quality is a major factor affecting marketing request. Grapes grown under sandy soil conditions have a problem of low productivity due to poor fertility of such soils. Thus, it is highly needed to treat in ways that lead to increase production and improve quality. Many previous studies revealed that P and K sprays especially at form of potassium dihydrogen phosphate enhanced nutritional status and improved yield and quality of different fruit crops. These studies were supported by Shawky *et al.* [1], Abd El-Migeed *et al.* [2] on oranges, Ibrahim *et al.* [3], El-Fangary [4] on mandarin and Saleh and Abd El-Monem [5] on mango.

On the other hand, powdery mildew disease caused by *Uncinula necator* is one of the most serious diseases attacking grapevines. In Egypt, *Uncinula necator* was found on different varieties of grapevines causing considerable losses in crop production [6, 7]. In this respect, powdery mildew is widely spread all over the world where temperature is relatively high and moisture occurs as heavy dews rather than as dashing rains [8, 9]. Many substances had been recommended by several workers as an active method for controlling powdery mildew [10, 12]. Among these materials; potassium dihydrogen phosphate was great effective substance in controlling this disease. Some substances contain relatively high amounts of certain chemical compounds which showed inhibitory effects to various fungi as reviewed by Zedan [13] and Zedan *et al.* [14].

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Therefore, the aim of the two experiments was improving the yield and fruit quality of Thompson seedless grape grown under sandy soil conditions through foliar sprays of potassium dihydrogen phosphate (KH_2PO_4) at different concentrations and periods. Also, study some factors affecting spore germination of the causal pathogen of grape powdery mildew, efficacy of some potassium dihydrogen phosphate concentrations compared with fungicide on both disease incidence and disease severity to control the disease under Egyptian conditions.

MATERIALS AND METHODS

This investigation was carried out during two successive seasons (2005 and 2006) and included two experiments:-

First experiment (field exp.): This experiment was done to investigate the effect of spraying potassium dihydrogen phosphate (KH_2PO_4) on leaf mineral content, yield and fruit quality of 6 years old Thompson seedless grape grown on sandy soil at a private vineyard located in Wadi El-Natron, El-Behera Governorate, Egypt.

The results of soil analysis indicated that pH ranged between 7.7 and 7.9, E.C. between 0.82 and 0.76 dsm^{-1}, $CaCO_3$ ranged between 5.1 and 6.3% and the organic matter between 0.53 and 0.54%. The soil texture was sandy.

For this investigation, 63 vines of almost similar vigor were selected and divided into 7 treatments in three replicates (three vines for each) and arranged in randomized complete block design as the following:

- Control (water spray),
- KH_2PO_4 at 1% every 10 days,
- KH_2PO_4 at 1% every 20 days,
- KH_2PO_4 at 1% every 30 days,
- KH_2PO_4 at 1.5% every 10 days,
- KH_2PO_4 at 1.5% every 20 days,
- KH_2PO_4 at 1.5% every 30 days.

All vines received the normal orchard managements usually practiced in the commercial vineyards located in this area. The application of KH_2PO_4 was carried out as foliar sprays beginning from April to end of July in both seasons.

The following parameters were determined:

- At harvest, number of clusters/vine and yield (kg/vine) were estimated.
- Six clusters were randomly picked from each vine to determine cluster weight (g), fruit weight (g), fruit dimensions (mm), total soluble solids (TSS%) and total acid content (expressed as gm tartaric acid/100 gm juice).
- Leaf mineral contents (total N, P and K %) were determined in petioles from mature leaves (5-7th leaves from shoot top) opposite to basal clusters [15] according to the methods described in Wilde *et al.* [16].

The data were subjected to analysis of variance and Duncan's multiple range test was used to differentiate means [17].

Second experiment (pathological trails):

1 - Laboratory trials

Identification of the causal organism: Fresh leaf specimens representing of Thompson seedless grape showing powdery mildew symptoms were collected from Behera Governorate during 2005 and 2006 seasons. The identification of the causal organism was determined according to Hammouda [18].

Pathogenicity test: Pathogenicity test was carried out in pots (40 cm in diameter) under green house conditions. Disease assessment was calculated as percentages of infected plants after 15 and 30 days of inoculation and reaction to fungal infection was also determined using the method suggested by Barratt and Horsfall [19].

Effect of KH_2PO_4 on spore germination and germ tube length: Percentage of germinated spores was estimated according to El-Naggar [11] as the following formula:

$$\text{Germination \%} = \frac{\text{No. of germinated spores}}{\text{Total No. of spores}} \times 100$$

Whereas germ tube length of germinated spore was measured using slide micrometer 2 mm long (2000 μ).

Effect of KH_2PO_4 on incidence and severity of powdery mildew on detached leaves: Discs (2 cm diameter) of healthy detached leaves of Thompson seedless on distilled water in Petri-dishes were used in this study. Inoculation with powdery mildew conidia on the leaf discs was carried out according to the Lab. technique described by Nagy [20] percentage of infected discs as well as disease severity were determined after 7 days from spraying, according to the methods described by Townsend and Heuberger [21].

2 - Green house trial (*In vivo*)

Effect of foliar spraying with KH_2PO_4 on incidence and severity of powdery mildew: One year old Thompson seedless grape was used in this study. The incidence was determined as the percentage of infected leaves after 7 days from the last spray, whereas, disease severity was determined according to the scale reported by Townsend and Heuberger [21] as follows:

0 = Leaves completely healthy,
1 = 1-2 spots per leaf,
2 = 3-5 spots per leaf,
3 = 6-10 spots per leaf,
4 = Up to 25 percent of the leaf area affected,
5 = Up to 50 percent of the leaf area affected,
6 = Up to 75 percent of the leaf area affected,
7 = More than 75 percent of the leaf area affected.

The percentage of disease severity (D.S.) for each particular treatment was calculated using the following formula:

$$D.S. = \frac{\text{Sum of } (n \times v)}{\text{Total No. of leaves observed in Sample} \times \text{Max. grading}} \times 100$$

Where: n = number of infected leaves in each category. v = numerical value of each category.

Data in these experiments were statistically analyzed using factorial design suggested by Snedecor and Cochran [22]. Least Significant Difference (LSD) at 5% probability was used to compare between treatment averages [23].

RESULTS AND DISCUSSION

First experiment (field exp.):

Leaf mineral content: Results in Table 1 showed the effect of potassium dihydrogen phosphate treatments on N, P and K content in Thompson seedless grape leaves. Generally, all KH_2PO_4 treatments increased N, P and K content in the leaves comparing with the control. This was true in the two seasons of the study. These results are in agreement with those obtained by Abd El-Migeed *et al.* [2] on orange, Eliwa *et al.* [24] on persimmon.

Yield and fruit quality

Yield: Results in Table 2 clearly showed that in the first season, all treatments gave more or less the same values of number of cluster/vine and no differences were detected than the control. While in the second season, treatments 4 and 5 reduced this parameter significantly compared to the other treatments including the control. The average of two seasons showed that the highest value was obtained by spraying KH_2PO_4 at 1.5% every 20 days followed by 1% every 10 days.

Table 1: Effect of KH_2PO_4 sprays on leaf mineral content of Thompson seedless grapevine during 2005 and 2006 seasons

		Nitrogen (%)		Phosphorus (%)		Potassium (%)	
	Treatments	2005	2006	2005	2006	2005	2006
1	Control	2.07c	2.03c	0.09c	0.09c	1.25c	1.27c
2	KH_2PO_4 at 1% every 10 days	2.19a	2.23ab	0.15a	0.15a	1.58a	1.58a
3	KH_2PO_4 at 1% every 20 days	2.02c	2.25a	0.13ab	0.11bc	1.51b	1.50b
4	KH_2PO_4 at 1% every 30 days	2.09b	2.18b	0.15a	0.11bc	1.49b	1.49b
5	KH_2PO_4 at 1.5% every 10 days	2.17a	2.19ab	0.11bc	0.11bc	1.50b	1.51a
6	KH_2PO_4 at 1.5% every 20 days	2.20a	2.23ab	0.15a	0.15a	1.58a	1.58a
7	KH_2PO_4 at 1.5% every 30 days	2.16a	2.18b	0.12b	0.12b	1.49b	1.48b
	Significance at 5% level	S	S	S	S	S	S

Table 2: Effect of KH_2PO_4 sprays on number of clusters/vine, cluster weight and yield weight/vine of Thompson seedless grapevine during 2005 and 2006 seasons

		No. of clusters/vine			Cluster weight (g)			Yield wt./vine (kg)			Increase over
	Treatments	2005	2006	Average	2005	2006	Average	2005	2006	Average	control (%)
1	Control	15.3ab	17.6a	16.5	344g	372e	358	5.2c	6.5c	5.9	---
2	KH_2PO_4 at 1% every 10 days	16.6a	18.0a	17.3	576c	469c	522	9.6ab	8.4ab	9.0	52.0
3	KH_2PO_4 at 1% every 20 days	16.3ab	17.3a	16.8	464f	521a	493	7.5bc	9.0a	8.3	40.0
4	KH_2PO_4 at 1% every 30 days	15.6ab	15.3b	15.5	545d	529a	492	8.5ab	8.1abc	8.3	40.0
5	KH_2PO_4 at 1.5% every 10 days	14.0b	15.0b	14.5	673a	487b	580	9.4ab	7.3bc	8.3	41.0
6	KH_2PO_4 at 1.5% every 20 days	16.3ab	19.3a	17.8	637b	490b	564	10.4a	9.4d	9.9	67.0
7	KH_2PO_4 at 1.5% every 30 days	15.6ab	17.6a	16.6	522e	456d	489	8.1ab	8.0abc	8.1	36.0
	Significance at 5% level	S	S	---	S	S	---	S	S	---	---

Means having the same letters within a column are not significantly different at 5% level

Table 3: Effect of KH_2PO_4 sprays on physical and chemical properties of Thompson seedless grapevine during 2005 and 2006 seasons

		Berry length (mm)		Berry diameter (mm)		Berry weight (g)		TSS (%)		Acidity (%)	
Treatments		2005	2006	2005	2006	2005	2006	2005	2006	2005	2006
1	Control	15.8b	16.2b	12.8b	13.1b	1.90b	1.88d	16.2c	16.3c	0.54a	0.57a
2	KH_2PO_4 at 1% every 10 days	18.0a	18.0a	14.3ab	14.7a	2.45ab	2.37b	18.2ab	18.6a	0.48ab	0.46b
3	KH_2PO_4 at 1% every 20 days	16.7ab	17.9a	13.8ab	14.1ab	2.15ab	2.30bc	17.6ab	17.4abc	0.52ab	0.49b
4	KH_2PO_4 at 1% every 30 days	17.7a	17.7ab	13.4ab	13.6b	2.28ab	2.34b	17.4ab	17.5abc	0.52ab	0.51b
5	KH_2PO_4 at 1.5% every 10 days	17.6a	17.6ab	14.0ab	13.8ab	2.37ab	2.37b	17.6ab	17.6abc	0.50ab	0.51b
6	KH_2PO_4 at 1.5% every 20 days	18.0a	18.0a	14.7a	14.8a	2.59a	2.59a	18.4a	18.2ab	0.46b	0.46b
7	KH_2PO_4 at 1.5% every 30 days	16.6ab	16.5ab	13.3ab	13.2b	2.00ab	2.21c	17.3b	17.2bc	0.51ab	0.50b
	Significance at 5% level	S	S	S	S	S	S	S	S	S	S

Means having the same letters within a column are not significantly different at 5% level

Table 4: Pathogenicity test (infected plants %) on Thompson seedless grape with *Uncinula necator* spores under green house conditions

	Infected plants (%)	
Treatments	15 days after inoculation	30 days after inoculation
Inoculated	35.3	57.5
Control	0.0	0.0
Disease reaction	High susceptible	

As for cluster weight, treatments significantly increased this parameter compared to the control in both studied seasons, where the highest cluster weight was obtained by treatment 5 in the first season, while in the second season treatment 4 followed by treatment 3 gave the best results. However, the average of the two seasons indicted that spraying KH_2PO_4 at 1.5% every 10 days followed by 1.5% every 20 days gave the heaviest cluster.

Regarding yield weight/vine, results revealed that all treatments were effective in increasing yield per vine compared to the control. The highest yield was obtained when KH_2PO_4 was sprayed at 1.50 every 20 days, while the lowest value was obtained by the control. This was true in both seasons of the study and the average of the two seasons. However, the increment in yield caused by potassium dihydrogen phosphate treatments ranged between 36-67% over the control.

The increment in yield weight obtained by KH_2PO_4 sprays could be explained by the improving effect of such treatments on nutritional status of the vines specially the relatively higher leaf NPK% obtained by these treatments which certainly reflected on increasing cluster weight, berry weight and finally yield per vine. These results are supported by Ashour [25] on Anna apple, Abd El-Migeed *et al.* [2] on Hamlin orange, Eliwa *et al.* [24] on Costata persimmon and Elmogy *et al.* [26] on Thompson seedless grapevine, who found that spraying potassium and phosphate increased yield compared to the control plants.

Berries quality: Physical and chemical properties of Thompson seedless grape berries are shown in Table 3.

Physical properties: As for berry length, results indicated that potassium dihydrogen phosphate at any concentration produced longer berries compared with the control. However, spraying KH_2PO_4 at 1% every 10 days or 1.5% every 20 days lengthened berries compared with the other treatments. Similar results were obtained among berry diameter and berry weight, since spraying KH_2PO_4 at 1% every 10 days or 1.5% every 20 days gave the maximum values in both studied seasons and the average of the two seasons.

The above results are in line with those obtained by Elmogy *et al.* [26] who found that potassium spray increased both weight and berry dimensions of Thompson seedless grape. Also the results are in harmony with those finding by Ashour [25] on apple, Abd El-Migeed *et al.* [2] on Hamlin orange.

Chemical properties: As for total soluble solids in berry juice, all treatments significantly increased this parameter compared to the control especially in the first season. The highest percentage was obtained by spraying 1% KH_2PO_4 every 10 days and 1.5% every 20 days. Concerning acidity percentage in berry juice, it was reduced by KH_2PO_4 treatments comparing with the control in both studied seasons.

The obtained results are in line with those reported by Eliwa *et al.* [24] on Costata persimmon, Saleh and Abd El-Monem [5] on Fagri Kalan mango and Elmogy *et al.* [26] on Thompson seedless grape.

From the abovementioned results, it could be concluded that using potassium dihydrogen phosphate as a foliar sprays had a positive effect on leaf mineral content, yield weight and fruit quality of Thompson seedless grapevines specially when sprayed at 1%

Table 5: Effect of different KH_2PO_4 conentrations on spore germination of *Uncinula necator in vitro*, 24 h after inoculation at 25°C and 100% RH

	Germination (%) at KH_2PO_4 conc. (%)					Reduction * (relative to the control)				
Treatments	0.5	1.0	1.5	2.0	2.5	0.5	1.0	1.5	2.0	2.5
Commercial (75%)	45.00	36.30	31.90	17.40	0.00	35.50	48.40	54.30	75.10	100.00
Pure (100%)	35.30	32.50	22.60	9.60	0.00	49.40	53.40	67.60	86.20	100.00
Afugan	16.20	12.00	0.00	0.00	0.00	76.80	82.80	100.00	100.00	100.00
Control (water only)	69.80	69.80	69.80	69.80	69.80	0.00	0.00	0.00	0.00	0.00
LSD at 5% level	5.70	3.95	3.22	2.90	----	5.35	6.13	8.24	4.11	----

* Reduction = Control-treatment×100, Control

Table 6: Effect of KH_2PO_4 concentrations on germ tube length of *Uncinula necator in vitro*, 24 h after inoculation at 25°C and 100% RH

	Germ tube length (µ) at KH_2PO_4 conc. (%)					Reduction (relative to the control)				
Treatments	0.5	1.0	1.5	2.0	2.5	0.5	1.0	1.5	2.0	2.5
Commercial (75%)	32.70	31.80	29.50	22.90	0.00	17.20	19.50	25.30	42.00	100.00
Pure (100%)	28.60	24.00	23.30	19.80	0.00	27.60	39.20	41.00	49.90	100.00
Afugan	12.50	7.60	0.00	0.00	0.00	68.40	80.80	100.00	100.00	100.00
Control (water only)	39.50	39.50	39.50	39.50	39.50	0.00	0.00	0.00	0.00	0.00
LSD at 5% level	3.75	2.65	3.77	2.60	---	3.33	2.40	2.96	3.80	---

Table 7: Effect of spaying with KH_2PO_4 at 2.5% on powdery mildew incidence and severity on detached Thompson seedless grape leaves, artificially inoculated with *Uncinula necator*, 24 h after or before spraying

	(%) Disease incidence		(%) Disease severity	
Treatments	24 h before inoculation	24 h after inoculation	24 h before inoculation	24 h after inoculation
Commercial (75%)	43.10	47.30	32.00	39.60
Pure (100%)	16.70	25.30	13.20	17.50
Afugan	12.30	13.20	10.50	12.60
Control (water only)	66.50	64.00	55.20	63.50
LSD at 5% level	3.43	4.14	2.80	2.41

concentration every 10 days or 1.5% every 20 days from the beginning of April till end of July, which considered the promising treatments under such conditions.

Second experiment (pathological trails)

Identification of the causal organism: Identification trials were carried out according to the conidial stage characteristics [27].

Pathogenicity test: Data in Table 4 indicated that the percentage of infected plants was increased by aging of plants from 15 to 30 days after inoculation. In this respect, Czerniawska *et al.* [28] reported that Thompson seedless grapevine was highly susceptible to powdery mildew disease.

Effect of KH_2PO_4 on spore germination and germ tube of *Uncinula necator.*: Data obtained in Table 5 and 6 show that all tested concentrations of potassium dihydrogen phosphate (KH_2PO_4)were effective in decreasing spore germination percentage and germ tubes length especially under 2.5% compared with the control treatment (water only). However, the commercial and pure salt as well as Afugan fungicide inhibited spore germination and germ tubes length when applied at high concentration (25 g l^{-1}. water).

These results are in agreement with those obtained by Steinhauer and Besser [29]; Seddon and Schmitt [30] and Nair and Arora [31].

The superiority of KH_2PO_4 may be due to: (1) Changing in physio-chemical properties of the salt such as viscosity, pH, acidity …etc. due to the appearance of new compounds and disappearance of the others by heat effectiveness, (2) The high release of the antifungal toxic compounds by heat, (3) High temperature might help anther toxic substance of antifungal effect.

Effect of KH_2PO_4 on incidence and severity of powdery mildew on detached leaves: Spraying Thompson seedless grape detached leaves with KH_2PO_4 at 2.5%, 24 h. before (preventive treatment) or after (curative treatment) artificial inoculation with conidiospores of *Uncinula necator* resulted in significant reduction regarding percentages of disease incidence and severity of powdery mildew comparing with water spray (Table 7).

Table 8: Effect of foliar spraying with KH_2PO_4 on disease and severity of powdery mildew Thompson seedless grape plants, 7 days after artificial inoculation with *Uncinula necator* spores, under green house conditions

Treatments*	Disease** incidence (%)	Reduction*** (%)	Disease severity (%)	Reduction (%)
Commercial (75%)	31.90	60.90	37.20	50.10
Pure (100%)	24.10	70.50	28.80	61.30
Afugan	19.50	76.10	25.70	65.50
Control (water only)	81.60	---	74.50	---
LSD at 5% level	3.55	2.45	5.21	1.86

*Plants were sprayed weekly for 4 weeks with KH_2PO_4 salt, ** Disease incidence and severity were determined 7 days after the last fourth spray treatment, *** Reduction relative to the control (spraying with water only)

Applying potassium dihydrogen phosphate, 24 h. before spores inoculation gave the highest significant reduction concerning the percentage of disease incidence and disease severity. Contrarily, commercial KH_2PO_4 was the least effective treatment on disease incidence and severity. These results are in full accordance with those obtained by Singh and Prithiviraj [32]; Abo-Zied [33] and Sallam, Minaas [34].

Effect of spraying with KH_2PO_4 on powdery mildew disease parameter: Spraying with potassium dihydrogen phosphate significantly decreased powdery mildew infection parameter (incidence and severity) on Thompson seedless grape comparing with water spray only (Table 8). Pure KH_2PO_4 salt (100%) was more effective than those of commercial one (75%) in decreasing disease infection parameters. Percentages of reductions rather than the control for both disease incidence and severity ranged between 70.5 and 61.3%, respectively, in case of pure (100%), while they were 60.9 and 50.1% respectively, with the commercial (75%). On the other hand, reduction percentages in incidence and severity powdery mildew occurred with Afugan fungicide were 76.1 and 65.5% [8, 34-37].

According to the above results obtained from both experiments, it is clear that the efficiency of using potassium dihydrogen phosphate under field conditions was achieved when sprayed at 1.0% every 10 days or 1.5% every 20 days, while it was 2.5% under the pathological trails conditions, it was noticed with 2.5%. So, we suggest more studies under field conditions using higher concentrations of potassium dihydrogen phosphate than 1.5% with different application periods.

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