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Annals of Agricultural Science, Moshtohor (ASSJM)
https://assjm.journals.ekb.eg/

ISSN:1110-0419

Original Article Vol. 62(4) (2024), 161 – 178 DOI: 10.21608/assjm.2025.346462.1333

Effect of Different Potassium Forms (With/Without Bio-K) on Vegetative Growth and Nutritional Status of Naomi Mango Trees in Menofyia Governorate

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Abstract

This study investigated the effect of different **Potassium forms with or without bio-K o**n vegetative growth and nutritional status of mango trees "Naomi" cv. The specific and interaction effects of the two studied factors were evaluated. The vegetative growth (Shoot length and average leaf area) as well as nutritional status (Total chlorophyll and leaf (N, P, K, Ca, Mg as percentages" %") and (Fe, Zn and Mn part per million "ppm") were determined. The combination of foliar spraying with potassium (acetate, 3 cm/L) + soil drench application of Bio-K proved to be the most effective treatment for most of the parameters examined in this study. Treated Naomi mango trees with Bio-K only or potassium "K" (acetate) and interaction between them affected significantly all evaluated measurements. Also, it gave the highest values in all leaf mineral contents and total chlorophyll (SPAD) compared to the control. Results of leaf nutritional status characteristics and total chlorophyll (SPAD) took, to some extent, a similar trend to that of growth traits. On the contrary, the response trend took the other way around with P concentrations that showed a progressive increase with the gradual increase in untreated "control" treatments without or with Bio-K.

Keywords: Naomi, Mango, acetate, citrate, phosphate; nitrate and Mono potassium phosphate, Vegetative growth and nutritional status

Introduction

A member of the Anacardaceae family, mangoes (*Mangifera indica* L.) are indigenous to Southeastern Asia and are regarded as one of the most significant evergreen fruits in tropical and sub-tropical regions. Its rich and delectable flavor (taste and aroma) makes it one of the most well-liked and well-known fruits. According to **Galan-Sauco (1993)**, the mango is regarded as the king of fruits. The mango is ranked third among all fruit crops worldwide. There are 2.5 million hectares of cultivated land worldwide. Approximately 56 million tons of fruits are produced there (**FAO, 2020**).

One of the most widely grown tropical fruit crops in the Arab Republic of Egypt is the mango. Mango trees were brought to Egypt in 1825, and since then, their cultivation has spread slowly throughout the nation, making them one of the most popular fruits farmed there, currently coming in third place behind grape and citrus harvests. According to the **Ministry of Agriculture and Land Reclamation (2022)**, Egypt's entire cultivated area was 326626 feddans, yielding around 1280310 tons. The governorates of Ismailia, Noubaria, Cairo, Ismailia and Sharkia are the main locations for production. The Naomi tree is generally upright and of medium size. The leaves are reddish-brown when young. The seed has only one embryo. The flesh has a moderate flavor, is yellow in color, and has no fiber. The medium-sized fruits are oval and rectangular in shape, and when ripe, they change color. According to **Tomer *et al*. (1993)**, Naomi is a mango that is in season.

Potassium (K) is the most abundant inorganic cation, and it is important for ensuring optimal plant growth **(White and Karley, 2010**). Potassium is an essential element with roles in plant growth and final yield as it controls ionic balance, protein synthesis, photosynthesis, stress tolerance, translocation of photosynthates, and activation of several plant enzymes (**Marschner 1997**, **Stino et al 2011**). Potassium has a special role in flowering, fruiting, and the formation of starch K is also very important for cell growth, which is an important process for the function and development of plants **(Hepler et al., 2001).** In terms of the growth-promoting mechanism of K, it is generally agreed that K stimulates and controls ATPase in the plasma membrane to generate acid stimulation, which then triggers cell wall loosening and hydrolase activation **(Oosterhuis et al., 2014)**, thus promoting cell growth. K has strong mobility in plants and plays an important role in regulating cell osmotic pressure and balancing the cations and anions in the cytoplasm **(Kaiser, 1982; Hu et al., 2016).** Potassium nutrition is one of the most important problems facing organic agriculture because most natural sources of K are poorly soluble, which reduces plant uptake (**Bolland et al., 2000 and Ciceri et al., 2019).** The use of bio-fertilizers, which are applied to soil or plants, is an effective approach to minimize the application of chemical fertilizers and increase food safety for human consumption **(Meena et al., 2016, Toumi et al., 2016 and Youssef et al., 2017).**

Micronutrients are essential for the translocation of macronutrients and for a variety of plant metabolic processes, including respiration, the construction of cell walls, the production of chlorophyll, photosynthesis, hormone synthesis, nitrogen fixation, and enzyme activity (**Das, 2003**). Using K, Ca, and B efficiently boosted fruit set, fruit retention, and fruiting features. Co-application of Ca and B at 3.0 m/L has a beneficial effect on pollen germination and fruit set. Even when boron (B) is abundant, several illnesses are associated with B insufficiency, indicating that these disorders are physiological in character and have to do with the mobility of B in plant tissues. Furthermore, fruit B content is responsible for fruit setting and fruit retention percentage (**Tohidloo and Souri, 2009**).

Thus, this study aimed to evaluate the effect of different potassium sources on the vegetative growth and nutritional status of Naomi mango trees.

Materials and Methods

This study was carried out on seven-year-old Naomi mango trees in a private orchard located in El-Khatatbeh region, El-Sadat City, Minoyfia Governorate (30°22`31.4" N. 30°38`55.3" E) during the 2023 and 2024 seasons. The trees were planted on sandy soil at 2x3 meters, with drip irrigation.

Table (a): The maximum and minimum temperature and rain data for the whole year as an average taken from the last 12+ years of historical data for Menouf district.

Month	Day	Night	Rain Days
January	19°C	10°C	1
February	21°C	10°C	1
March*	25°C	12°C	1
April*	29°C	14°C	0
May*	34°C	18°C	0
June*	36°C	22°C	0
July*	37°C	23°C	0
August	37°C	23°C	0
September	35°C	22°C	0
October	31°C	20°C	1
November	26°C	16°C	1
December	21°C	12°C	1

***Average weather in Menouf during treatment periods (World WeatherOnline.com.)**

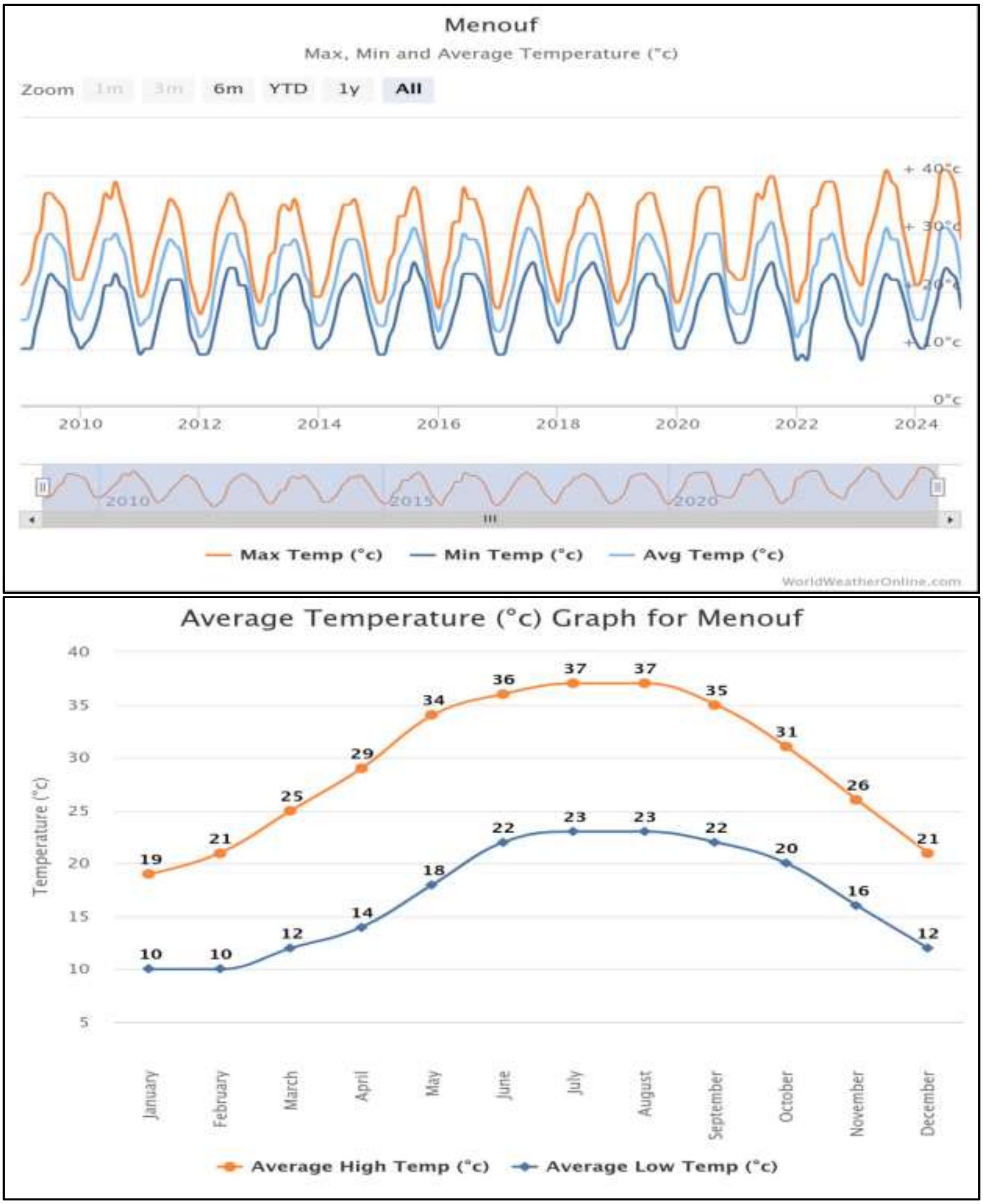

Fig. (1): The maximum and minimum temperature and rain data for the whole year as an average taken from the last 12+ years of historical data for Menouf district.

Some physical and chemical properties of the soil used by study experiment are shown in Table (a) according to the methods described by (**Page *et al.*, 1982**).

Table (a). The physical and chemical analysis of the soil used by study .

S.P.	E.C.	pH	Cations (meq/L)				Anions (Meq/L)			
	(d.S/m)		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}
25	4.19	7.05	24.24	10.84	10.08	0.59	--	1.89	17.8	26.06

Two factors were included in the factorial experiment: the first was with or without biofertilizers via soil additional and the second one was some forms of potassium were sprayed and combinations.

The following therapies were used in this study:

Without (Bio-K) foliar spray only	With (Bio-K) + soil addition
1- Control (trees sprayed with tap water)	2- Control (trees sprayed with tap water)
3 - Potassium acetate 3 cm/L	4- Potassium acetate 3 cm/L
5- Potassium citrate 3 cm/L	6- Potassium citrate 3 cm/L
7- Potassium phosphate 3 cm/ L	8- Potassium phosphate 3 cm/ L
9- Potassium nitrate 3 g/L	10- Potassium nitrate 3 g/L
11- Mono potassium phosphate 3 g/L	12- Mono potassium phosphate 3 g/L

Experimental layout:

The differential treatments (combinations between two parameters included in this study) were arranged using a randomized complete block design with three replications (3 trees/ replication). As a result, the projected number of trees needed for each study was as follows: To represent soil addition without or with Bio-K and (Potassium acetate, citrate, phosphate, nitrate, and Mono potassium phosphate) foliar spray under sandy soil conditions, thirty-six healthy uniformed and disease/insect-free Naomi mango trees were carefully chosen. During the first week of January to May (four doses) in the two experimental seasons, soil was added with Bio-K. Additionally, foliar sprays of various solutions, including tap water spray (control), were applied five times a year in early March to July in the two experimental seasons, respectively, in 2023 and 2024. Three liters of spray solution per tree were sufficient in this respect, however each treatment's spray solution was administered until it run off.

To assess the specific and interaction impacts of two factors under study in either the first or second experimental seasons, the following measurements were examined to see how they changed (reacted):

1. Vegetative growth parameters:

In this case, shoot length and average leaf area (cm^2) were the two growth indicators evaluated for the Naomi mango trees. These measurements were taken during the last week of September.

2- Total chlorophyll and the amount of N, P, K, Ca, Mg, Fe, Mn, and Zn in the leaves indicate the nutritional status:

During the final week of September during the two experimental seasons, samples of the spring-flushed shoots' fully grown leaves were taken. After being roughly washed with moist rags, distilled water was added, and it was dried in an electric oven set at 80 degrees Celsius until its weight remained constant. Finally, to prevent any metal contamination, it was pulverized using a stainless-steel mill. As explained by **Chapman and Pratt (1961)**, a mixture of sulphoric and percholoric acids was used to wet digest roughly 0.5 g of dry matter from leaves.

Total N was measured using a micro Kjeldahl by **Pregl (1945)**, and phosphorus was measured using a Spekol spectrophotometer set at 882.0 UV following **Murphy and Riely (1962)** technique. The Flam photometer was used to calculate K following **Chapman and Pratt (1961)**. But according to **Jackson (1973) and Wild *et al.* (1985)**, atomic absorption (3300) was used to identify Ca, Fe, Mg, Mn and Zn respectively.

- Statistical Analysis:

Analysis of variance was performed on the data collected from each experiment over both experimental seasons, and significant differences between means were identified (**Snedecor and Cochran, 1980**). Additionally, Duncan's multiple test range (**Duncan, 1955**) was employed to differentiate significant differences among means. The values of specific and interaction effects were denoted by capital and small letters, respectively.

Results and Discussions

Two vegetative growth parameters (shoot length and average leaf area) were measured to examine how Naomi mango trees responded to foliar application and soil addition, either with or without Bio-K rates and various forms of K (acetate, citrate, phosphate 3 cm/l; nitrate and Mono potassium phosphate 3 g/L).

Vegetative growth measured parameters:

A. Specific effect:

Data obtained in Table (1) and Figs. (1 and 2) showed the effect of the two elements under investigation (without or with Bio-K rates) and forms of K on the two parameters under investigation (shoot length and average leaf area) of Naomi mango plants. According to the data in Table (1) and Figs. (1 and 2), the two factors under examination were moving in tandem and with equal magnitude in their effects on the two parameters under investigation (shoot length and average leaf area) compared with control treatment during the first and second seasons, respectively. Comparing the two metrics under investigation with and without Bio-K, the foliar spray for Bio-K and soil addition were linked to the greatest significant values of the two previously mentioned parameters. During both study seasons, T2 with the Bio-K tree achieved the highest results in this regard, indicating that it was the superior level during the first and second seasons.

B. Interaction effect:

Concerning the interaction between the two investigated factors without or with Bio K and forms from K foliar and soil addition (acetate, citrate, phosphate 3 cm/l; nitrate and Mono potassium phosphate 3 g/l) on the two vegetative investigated parameters (shoot length and average leaf area) of Naomi mango trees, data presented in Table (1) and Figs. (1 and 2) revealed that the maximum values of the two investigated were detected with the combination between with Bio-K + acetate or citrate foliar spray at 3 cm/l during both the 2023 and 2024 seasons of study.

Table 1. Effect of various K forms foliar sprays (with or without Bio-K added to the soil) and their interactions on Naomi mango trees shoot length (cm) during the 2023 and 2024 experimental seasons.

Soil addition (Bio-K)	Shoot length (cm)					
	First season; 2023		Mean*	Second season; 2024		Mean*
Foliar spray	Without (Bio-K)	With (Bio-K)		Without (Bio-K)	With (Bio-K)	
T1. Control (trees sprayed with tap water)	11.01k	11.26j	**11.13F**	11.07j	11.31i	**11.19E**
T2. Potassium acetate 3 cm/L	14.98c	15.29a	**15.14A**	14.27d	15.40a	**14.84A**
T3. Potassium citrate 3 cm/L	14.10e	15.29a	**14.69C**	14.23d	15.29b	**14.76B**
T4. Potassium phosphate 3 cm/ L	12.44g	13.24f	**12.84D**	12.54f	13.22e	**12.88C**
T5. Potassium nitrate 3 g/L	14.44d	15.19b	**14.82B**	14.47c	15.28b	**14.87A**
T6. Mono potassium phosphate 3 g/L	12.03i	12.33h	**12.18E**	12.18h	12.41g	**12.29D**
Mean**	**13.17B**	**13.77A**		**13.13B**	**13.82A**	
	Leaf area (cm^2)					
T1. Control (trees sprayed with tap water)	56.86j	58.66i	**57.76F**	56.87j	57.22j	**57.04E**
T2. Potassium acetate 3 cm/L	79.47b	82.24a	**80.85A**	78.91c	84.06a	**81.48A**
T3. Potassium citrate 3 cm/L	72.78b	79.50b	**76.14C**	72.29e	80.47b	**76.38B**
T4. Potassium phosphate 3 cm/ L	65.16f	70..03e	**67.59D**	63.65g	63.68f	**66.67C**
T5. Potassium nitrate 3 g/L	74.17c	79.27b	**76.72B**	73.43d	79.03c	**76.23B**
T6. Mono potassium phosphate 3 g/L	59.97h	60.61g	**60.29E**	59.83i	60.38h	**60.10D**
Mean**	**68.07B**	**71.72A**		**67.50B**	**71.81A**	

- Means within a column or row having the same letters are not significantly different according to Duncan's New Multiple Range t-tests at 5 % level.

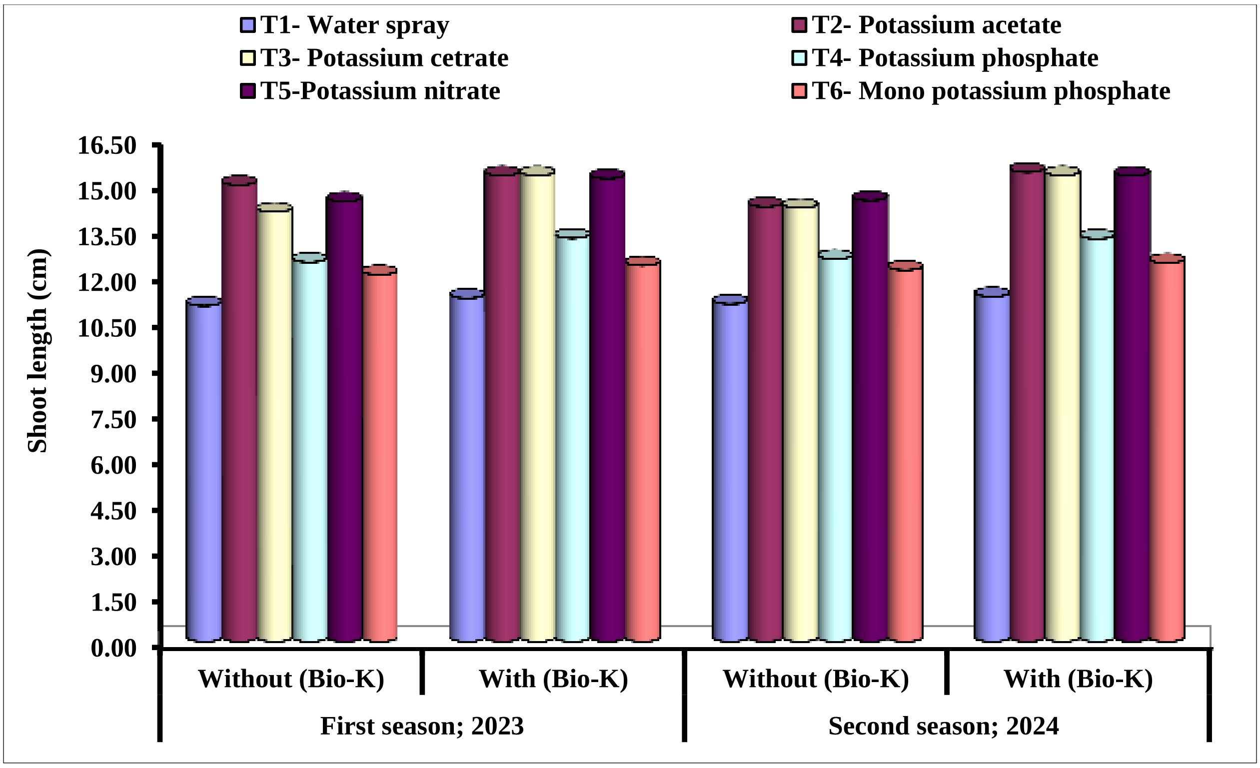

Fig. (1): Effect of various K forms foliar sprays (with or without Bio-K added to the soil) and their interactions on Naomi mango trees shoot length (cm) in the 2023 and 2024 experimental seasons.

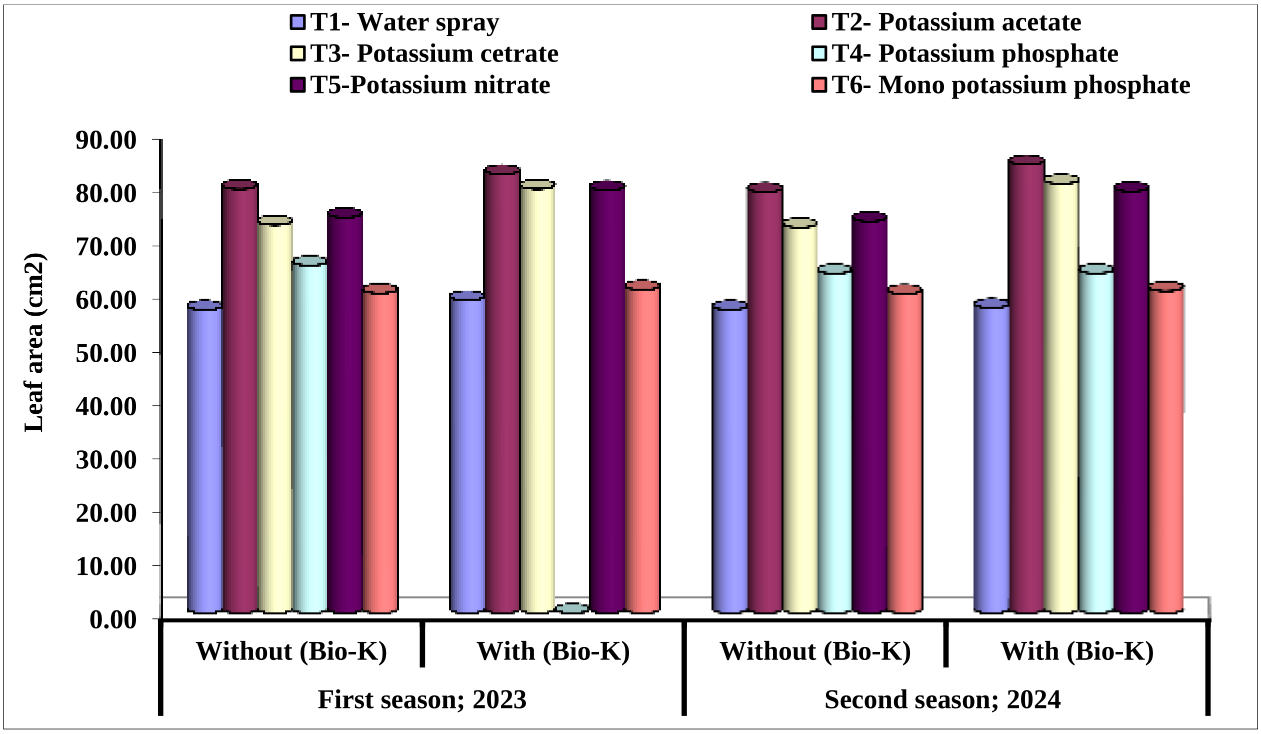

Fig. (2): Effect of various K forms foliar sprays (with or without Bio-K added to the soil) and their interactions on Naomi mango trees leaf area (cm^2) in 2023 and 2024 experimental seasons.

2- Nutritional status:

a) Total chlorophyll (SPAD):

A. Specific effect of leaf minerals:

The results are shown in Table (2) and Figs. (3, 4, and 5) regarding the specific effect of the two studied factors (with or without Bio-K) and five forms of potassium; i.e. "acetate, citrate, phosphate, nitrate, and mono-potassium phosphate" on the total chlorophyll content of Naomi mango trees, indicate that the use of Bio-K as a foliar or soil addition with Bio-K outperformed without Bio-K in this study. This treatment led to an increase in the total chlorophyll content of the leaves during the two successive seasons.

B. Interaction effect:

Regarding the effect of the interaction between the two studied factors, with or without bio-potassium and five different forms of potassium as a foliar spray or soil addition, on the total chlorophyll content in the leaves of Naomi mango trees. The data presented in Table (2) and Figs. (3, 4, and 5) clearly show that the combination of potassium acetate as foliar spray + bio-K as soil addition was the best, as it significantly increased the total chlorophyll content in the leaves of the Naomi mango tree during the two academic seasons.

a) Macro-elements (N, P, K, Ca and Mg %) contents: -

A. Specific effect of leaf minerals:

The results are shown in Table (2) and Figs. (3, 4 and 5) regarding the specific effect of the two studied factors (with or without Bio-K) and five forms of potassium in different forms: "acetate, citrate, phosphate; nitrate, and mono-potassium phosphate" on the nitrogen and phosphorus content of the leaves of Naomi mango trees indicated that the recorded data showed that the using of Bio-K as a soil addition with Bio-K outperformed without Bio-K, as this treatment led to an increase in the nitrogen content of the leaves during both seasons. On the contrary, the results recorded in Table (2) and Figs. (3, 4, and 5) for the phosphorus element during the two study seasons, respectively.

Table 2. Effect of different forms of K (foliar spray), soil addition, and interaction effect total chlorophyll (SPAD); N and P (%) concentrations of Naomi mango trees during 2023 and 2024 seasons.

Soil addition (Bio-K)	Total chlorophyll (SPAD)					
	First season; 2023		Mean*	Second season; 2024		Mean*
Foliar spray	Without (Bio-K)	With (Bio-K)		Without (Bio-K)	With (Bio-K)	
T1. Control (trees sprayed with tap water)	37.28k	37.48k	**37.38F**	36.39l	37.36k	**36.88E**
T2. Potassium acetate 3 cm/L	44.31d	47.95a	**46.13A**	43.85d	47.88a	**45.86A**
T3. Potassium citrate 3 cm/L	42.12f	46.22b	**44.17B**	41.94f	45.47b	**43.71B**
T4. Potassium phosphate 3 cm/ L	40.50h	41.77g	**41.14D**	40.19h	41.03g	**40.61C**
T5. Potassium nitrate 3 g/L	42.46e	44.96c	**43.71C**	41.54e	44.69c	**43.62B**
T6. Mono potassium phosphate 3 g/L	38.87j	39.63i	**39.25E**	38.01j	39.45i	**37.73D**
Mean**	**40.92B**	**43.00A**		**40.49B**	**42.65A**	
			N (%)			
T1. Control (trees sprayed with tap water)	2.02l	2.11k	**2.07F**	2.03j	2.17i	**2.10F**
T2. Potassium acetate 3 cm/L	2.61d	2.85a	**2.73A**	2.65c	2.89a	**2.77A**
T3. Potassium citrate 3 cm/L	2.49f	2.73b	**2.61B**	2.50e	2.76b	**2.63B**
T4. Potassium phosphate 3 cm/ L	2.33h	2.41g	**2.37D**	2.36f	2.48e	**2.42D**
T5. Potassium nitrate 3 g/L	2.53e	2.65c	**2.59C**	2.53d	2.67c	**2.60C**
T6. Mono potassium phosphate 3 g/L	2.19j	2.25i	**2.22E**	2.21h	2.29g	**2.25E**
Mean**	**2.36B**	**2.50A**		**2.38B**	**2.54A**	
			P (%)			
T1. Control (trees sprayed with tap water)	0.250a	0.246ab	**0.248A**	0.251a	0.249a	**0.250A**
T2. Potassium acetate 3 cm/L	0.225c-e	0.218e	**0.222C**	0.225bc	0.220c	**0.222D**
T3. Potassium citrate 3 cm/L	0.227b-e	0.218e	**0.223C**	0.226bc	0.223bc	**0.225CD**
T4. Potassium phosphate 3 cm/ L	0.235a-e	0.230b-e	**0.233BC**	0.237a-c	0.233a-c	**0.235BC**
T5. Potassium nitrate 3 g/L	0.226c-e	0.222de	**0.224C**	0.225bc	0.223bc	**0.224CD**
T6. Mono potassium phosphate 3 g/L	0.243a-c	0.241a-d	**0.242AB**	0.247a	0.241ab	**0.244AB**
Mean**	**0.234A**	**0.229A**		**0.235A**	**0.231A**	

- Means within a column or row having the same letters are not significantly different according to Duncan's New Multiple Range t-tests at a 5 % level.

Also, regarding the specific effect of the studied factors (with or without Bio-K and five forms of potassium in different forms; acetate, citrate, phosphate; nitrate, and mono-potassium phosphate" on the leaf content of potassium, calcium, and magnesium elements in Table (3) and Figs. (6, 7, and 8), the using of potassium in its five forms is better than the control, without or with Bio-K, as it recorded the highest significant values in the leaf content of potassium, calcium, and magnesium elements during both seasons of the study.

B. Interaction effect:

Regarding the interaction effect on the nitrogen content in the leaves of Naomi mango trees, between with Bio-K or without Bio-K and different forms of potassium (acetate, citrate, phosphate; nitrate and mono-potassium phosphate). The data shown in Table (2) and Figs. (3, 4, and 5) indicated that the best combination was the one containing and using Bio-K and potassium acetate during both seasons, respectively. In reverse, it was evident from the results how the phosphorus element performed during the research seasons.

The data shown in Table (3) and Figs. (6, 7, and 8), illustrated the effect of the interaction between the two studied factors (without or with Bio-K and five forms of potassium in different forms: "acetate, citrate, phosphate; nitrate, and mono-potassium phosphate" on the leaf content of potassium, calcium, and magnesium in the leaves of Naomi mango trees. The recorded data indicate that the use of soil addition with Bio-K + potassium acetate outperformed all the different treatments during the two study seasons, as this treatment had the highest concentration of potassium, calcium, and magnesium in the leaf content during the two study seasons, respectively.

Table 3. Effect of different forms of K (foliar spray), soil addition, and interaction effect on K, Ca, and Mg (%) concentrations of Naomi mango trees during the 2023 and 2024 seasons.

Soil addition (Bio-K)	K (%)					
	First season; 2023		Mean*	Second season; 2024		Mean*
Foliar spray	Without (Bio-K)	With (Bio-K)		Without (Bio-K)	With (Bio-K)	
T1. Control (trees sprayed with tap water)	2.19k	2.21k	**2.20F**	2.17i	2.18i	**2.18F**
T2. Potassium acetate 3 cm/L	2.59d	2.95a	**2.77A**	2.58d	2.92a	**2.75A**
T3. Potassium citrate 3 cm/L	2.49f	2.82b	**2.66B**	2.46f	2.83b	**2.65B**
T4. Potassium phosphate 3 cm/ L	2.39h	2.44g	**2.41D**	2.38g	2.44f	**2.41D**
T5. Potassium nitrate 3 g/L	2.53e	2.65c	**2.59C**	2.51e	2.63c	**2.57C**
T6. Mono potassium phosphate 3 g/L	2.27j	2.34i	**2.31E**	2.29h	2.29h	**2.29E**
Mean**	**2.41B**	**2.57A**		**2.40B**	**2.55A**	
	Ca (%)					
T1. Control (trees sprayed with tap water)	1.21l	1.28k	**1.24F**	1.23l	1.26k	**1.24E**
T2. Potassium acetate 3 cm/L	1.62d	1.91a	**1.76A**	1.58d	1.85a	**1.72A**
T3. Potassium citrate 3 cm/L	1.51f	1.78b	**1.65B**	1.49f	1.73b	**1.61B**
T4. Potassium phosphate 3 cm/ L	1.42h	1.46g	**1.44D**	1.39h	1.44g	**1.41C**
T5. Potassium nitrate 3 g/L	1.55e	1.69c	**1.62C**	1.53e	1.66c	**1.60B**
T6. Mono potassium phosphate 3 g/L	1.32j	1.37i	**1.35E**	1.29j	1.35i	**1.32D**
Mean**	**1.44B**	**1.58A**		**1.42B**	**1.55A**	
	Mg (%)					
T1. Control (trees sprayed with tap water)	0.449h	0.456gh	**0.45D**	0.449h	0.456gh	**0.45D**
T2. Potassium acetate 3 cm/L	0.542d	0.671a	**0.61A**	0.544d	0.669a	**0.61A**
T3. Potassium citrate 3 cm/L	0.486f	0.643b	**0.56B**	0.489f	0.638b	**0.56B**
T4. Potassium phosphate 3 cm/ L	0.472fg	0.476fg	**0.47C**	0.468gh	0.474fg	**0.47C**
T5. Potassium nitrate 3 g/L	0.516e	0.615c	**0.56B**	0.517e	0.612c	**0.56B**
T6. Mono potassium phosphate 3 g/L	0.465f-h	0.471fg	**0.47C**	0.463gh	0.466gh	**0.46CD**
Mean**	**0.49B**	**0.56A**		**0.49B**	**0.55A**	

- Means within a column or row having the same letters are not significantly different according to Duncan's New Multiple Range t-tests at a 5 % level.

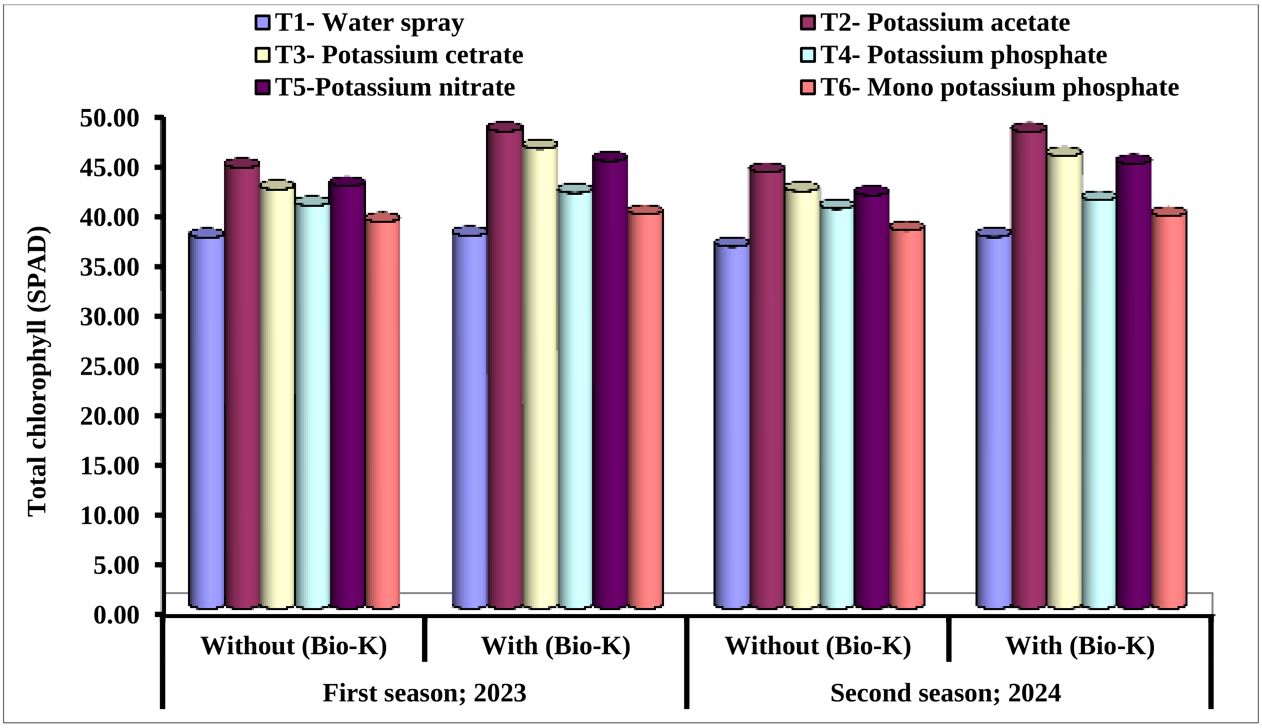

Fig. (3): Effect of different forms of K (foliar spray), soil addition, and interaction effect total chlorophyll (SPAD) concentrations of Naomi mango trees during the 2023 and 2024 seasons.

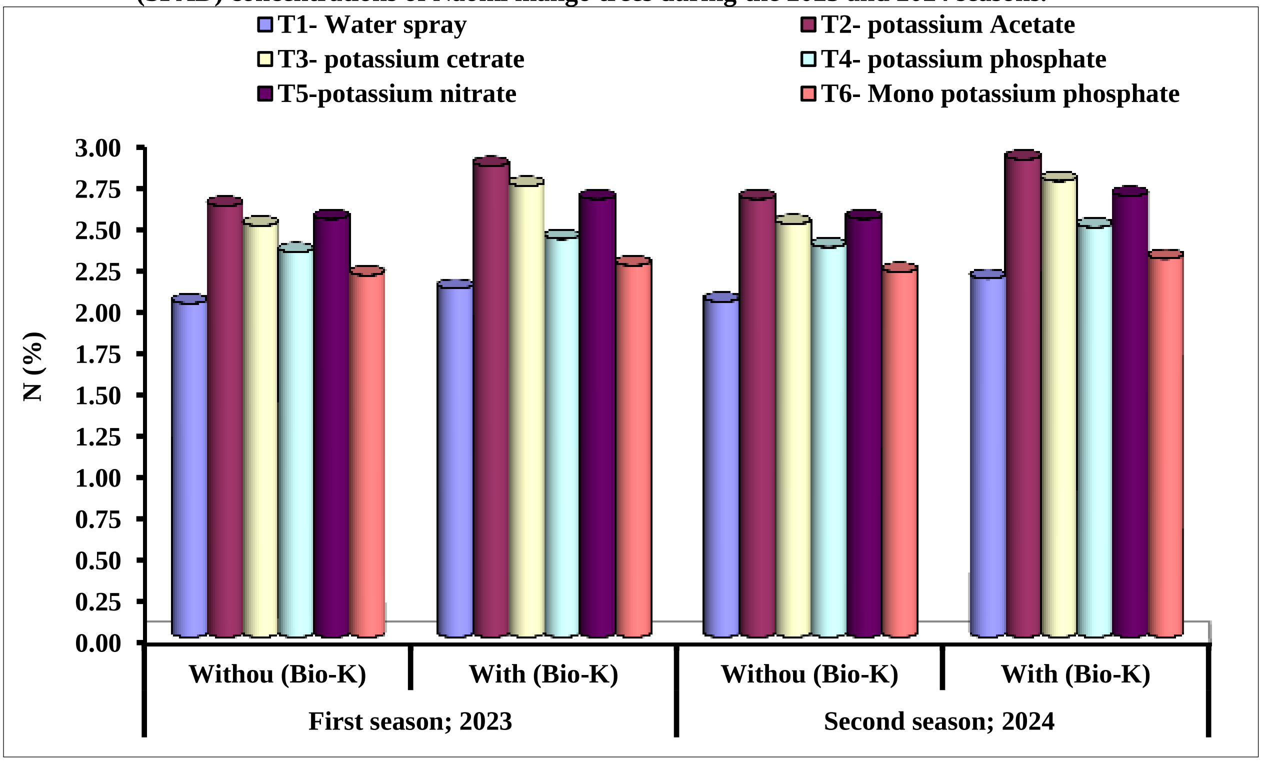

Fig. (4): Effect of different forms of K (foliar spray), soil addition, and interaction effect N (%) concentrations of Naomi mango trees during the 2023 and 2024 seasons.

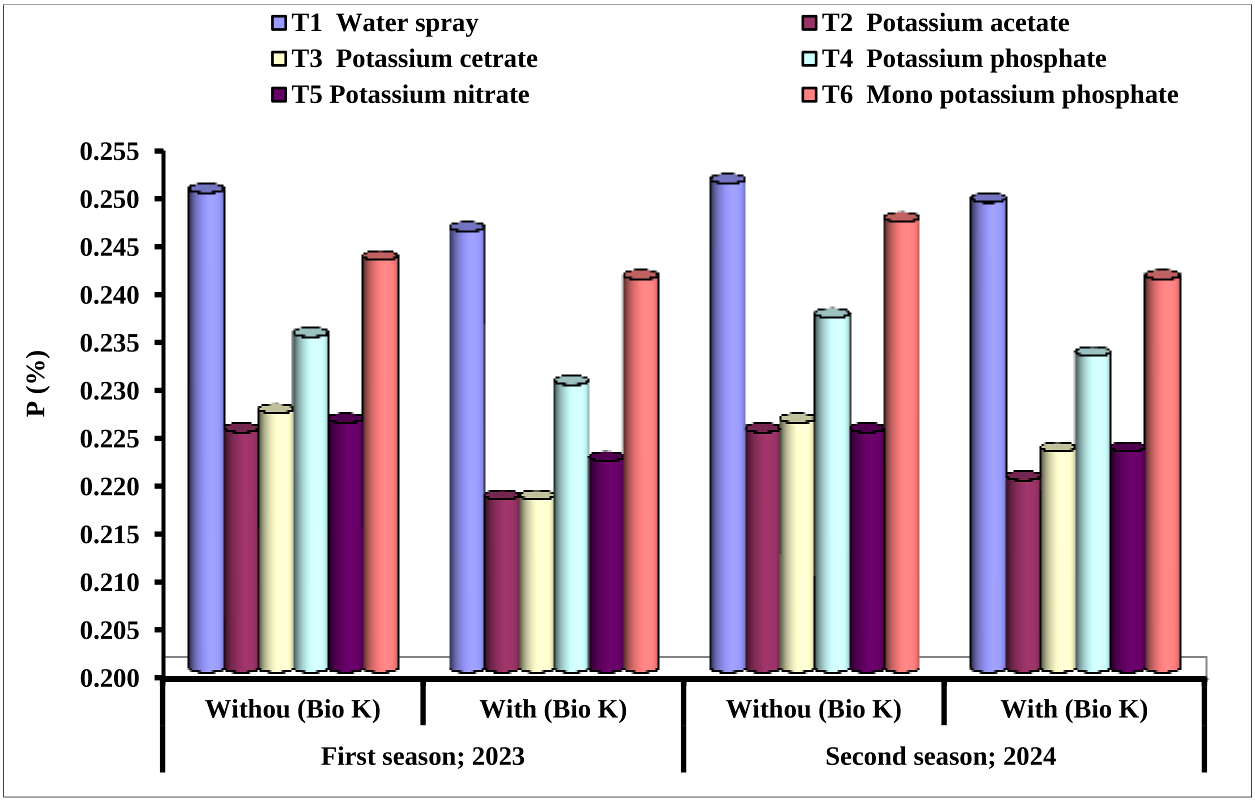

Fig. (5): Effect of different forms of K (foliar spray), soil addition, and interaction effect P (%) concentrations of Naomi mango trees during the 2023 and 2024 seasons.

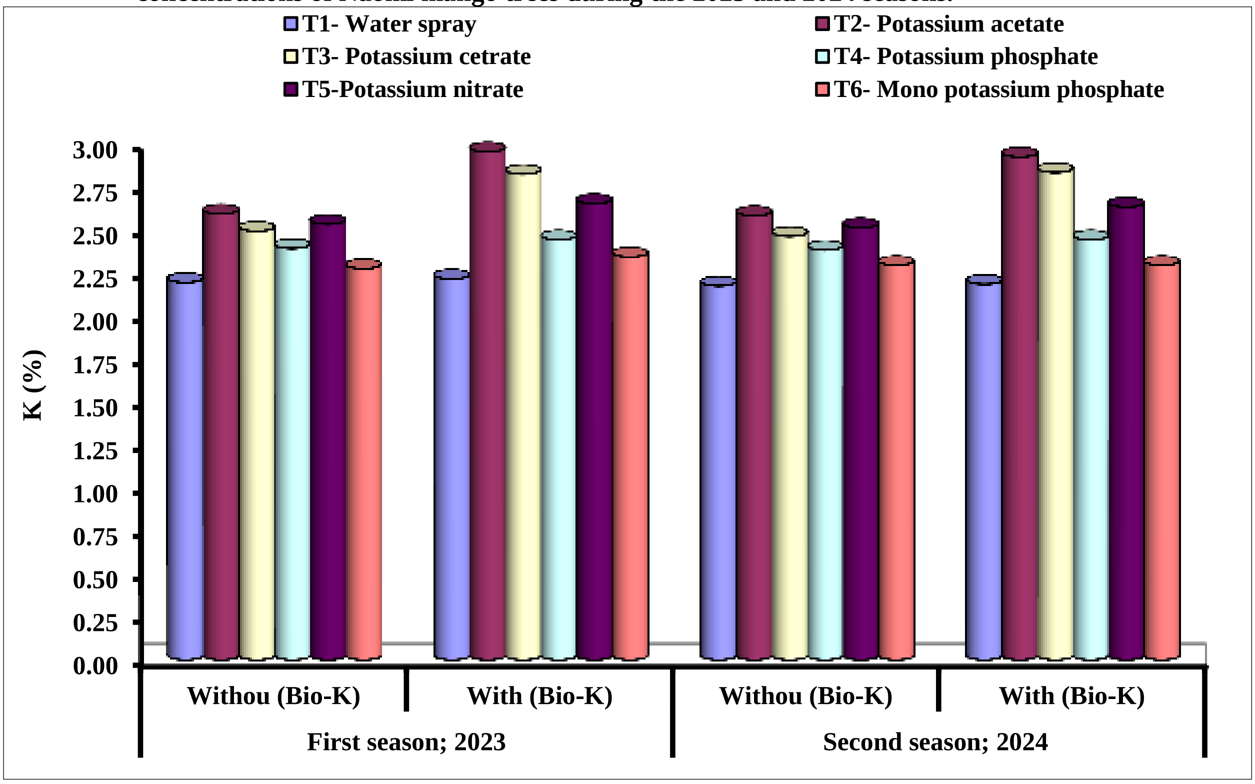

Fig. (6): Effect of different forms of K (foliar spray), soil addition, and interaction effect K (%) concentrations of Naomi mango trees during the 2023 and 2024 seasons.

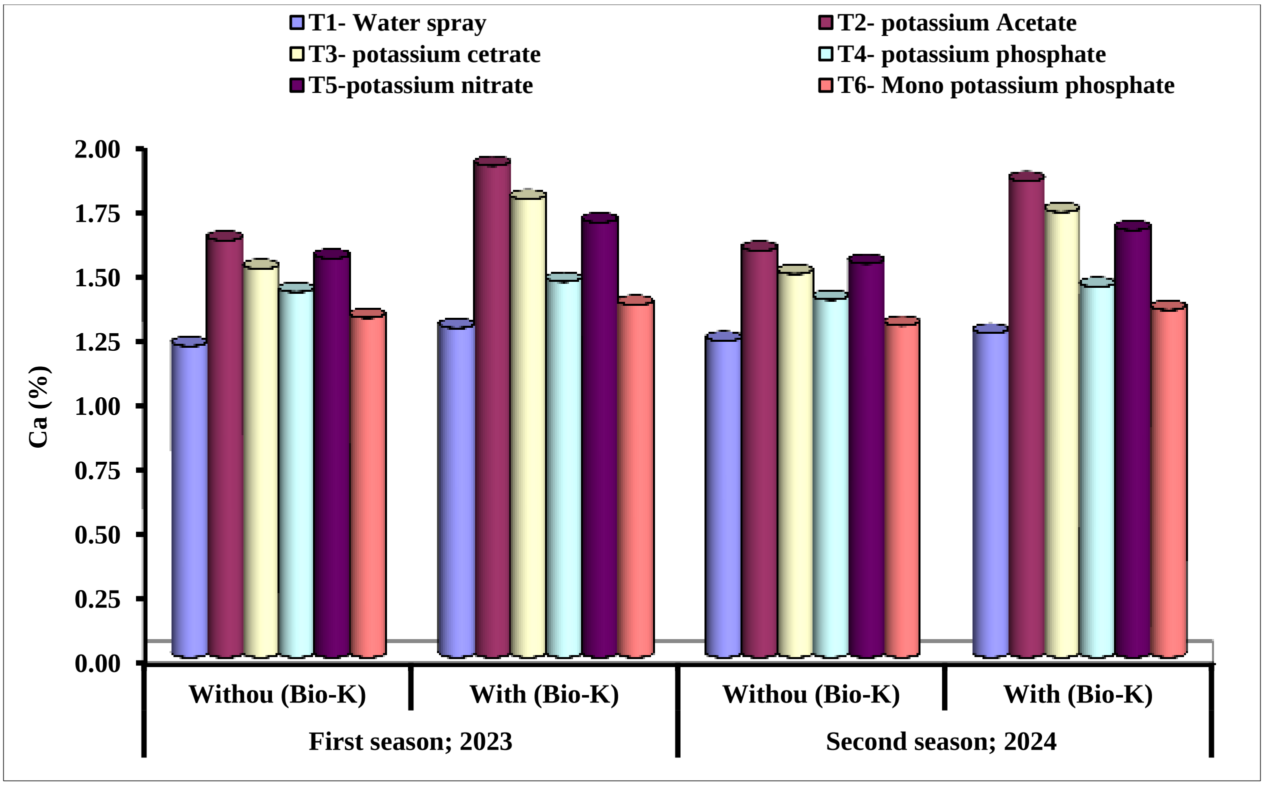

Fig. (7): Effect of different forms of K (foliar spray), soil addition, and interaction effect Ca (%) concentrations of Naomi mango trees during the 2023 and 2024 seasons.

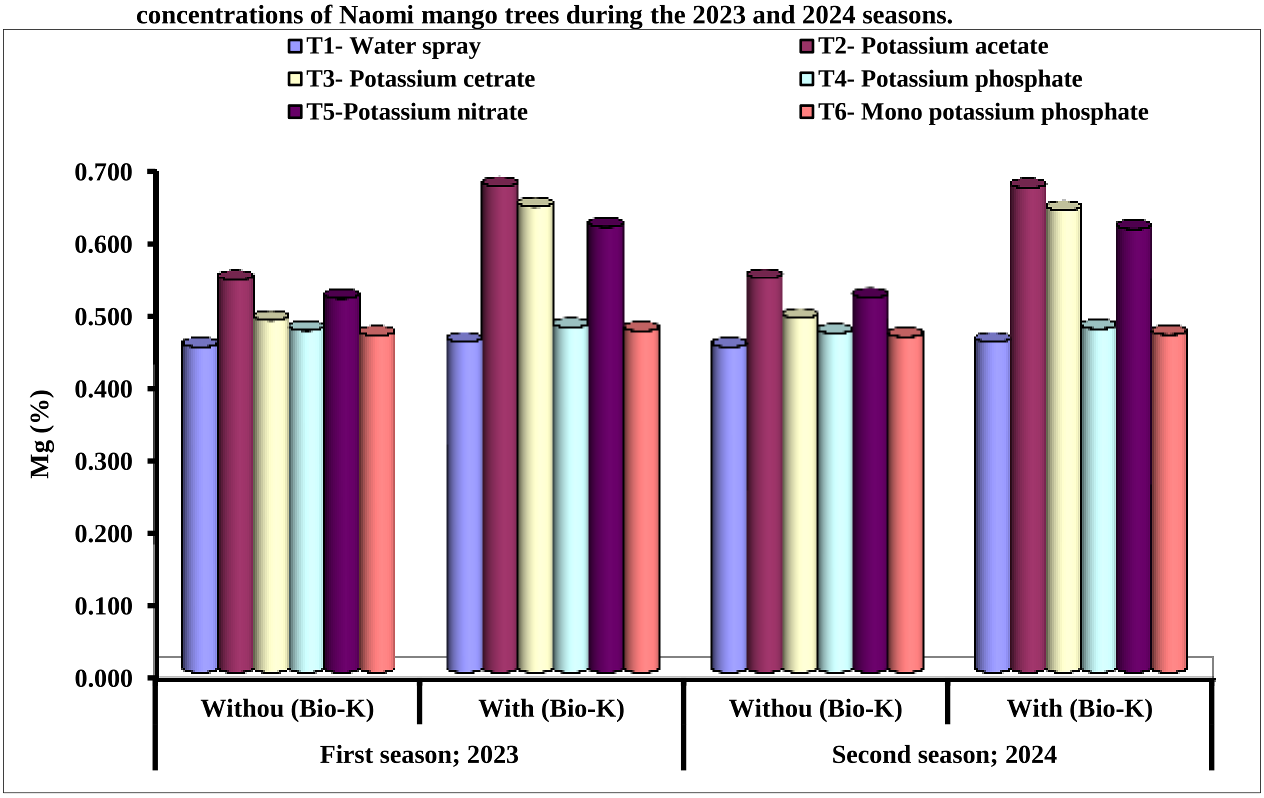

Fig. (8): Effect of different forms of K (foliar spray), soil addition, and interaction effect Mg (%) concentrations of Naomi mango trees during the 2023 and 2024 seasons.

b) Micro-nutrients (Fe, Mn and Zn ppm) contents: -

A. Specific effect of leaf minerals:

Data in Table (4) and Figs. (9, 10 and 11) cleared that the specific effect of the two studied factors (with or without Bio-K) and five forms of potassium in different forms: "acetate, citrate, phosphate; nitrate, and mono-potassium phosphate" on the iron, manganese, and zinc content of the leaves of Naomi mango trees showed that the recorded data the using of Bio-K as soil addition with Bio-K outperformed without Bio-K, as this treatment led to an increase in the three elements (Fe, Mn, and Zn) content of the leaves during both seasons. On the contrary, the results recorded in Table (4) and Figs. (9, 10, and 11) without Bio-K had the lowest values during both seasons in this study, respectively.

So, concerning the specific effect of the studied factors for five forms of potassium in different forms; acetate, citrate, phosphate; nitrate, and mono-potassium phosphate" on the leaf content of potassium, calcium, and magnesium elements in Table (4) and Figs. (9, 10, and 11), the using of potassium in its five forms is better than the control during both seasons of the study.

B. Interaction effect:

Data presented in Table (4) and Figs. (9, 10, and 11), declared that the effect of the interaction between the two studied factors (without or with Bio-K) and five different forms of potassium i.e., "acetate, citrate, phosphate; nitrate, and mono-potassium phosphate" on the leaf content of Fe, Mn, and Zn in the leaves of Naomi mango trees. The values recorded data indicated that the use of K a (potassium acetate) as a foliar + soil addition with Bio-K surpassed all the different treatments during the first and second seasons in this study, as this treatment had the highest concentration of Fe, Mn, and Zn in the leaf content during both study seasons, respectively.

Table 4. Effect of different forms of K (foliar spray), soil addition, and interaction effect on Fe, Mn, and Zn (ppm) concentrations of Naomi mango trees during the 2023 and 2024 seasons.

Soil addition (Bio-K) / Foliar spray	Fe (ppm)					
	First season; 2023		Mean*	Second season; 2024		Mean*
	Without (Bio-K)	With (Bio-K)		Without (Bio-K)	With (Bio-K)	
T1. Control (trees sprayed with tap water)	96.58l	97.88k	**97.23F**	96.06l	96.41k	**96.24E**
T2. Potassium acetate 3 cm/L	119.10d	128.90a	**124.00A**	117.40d	127.50a	**122.50A**
T3. Potassium citrate 3 cm/L	114.20f	124.20b	**119.20B**	113.60f	123.10b	**118.40B**
T4. Potassium phosphate 3 cm/ L	107.30h	111.00g	**109.10D**	106.20h	111.20g	**108.70C**
T5. Potassium nitrate 3 g/L	116.40e	120.70c	**118.60C**	115.90e	120.50c	**118.20B**
T6. Mono potassium phosphate 3 g/L	99.74j	103.50i	**101.60E**	99.24j	102.80i	**101.00D**
Mean**	**108.90B**	**114.40A**		**108.10B**	**113.60A**	
	Mn (ppm)					
T1. Control (trees sprayed with tap water)	37.12k	37.98j	**37.55E**	36.09l	37.09k	**36.59F**
T2. Potassium acetate 3 cm/L	49.35d	52.81a	**51.08A**	48.86c	51.51a	**50.19A**
T3. Potassium citrate 3 cm/L	47.30e	50.47b	**48.89B**	46.58f	50.42b	**48.50B**
T4. Potassium phosphate 3 cm/ L	43.81g	45.45f	**44.63C**	43.67h	45.36g	**44.51D**
T5. Potassium nitrate 3 g/L	47.44e	49.90c	**48.67B**	47.12e	48.28d	**47.70C**
T6. Mono potassium phosphate 3 g/L	39.87i	41.70h	**40.78D**	39.80j	41.04i	**40.42E**
Mean**	**44.15B**	**46.38A**		**43.69B**	**45.62A**	
	Zn (ppm)					
T1. Control (trees sprayed with tap water)	36.19k	37.42j	**36.80F**	35.97l	38.63k	**37.30F**
T2. Potassium acetate 3 cm/L	44.87c	47.39a	**46.13A**	44.40d	47.75a	**46.08A**
T3. Potassium citrate 3 cm/L	42.81e	46.70b	**44.76B**	42.68f	46.81b	**44.75B**
T4. Potassium phosphate 3 cm/ L	41.48g	42.11f	**41.79D**	41.45h	42.32g	**41.88D**
T5. Potassium nitrate 3 g/L	43.36d	45.21c	**44.29C**	43.43e	45.57c	**44.50C**
T6. Mono potassium phosphate 3 g/L	38.21i	39.89h	**39.05E**	39.10j	40.39i	**39.74E**
Mean**	**41.15B**	**43.12A**		**41.17B**	**43.58A**	

- Means within a column or row having the same letters are not significantly different according to Duncan's New Multiple Range t-tests at a 5 % level.

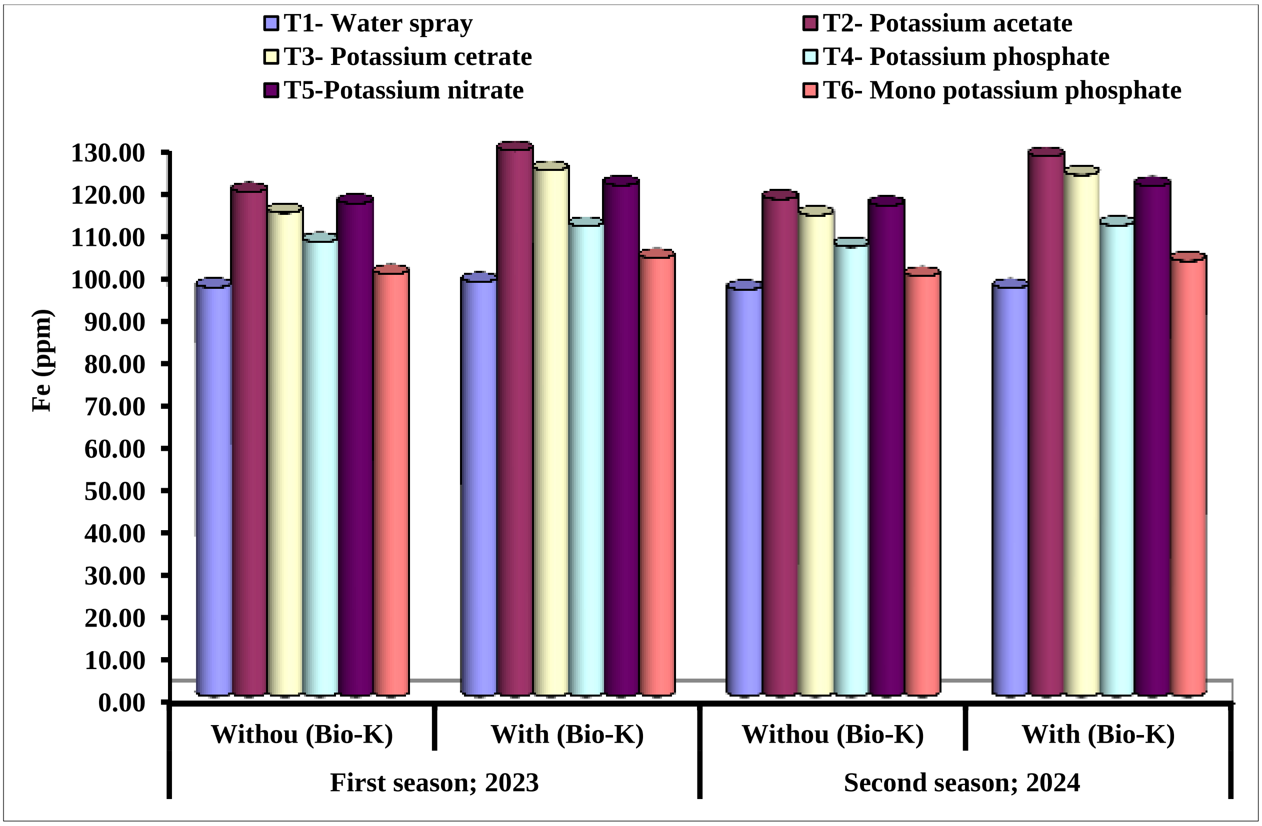

Fig. (9): Effect of different forms of K (foliar spray), soil addition and interaction effect Fe (ppm) content of Naomi mango trees during 2023 and 2024 seasons.

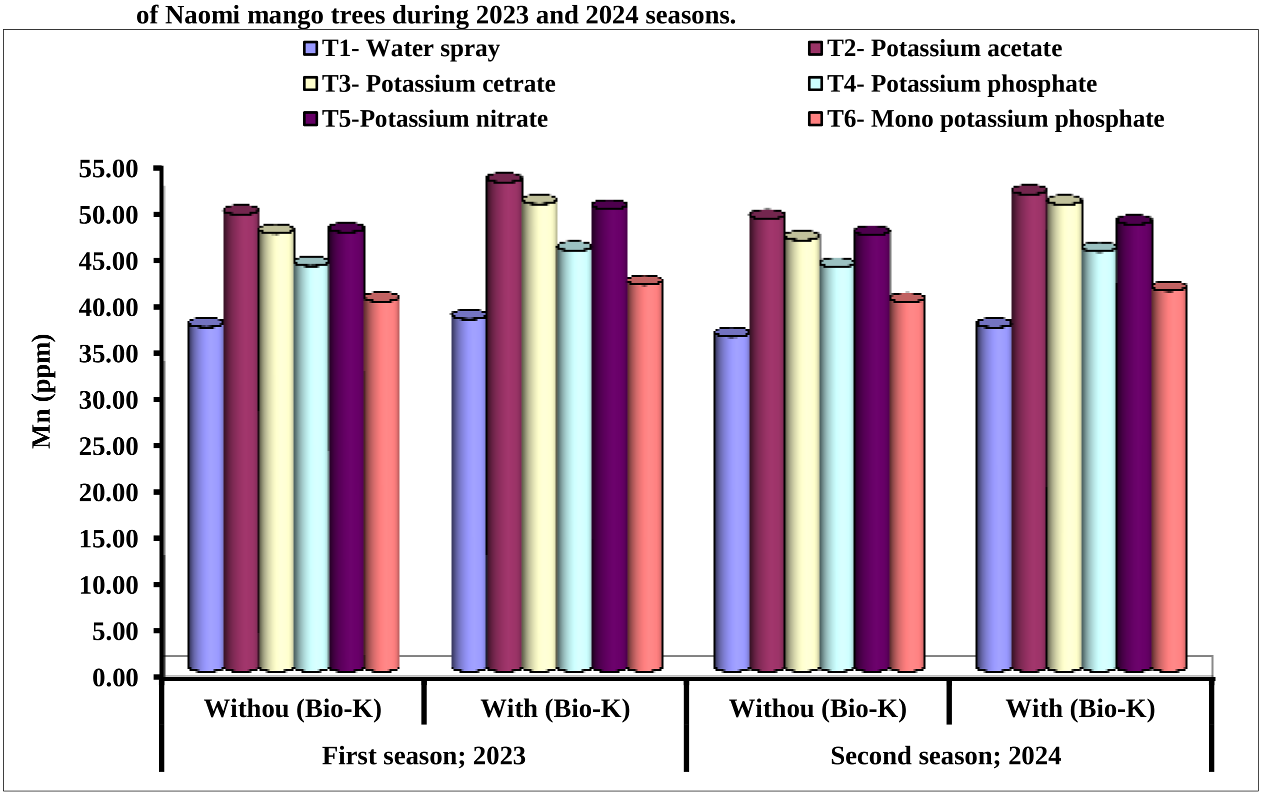

Fig. (10): Effect of different forms of K (foliar spray), soil addition and interaction effect Mn (ppm) content of Naomi mango trees during 2023 and 2024 seasons.

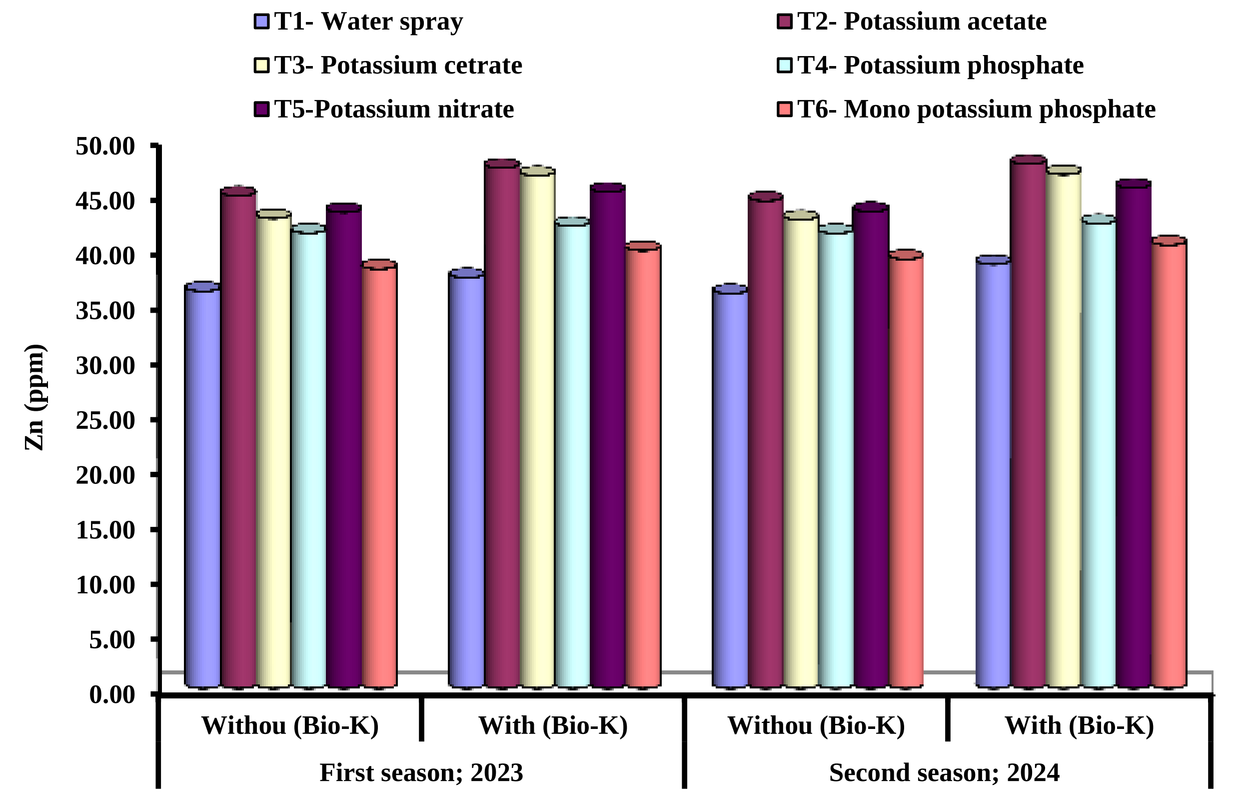

Fig. (11): Effect of different forms of K (foliar spray), soil addition and interaction effect Zn (ppm) content of Naomi mango trees during the 2023 and 2024 seasons.

Discussion

The positive effect of potassium citrate on growth characteristics is that citric acid plays a vital role in plant metabolism **(Singh *et al.*, 2010; El Gammal *et al.*, 2015).** Moreover, citric acid chelating these free radicals and protecting plants from injury could result in prolonging the shelf life of plant cells and enhancing growth characteristics **(Maksoud *et al.*, 2009 and Rao *et al.*, 2000).** Also, K is the prevalent cation in the plant and plays a vital role in the maintenance of ionic balance in the cell as well as bound ionically to the enzyme pyruvate kinase, which is essential in respiration and carbohydrate metabolism **(Marschner, 1995). Gad *et al.* (2021)** found that spraying Ewaise mango with potassium at 0.6 g/l achieved the highest growth traits. The improvement in growth characters, which were associated with the increment in leaf content of potassium and chlorophylls because of the use of potassium as spray compared to untreated trees. These effects might be due to the role of chlorophyll and this element in enhancing photosynthesis and their role in improving growth traits. The positive effect of potassium citrate in this study might be related to the important role of citric acid. It is an antioxidant which has anti-stress effect leading to the protection of photosynthetic pigments and photosynthesis systems of the leaves **(Fayed, 2010** and **Allahveran *et al.*, 2018).** Previous research reclaimed that antioxidants have a positive effect on photosynthesis, stomatal conductance, respiration decrease, chlorophyll, leaf area and leaf weight **(Zulaikha, 2013 and Allahveran *et al.*, 2018).** In addition, citric acid is an antioxidant that has as auxinic action which provided to disease control, cell division and promotion of lipase and its synergistic effect shoot system. Different physiological processes like nutrient uptake, respiration, plant pigments, photosynthesis as well as biosynthesis of protein and hormones depend on availability of the citric acid **(Ahmed *et al.*, 2003 and Abo El-Komsan *et al.*, 2003).** The previous lines could be explained the positive effects of potassium and citric acid on the vegetative growth which is noted in the current study.

Baiea *et al.* (2015) reported that all potassium forms treatments enhanced the fruit physical properties of mango cv. Hindi namely, fruit weight, pulp weight, peel weight and stone weight compared to the control trees. They added that the higher values were scored by spraying 2% potassium nitrate. Meanwhile, the lowest values of these characters were noticed with the control trees. The positive effect of potassium in enhancing fruit might be due to its function in improving synthesis of photosynthates and their transport to fruit. Also, the effect of K on fruit quality can be also indirect due to its positive interaction with other nutrients, especially with N and production practices. So, potassium application enhanced fruit quality of mango

(Usherwood, 1985; Ebeed *et al*., 2005; Stino *et al*., 2011; Abd El-Razek *et al*., 2013 and Taha *et al*., 2014).

Conclusion

In conclusion, it is obvious that the all-successful treatment for most of the parameters studied in this study was the combination of foliar spraying with potassium acetate 3 cm/L with Bio-K to the soil. Therefore, under the same conditions, this treatment is a prospective agent to enhance the vegetative growth and nutritional status of Naomi mango trees under El-Khatatbeh region, Minoyfia Governorate conditions.

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تأثير صور البوتاسيوم المختلفة في وجود أو عدم وجود البوتاسيوم الحيوي على النمو الخضري والحالة الغذائية لأشجار المانجو صنف الناعومي تحت ظروف محافظة المنوفية

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قسم البساتين – كلية الزراعة – جامعة بنها – مصر

أجريت هذه الدراسة خلال موسمين متتاليين 2023 و 2024 على أشجار المانجو عمر 7 سنوات صنف الناعومي المنزرعة في منطقة الخطاطبة، مدينة السادات، محافظة المنوفية، مصر تحت ظروف الري بالتنقيط على مسافات زراعة 2 × 3 متر، بهدف دراسة تأثير استخدام مصادر مختلفة من البوتاسيوم رشاً (اسيتات بوتاسيوم، سترات بوتاسيوم، البوتاسيوم فوسفيت، ونترات البوتاسيوم والمونو بوتاسيوم فوسفات بالإضافة إلى معاملة الكنترول (المقارنة) في وجود أو عدم وجود البوتاسيوم الحيوي

وتم إجراء المعاملات بالرش خمس مرات شهرياً بداية من شهر مارس إلى شهر يوليو والمعاملات الأرضية إضيفت اربع مرات بداية من نهاية شهر فبراير إلى نهاية شهر مايو.

اشارت النتائج الي ان أفضل المعاملات هي اسيتات البوتاسيوم بتركيز 3 سم/لتر يليه سترات البوتاسيوم في وجود البوتاسيوم الحيوي. وعلى العكس من ذلك كانت أقل المعاملات هي معاملة المقارنة (الكنترول).

وتوصي الدراسة برش أسيتات البوتاسيوم في وجود البوتاسيوم الحيوي للحصول على أفضل نمو خضري وحالة غذائية لأشجار المانجو صنف الناعومي تحت نفس ظروف التجربة.