IMPACT OF SPRAYING MELATONIN, POTASSIUM, AND ZINC ON KUMQUAT FRUIT TRAITS AND SOME CHEMICAL CONCENTRATIONS

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ABSTRACT

This experiment was conducted at the Department of Horticulture and Landscape Engineering, College of Agricultural Engineering Sciences, University of Baghdad, during 2022 season to investigate the effect of spraying with melatonin, potassium sulfate, and organic zinc on the flowering and production stage, of 3-year old Kumquat saplings grafted onto lemon rootstock. The experiment was factorial within Randomized Completely Block Design using three replications. The factors of the experiment were foliar spraying with melatonin, potassium sulfate, and organic zinc. The treatments were applied at two times, spring and autumn. Each of the three factors independently influenced both the fruit characteristics and the concentration of chemical elements within the fruits. Melatonin application at a concentration of 20 mg.L^{-1} resulted in a remarkable improvement in fruit traits, specifically by increasing the number of fruits, fruit size, and fruit weight. This treatment also demonstrated a positive impact on the concentrations of various chemicals within the fruits, including TSS, total sugars, ascorbic acid, carotenoids, and phenols. Potassium sulfate applied at a concentration of 3000 mg.L^{-1} and organic zinc applied at a concentration of 1000 mg.L-1 exhibited the most pronounced effects on the same fruit traits that were positively influenced by melatonin.

Keywords: fruit size, ascorbic acid, tss, phenols, carotenoids

تأثير رش الميلاتونين والبوتاسيوم والزنك في صفات ثمار الكمكوات وبعض التراكيز الكيميائية

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المستخلص

اجريت التجربة في – قسم البستنة وهندسة الحدائق– كلية علوم الهندسة الزراعية – جامعة بغداد، للموسم 2022 لدراسة تأثير الرش بالميلاتونين وكبريتات البوتاسيوم والزنك العضوي في ازهار وانتاج شتلات الكمكوات المطعمة على أصل الليمون، كانت التجربة عاملية في تصميم القطاعات الكاملة المعشاة وبثلاثة مكررات. عوامل التجربة الرش الورقي بالميلاتونين، كبريتات البوتاسيوم والزنك العضوي المعاملة بهم كانت في موعدين ربيعي وخريفي. اعطت العوامل الثلاثة منفردة تأثيرا معنويا على الصفات الثمرية وتركيز الثمار من العناصر الكيميائية. تفوق التركيز 20ملغم.لتر$^{-1}$ من الميلاتونين في الصفات الاتية (عدد الثمار, حجم الثمار, وزن الثمار) كما وادت نفس المعاملة بزيادة تركيز المواد الكيميائية في الثمار على النحو الاتي (TSS, السكريات الكلية, حامض الاسكوربيك, الكاروتينات, الفينولات), كما نلاحظ بان كبريتات البوتاسيوم وبتركيز 3000 ملغم.لتر$^{-1}$ و الزنك العضوي بتركيز 1000 ملغم.لتر$^{-1}$ قد اعطيتا اعلى القياسات ولنفس الصفات التي اثر فيها الميلاتونين.

الكلمات المفتاحية: حجم الثمار, حامض الاسكوربيك, الفينولات, TSS, الكاروتينات

Received: 16/10/2023, Accepted:18/2/2024, Published:30 June.

INTRODUCTION

Kumquats (*Fortunella japonica* Swingle) are evergreen trees belonging to the Rutaceae family (10). The two most cultivated varieties of kumquat are "Marumi" or round-fruited kumquat (*Fortunella japonica* Swingle) and "Nagami" or elongated-fruited kumquat (*Fortunella margarita* Swingle). Kumquat fruits are characterized by their high concentration of active substances such as antioxidants, phenols, flavonoids, carotenoids, and vitamins compared to other citrus fruits (1, 25). Phytomelatonin is an antioxidant in plants that controls the rate of reactive oxygen species (ROS) in plants (6, 15). Melatonin acts as a promoter of seed germination, root development, plant growth, a stress protector that increases plant tolerance to critical environmental conditions (24, 28), biotic stress (22) and a growth regulator that affects flowering and fruit quality (8, 11, 30). melatonin proved it can long lasting peach fruit stored under high temperature after we sprayed trees with it, were treated with melatonin at 0.1 mill molar. liter^{-1} and then stored at a temperature of (25-28) °C for 7 days (13). Melatonin promotes ripening and delays senescence in fruits (7). In a study by (17), foliar application of melatonin was used to evaluate the flavonoid profile, total phenols, essential oils, and polyphenol compounds of two citrus species. A study by (14), Melatonin was evaluated at different concentrations to assess its effects on the physiological, metabolic, and molecular characteristics of peach saplings under waterlogging conditions. Foliar spraying of nutrients is considered an important process in plant nutrition. It involves spraying mineral elements in their ionic forms, available for absorption, so that the plant can directly benefit from (19). Foliar fertilization is used to supply plants with essential elements (macro and micro-nutrients) to improve their growth and achieve qualitative and quantitative improvement in the yield due to the scarcity of nutrients in the soil, which reduces their availability to the plant(12:26). The results confirmed that spraying potassium significantly increased fruit traits and there chemical contents(19). Another study showed that potassium plays an important role in increasing yield per unit area and improving quality traits through its indirect effect on many physiological activities in the plant (9). In a study of the effect of adding potassium to the soil as potassium sulfate at three levels of potassium sulfate and spraying on Ajami apple variety. The results showed that potassium had a significant effect on the studied traits, it gave the highest rate of number of fruits, fruit weight, and yield quantity, The percentage of TSS also increased and the percentage of total acidity in the fruit juice decreased, which led to the improvement of the qualitative traits of the fruits. In an experiment conducted by (4). In where grape fruit sprayed with potassium and ascorbic acid, result showed increase in fruit traits especially chemical concentration in it. Zinc plays a major role in the biosynthesis of plant pigments Zinc also involved in the uptake of phosphorus from the soil (2).

MATERIALS AND METHODS

This experiment was conducted in one of the lath house (covered with saran) belonging to the Department of Horticulture and Landscape Engineering, College of Agricultural Engineering Sciences, University of Baghdad, Research Station (B) for the 2022 season to study the effect of spraying with growth regulators melatonin, potassium and zinc on the growth and fruit production of kumquat saplings aged 3 years grafted on lemon rootstock. A factorial experiment consisting of three factors and three replications was conducted, using the RCBD experimental design**.** The first factor is melatonin added as a foliar application at three concentrations (0, 10, 20) mg.L^{-1} (3) with a total of six times starting in the spring of 2022، The second factor is potassium sulfate added a foliar application at three concentrations (0, 1500, 3000) mg.L^{-1} with a total of three sprays starting in the spring of 2022 and three sprays in autumn. The third factor organic zinc was added as a foliar application at two concentrations (0, 1000) mg.L^{-1} with a total of three sprays starting in the spring of 2022 and three sprays in the autumn. The number of treatments was 18 treatments with three replicates with two saplings per experimental unit, so the number of saplings was 108 saplings. The results were analyzed using the Genstat program and the means were

compared using the least significant difference (LSD) at a probability level of 5%.

RESULTS AND DISCUTION

Effect of melatonin, potassium sulfate, and organic zinc on fruit traits in kumquat saplings: The results of Table (1) show that there is a significant effects of spraying melatonin on the fruit traits of kumquat plants. The 20 mg.L^{-1} treatment showed superiority over the other treatments under investigation in the fruit traits (number of fruits, fruit volume, fruit weight), which reached (27.16 fruits. $plant^{-1}$, 15.76 cm^2 ,9.35 g) respectively. The results of also showed that spraying potassium was highly significant on kumquat plants, especially at the 3000 mg.L^{-1} treatment, which outperformed the other treatments in number of fruits, fruit volume, fruit weight, at 26.77 fruits. $plant^{-1}$,15.65 cm^2 and 8.76 g respectively. The spraying of organic zinc on kumquat plants at a concentration of 1000 mg.L^{-1} had a significant effects on number of fruits, and fruit weight at 25.66 fruits. $plant^{-1}$, and 8.2 g respectively.

Table 1.The Effect of Melatonin, potassium sulfate, and organic Zinc on fruit traits in kumquat saplings.

Treat	fruit number (fruit $plant^{-1}$)	Fruit volume(cm^3)	Fruit weight (gm)
M0	18.88	11.32	6.18
M1	24.27	13.35	7.93
M2	27.16	15.76	9.35
L.S.D	0.47	0.27	0.05
K0	20.16	10.97	6.38
K1	23.38	13.81	8.32
K2	26.77	15.65	8.76
L.S.D	0.47	0.27	0.05
Z0	21.22	11.52	7.44
Z1	25.66	15.43	8.20
L.S.D	0.39	0.22	0.04

The results of Table (2) indicate that there was a significant effect of Interaction between spraying melatonin and potassium on the fruit traits of kumquat plants. The 20 mg.L^{-1} melatonin and 3000 mg.L^{-1} potassium treatment which outperformed the other treatments in number of fruits, fruit volume, fruit weight, at 31.33 fruits. $plant^{-1}$, 17.60 cm^2 10.58 g. The spraying of melatonin and organic zinc on kumquat plants at a concentration of 20 mg.L^{-1} melatonin and 1000 mg.L^{-1} zinc had a significant effect on number of fruits, fruit volume and fruit weight at 29.86 fruits. $plant^{-1}$, 17,46 cm^2 and 9.99g respectively .the Interaction between potassium and zinc had a significant effects on number of fruits, fruit volume and fruit weight at 30.33 fruits. $plant^{-1}$, 17.51 cm^2 and 9.41g respectively

Table 2. Effect of the foliar application of Melatonin, potassium sulfate, and organic Zinc on Double interaction fruit traits in kumquat saplings.

Treat	fruit number (fruit $plant^{-1}$)	Fruit volume(cm^3)	Fruit weight (gm)
M0K0	16.50	8.01	5.23
M1K0	20.83	10.93	6.20
M2KO	23.16	13.98	7.73
MOK1	19.00	11.93	6.13
M1K1	24.16	13.80	9.08
M2K1	27.00	15.79	9.75
M0K2	21.16	14.01	7.18
M1K2	27.88	15.33	8.53
M2K2	31.33	17.60	10.58
LSD	0.82	0.48	0.09
M0Z0	17.66	9.26	6.12
M1Z0	21.55	11.25	7.47
M2Z0	24.44	14.05	8.74
M0Z1	20.11	13.37	6.24
M1Z1	27.00	15.45	8.40
M2Z1	29.86	17,46	9.96
LSD	0.67	0.39	0.07
K0Z0	18.88	9.06	6.13
K1Z0	21.55	11.72	8.08
K2Z0	23.22	13.78	8.12
K0Z1	21.44	12.86	6.64
K1Z1	25.22	15.90	8.55
K2Z1	30.33	17.51	9.41
L.S.D	0.67	0.39	0.07

The results of Table (3) show that there was a significant effect of Interference between spraying melatonin , potassium and organic zinc on he fruit traits of kumquat plants. The 20 mg.L^{-1} melatonin , 3000 mg.L^{-1} potassium 1000 mg.L^{-1}treatment which outperformed the other treatments in number of fruits, fruit volume, fruit weight, at 36.00 fruits. $plant^{-1}$, 19.13cm^2, 11.43 g. respectively showed superiority over the other treatments investigate in the fruit traits

Table 3. Effect of the foliar application of Melatonin, potassium sulfate, and organic Zinc on Triple interaction fruit traits in kumquat saplings.

Treat	fruit number (fruit plant-1)	Fruit volume (cm3)	Fruit weight (gm)
M0K0Z0	15.33	6.00	5.10
M0K0Z1	17.66	10.63	5.36
M0K1Z0	18.33	9.90	6.10
M0K1Z1	19.66	13.96	6.16
M0K2Z0	19.33	11.90	7.16
M0K2Z1	23.00	16.13	7.20
M1K0Z0	19.33	9.16	6.16
M1K0Z1	22.33	12.70	6.23
M1K1Z0	21.66	11.20	8.80
M1K1Z1	26.66	16.40	9.36
M1K2Z0	23.66	13.40	7.46
M1K2Z1	32.00	17.26	9.60
M2K0Z0	22.00	12.03	7.13
M2K0Z1	24.33	15.93	8.33
M2K1Z0	24.66	14.06	9.36
M2K1Z1	29.66	17.33	10.13
M2K2Z0	26.66	16.06	9.73
M2K2Z1	36.00	19.13	11.43
L.S.D	1.17	0.68	0.13

According to the experimental results melatonin has the effect of plant growth regulators. The increase in the number of buds of the treated plants was due to its effect in increasing the size of the vegetative mass, especially the height of the main stem and the number of lateral branches. It also showed a behavior similar to the effect of auxin, as it increased the differentiation of non-specialized buds into flower buds and then converted them into fruits later. In addition to its ability to increases the flowering period (16) by its effect on overcoming abnormal conditions in the climate or soil. This was reflected in an increases in the number of fruits, as it reduced the number of fallen fruits. It also had an effect similar to that of cytokinins, as cell division in the fruits increased, leading to an increase in their size compared to non-treated plants. In addition, it is observed that potassium has an effect on increasing the number and size of fruits in the plant due to its role in increasing the size of the fruits, which is due to the synthesis of carbohydrates and their conversion from one form to another, in addition to the movement of photosynthetic products from the production side to the storage organs. It also increases the attachent of the fruit to the plant by inhibiting the production of ethylene in the natural separation areas of the fruit. It has a role in maximizing the biosynthesis of proteins from carbohydrates resulting from the process of photosynthesis, so the fruits became water-attractive with an increase in their content of proteins and sugars. This is due to the increase in membrane permeability resulting from the effect of potassium, which led to an increases in the entry of nutrients to the fruits (5). The results also indicate that zinc also has an effect on increasing the division of fruit cells due to its effect on the formation of the middle lamella between the cell wall. It also helps in the cell swelling to enter in the transfer of nutrients between cells through the endoplasmic reticulum. It reduced June drop because zinc reduces the production of internal ethylene and then prevents it from forming (cellulase and polygalacturonase). It also led to an increases in the size of fruits, their weight and the yield of plants compared to non-treated plants (23).

Effects of melatonin, potassium sulfate, and organic zinc on the chemical content of kumquat fruits: The results in Table (4) indicate that spraying melatonin had a significant effect on the content of kumquat fruits of chemical compounds such as ascorbic acid, total soluble solids, sugars, phenols, and carotenoids, especially at a concentration of 20

mg L^{-1}, at 42.1 mg L^{-1}, 8.84%, 8.8%, 315.1 mg/100 g fruit peels, 0.302 respectively. The results also indicate that spraying potassium sulfate at a concentration of 3000 mg L^{-1} significantly affected the content of kumquat fruits of the following chemical compounds (ascorbic acid, total soluble solids, sugars, phenols, and carotenoids), which reached results (39.24 mg L^{-1}, 8.99%, 8.9%, 286.8 mg/100 g fruit peels, 0.280) respectively. While zinc had a significant effects on the content of the fruits of the following chemical compounds (ascorbic acid, total soluble solids, sugars, phenols, and carotenoids), which reached results (38.67 mg L^{-1}, 8.87%, 9.34%, 281.5 mg/100 g fruit peels, 0.293) respectively.

Table 4. Effect of the foliar application of Melatonin, potassium sulfate, and organic Zinc on chemical contents in fruit of kumquat .

Treatments	TSS (%)	Total sugar (%)	Ascorbic acid (mg.100ml juice)	Carotenoids (mg.100gm^{-1} dry weight)	Phenols (mg.gm^{-1}dry weight.)
M0	**5.39**	**8.4**	**32.65**	**0.188**	**184.2**
M1	**5.85**	**8.6**	**37.74**	**0.252**	**254.6**
M2	**6.29**	**8.8**	**42.10**	**0.302**	**315.1**
L.S.D	**0.03**	**0.04**	**0.29**	**0.002**	**2.95**
K0	**5.50**	**8.2**	**35.80**	**0.212**	**215.3**
K1	**5.78**	**8.5**	**37.74**	**0.250**	**251.7**
K2	**6.24**	**8.9**	**39.24**	**0.280**	**286.8**
L.S.D	**0.03**	**0.04**	**0.29**	**0.002**	**2.95**
Z0	**5.50**	**8.3**	**36.32**	**0.202**	**221.1**
Z1	**6.18**	**8.8**	**38.67**	**0.293**	**281.5**
L.S.D	**0.02**	**0.03**	**0.23**	**0.001**	**2.40**

The results of Table (5) show that there was a significant effect of Interference between spraying melatonin and potassium on the chemical compounds such as ascorbic acid, total soluble solids, sugars, phenols, and carotenoids, especially at a concentration of 20 mg L^{-1} of melatonin and 3000 mg.L^{-1} potassium treatment which outperformed the other treatments**.**at 43.53mg.100ml uice, 6.70%, 9.22%, 345.6mg. gm-1 ,0.337mg.100gm^{-1}.The spraying of melatonin and organic zinc on kumquat plants at a concentration of 20 mg.L^{-1} melatonin and 1000 mg.L^{-1} zinc had a significant effects on ascorbic acid, total soluble solids, sugars, phenols, and carotenoids, at 43.34mg.100ml juice,6.63%,9.03%,341mg.gm-^{1},0.335 mg.100gm, Interference between potassium and zinc had a significant effect on ascorbic acid, total soluble solids, sugars, phenols, and carotenoids, at40.34 mg. 100ml juice, 6.24%, 9.41%,328mg.gm-1,0.329 mg.100gm,respectively. From Table 6, shows that treatment with melatonin, potassium, and zinc outperformed all treatments and in all chemical characteristics, especially at concentration.(20 mg.L^{-1} melatonin , 3000 mg/L^{-1} potassium 1000 mg.L^{-1} zinc) had a significant effect on ascorbic acid, total soluble solids, sugars, phenols, and carotenoids, at 44.36 mg.100ml juice,7.30%,9.6%,389mg.gm-1,0.372 mg.100gm,respectively.

Table 5. Effect of the foliar application of Melatonin, potassium sulfate, and organic Zinc on Double interaction chemical contents in fruit of kumquat .

Treatments	TSS (%)	Total sugar (%)	Ascorbic acid (mg.100ml juice)	Carotenoids (mg.100gm^{-1} dry weight)	Phenols (mg.gm^{-1}dry weight.)
M0K0	5.07	8.03	31.25	0.146	148.3
M1K0	5.41	8.30	35.78	0.221	210.5
M2K0	5.63	8.54	40.36	0.269	287.3
M0K1	5.64	8.37	32.45	0.195	186.3
M1K1	6.06	8.58	37.50	0.256	256.5
M2K1	6.84	8.76	42.41	0.300	312.5
M0K2	5.75	8.76	34.25	0.236	218.1
M1K2	6.62	8.98	39.95	0.279	298.8
M2K2	6.70	9.22	43.53	0.337	345.6
LSD	0.05	0.07	0.5	0.003	5.10
M0Z0	5.07	8.11	31.81	0.137	150.8
M1Z0	5.47	8.35	36.30	0.201	223.1
M2Z0	5.95	8.65	40.86	0.269	289.3
M0Z1	5.71	8.68	33.48	0.240	217.6
M1Z1	6.81	8.89	39.18	0.303	286.1
M2Z1	6.63	9.03	43.34	0.335	341.0
LSD	0.04	0.06	0.41	0.003	4.17
KOZO	5.37	8.17	34.62	0.177	193.2
K1ZO	5.50	8.36	36.21	0.199	224.3
K2Z0	5.63	8.58	38.14	0.231	254.7
K0Z1	5.64	8.41	36.98	0.247	237.5
K1Z1	6.06	8.79	38.70	0.302	279.2
K2Z1	6.24	9.41	40.34	0.329	328.0
LSD	0.04	0.06	0.41	0.003	4.17

Table 6. Effect of the foliar application of Melatonin, potassium sulfate, and organic Zinc on Triple interaction chemical contents in fruit of kumquat.

Treatments	TSS (%)	Total sugar (%)	Ascorbic acid (mg.100ml juice)	Carotenoids (mg.100gm^{-1} dry weight)	Phenols (mg.gm^{-1}dry weight.)
M0K0Z0	4.91	7.8	30.40	0.118	118.3
M0K0Z1	5.24	8.2	32.10	0.175	178.0
M0K1Z0	5.11	8.1	31.73	0.135	155.0
M0K1Z1	5.85	8.6	33.16	0.256	217.6
M0K2Z0	5.18	8.4	33.30	0.158	179.3
M0K2Z1	6.32	9.1	35.20	0.289	257.0
M1K0Z0	5.38	8.1	34.63	0.175	184.3
M1K0Z1	5.64	8.4	36.93	0.267	236.6
M1K1Z0	5.48	8.3	35.83	0.197	229.3
M1K1Z1	6.07	8.7	39.16	0.315	283.6
M1K2Z0	5.61	8.5	38.43	0.231	255.6
M1K2Z1	6.91	9.4	41.46	0.327	338.0
M2K0Z0	5.82	8.5	38.83	0.238	277.0
M2K0Z1	6.05	8.5	41.90	0.300	297.6
M2K1Z0	5.93	8.6	41.06	0.256	288.6
M2K1Z1	6.55	8.8	43.76	0.335	336.3
M2K2Z0	6.10	8.8	42.70	0.303	302.3
M2K2Z1	7.30	9.6	44.36	0.372	389.0
L.S.D	0.07	0.10	0.71	0.005	7.22

Melatonin showed a highly significant effects at all its concentrations in increasing the plant's TSS content due to its similar effect to growth regulators in regulating the different major metabolic pathways of carbohydrate pathways as well as secondary metabolism

such as the synthesis of phenols and flavonoids. Melatonin has an effect on the production of auxin and cytokinins, and it also increases sugar and phenol levels when sprayed on the plant's leaves (29). It has been observed that spraying melatonin leads to an increase in the fruit's content of ascorbic acid, increasing its shelf life on trees and delaying its aging, by affecting the L-galactose pathway, which increases the fruit's content of ascorbic acid (21). It was also observed that potassium has an effective role in increasing sugars in fruits, which in turn increased the fruit's TSS content. It has a role in activating the enzymes involved in the synthesis and maintenance of ascorbic acid in fruits. The reason for this is that potassium has a special mechanism when dealing with the outputs of photosynthesis, as potassium helps in the synthesis, conversion, and movement of carbohydrates from the source to the sink (27). As for the foliar spraying of organic zinc on kumquat plants, it has increased the fruit's content of TSS, ascorbic acid, total sugars, and in addition, it has increased the fruit's content of phenols and carotenoids, which led to an increase in yield and improved fruit quality. This result is due to the fact that zinc affects certain enzymes that contribute to the increases in the production of sugars, acids, and proteins. The addition of external zinc has affected the internal physiology of fruit growth and development (20).

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

DECLARATION OF FUND

The authors declare that they have not received a fund.

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