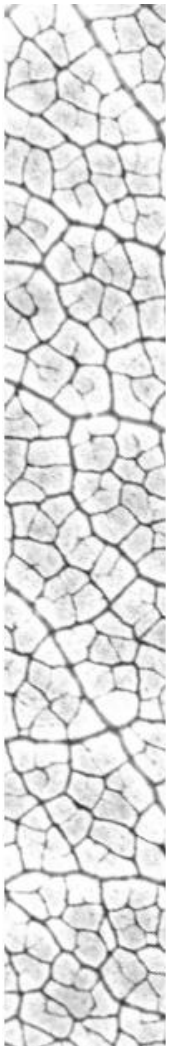

EurAsian Journal of BioSciences
Eurasia J Biosci 14, 4689-4695 (2020)

Impact of potassium sulphate and naphthalene acetic acid spray on yield and fruit quality of date palm cv. Barhee

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Abstract
The objective of this study is to investigate the effect of spraying potassium sulphate (as a source of potassium) and Naphthalene Acetic Acid (NAA) on yield and some fruit quality characteristics of date palm cv. Barhee. Bunches were sprayed with potassium sulphate at 0(spray with distilled water), 0.5%, 1%, and 1.5%, spraying was applied twice, after fruit set and after 4 weeks from the first spray. NAA were sprayed at 0(spray with distilled water), 50 mg.l^{-1} and 100 mg.l^{-1}. Bunches were sprayed at the beginning of kimri stage and the second spray was done after 4 weeks from the first spray at the beginning of khalal stage. The present results indicated that spraying bunches with potassium sulphate at 1.5% significantly increased the fruit weight, bunch weight, yield, and fruit ripening while 1% increased total soluble solids, total sugars, and reducing sugars. NAA spray at 100 mg.l^{-1} significantly increased fruit weight, bunch weight and yield, while reducing fruit drop, fruit ripening, total soluble solids, total sugars, and reducing sugars.

Keywords: potassium sulphate, growth regulators, foliar spray, date palm

Al-Falahy ThHR, Hasan AM (2020) Impact of potassium sulphate and naphthalene acetic acid spray on yield and fruit quality of date palm cv. Barhee. Eurasia J Biosci 14: 4689-4695.

INTRODUCTION

Date palm tree (*Phoenix dactylifera* L.) is the first tree of Iraq and is one of the evergreen fruit trees that belong to the Arecaceae palm tree, it is one of the important fruit trees in the Arab and Islamic world for a long time and whose growth is recovering in the subtropical regions where the rains are scarce and the Arabian Gulf region is the widest area Palm cultivation, as it is considered one of the most valuable species due to its ritual importance in human societies, health benefits and production capacity in semi-arid and dry environments (Al-Baker 1972), palm fruits occupy an important place economically because of their nutritional value, they contain a high percentage of sugars, amino acids and proteins (Ismail et al 2006). The number of palm trees in Iraq is 170,365,560 palm trees, and the total production of the governorates covered is 639.3 thousand tons, with an average productivity of the date palm of 62.6kg (Central Statistical Organization 2019). Barhee is considered one of the commercially important varieties in Iraq and widespread in the Middle East and the world, and it is usually picked and consumed in the Khalal (Bisir) stage, as it is preferred by the consumer compared to the Rutab and Tamar stages, but soon the fruits enter the Rutab stage (El-Zoghbie 2004 and Ismail et al 2006), which is an excellent variety of Basra dates and is spread in all areas of palm cultivation in Iraq and the fruits are free from tannin in the Khalal stage, therefore the fruits are eaten in this stage and it is considered a medium to late-ripening varieties (Hussein 2002).

Potassium ion(K^+), is the only ion that plants need despite not involved in the formation of any organic compound, the plants needs it in a large quantities for its growth and development, it is considered one of the main solubles important in the expansion and elongation of the cell and hence the fruits (Marschner 1995). Potassium play a major role in stimulating the action of more than 60 enzyme that contributes to the growth and development of plants and fruits as enzymes play an important role in stimulating chemical reactions in addition to its important role in transferring the sugars produced in photosynthesis through the phloem to other parts of the plant for use or storage (Van Brunt & Sultenfuss 1998). The positive effect of potassium spray on date palms has been investigated by many researchers, Abdel-Migeed et al (2013) found that spraying date palm cv. Amhat with potassium citrate had

Received: October 2019
Accepted: March 2020
Printed: October 2020

achieved an increase in the weight, length and diameter of fruits in addition to qualitative fruit traits such as total soluble solids, reducing sugars, non-reducing sugars and total sugars, Malaka et al (2016) also found that spraying potassium nitrate with a concentration of 2% showed significant effect on the physical and chemical characteristics of Medjool date palm fruits.

Auxin is one of the growth regulators used in practical and commercial applications, as growth regulators play an important role in regulating growth and development of fruits and increasing productivity in date palm (El-Kosary, 2009), and some other types of fruits (Davies, 2004 ; Agusti, et al 2003), through their effect on stimulating cell expansion and delaying fruits ripening, such as delaying the loss of hardness of fruits and decomposition of chlorophyll as well as improving the characteristics of fruits. Abdlhossein and Mohammad (2015) found that foliar spray of NAA(1-Naphthalene acetic acid) at a concentration of 30 and 60 $mg.l^{-1}$ at the beginning of the Kimri stage (6 weeks after pollination) an increase in the length, diameter, weight of the fruit and delayed ripening of the cultivar Zahedi. Hoda (2015) also found that spraying NAA at a concentration of $100mg.l^{-1}$ on Zaghloul cultivar increased bunch weight, length and diameter of the fruit.

The objective of the present study is to investigate the effect of Potassium Sulphate, NAA sprays and combination between them on the yield and fruit quality, as well as the ability to extend the marketing life of the fruits by delaying the entry of the fruits in the Rutab stage.

MATERIALS AND METHODS

The study was conducted for the period from March to September 2020 in one of the private orchards of Al-Abayji township-Tarmiyah district, 55 km north of Baghdad, to study the effect of foliar spraying with potassium sulfate (K2SO4) and Naphthalene Acetic Acid (NAA) on some fruit characteristics and the yield of date palm cv. Barhee, the experiment was carried out on 36 palm trees with homogeneous vegetative growth as much as possible and at the age of 18 years and planted with 10 m apart and subjected to the same management and cultural practices for all trees equally and the trees were pollinated in April with the vaccination of the male variety (Red Ghanami) in three batches, by placing 6 male fresh strands in the middle of each female flower cluster, the bunches were adjusted into 8 bunches for each date palm. The spray was carried out with K2SO4 at a concentration of K0 (spraying with distilled water only), K1 (0.5%), K2 (1.0%), and K3 (1.5%), spraying was applied twice, after fruit set (Hababouk phase) and after 4 weeks from the first spray(at the beginningof Kimri stage). As for the second factor, it included spraying bunches with NAA (assay 99%) and at three concentrations, A0 (spraying with distilled water only), A1 (spraying bunches at a concentration of 50 $mg.l^{-1}$) and A2 (spraying bunches at a concentration of 100 $mg.l^{-1}$).The bunches were sprayed at the beginning of Kimri stage and the second spray was done after 4 weeks from the first spray (at the beginning of Khalal stage). Spraying was carried out early in the morning till run- off with 0.1% tween 20 as diffuser, and then the following traits were measured:

Fruit weight (gm): 20 fruits from the pre-marked strands were selected to measure the weight of the fruit in the Khalal stage, according to (Sakr et al 2010). The weight of the random sample was measured, and then the average weight of one fruit was calculated.

Bunch weight and Yield (kg): during the Tamar stage, each bunch was weighed separately to get bunch weight (kg), and then yield per palm was calculated (kg).

Fruit drop (%): After 2 weeks of pollination, 10 strands were randomly selected, and they were marked, the total fruits were calculated, and the percentage of fruit drop was calculated at the end of the Khalal stage according to the following equation:

$$\textbf{Fruit drop}\ (\%) = \frac{\textbf{Number of dropped fruits per bunch}}{\textbf{Number of total fruits per bunch}} \times \mathbf{100}$$

Fruit ripening (%): When the fruits enter the Rutab stage (softening approximately 25% of the fruit area), and the percentage of ripe fruits was calculated according to Mohamed (2007).

Total Soluble Solids (%): It was estimated using a Hand Refractometer, according to (A.O.A.C. 1995).

Total, Reducing and Non-reducing Sugars (%): Total sugars and reducing sugars were estimated in the flesh of the fruits after taking 10 g of fresh fruits and adding distilled water to them, according to (Dubois et al 1956), while non-reducing sugars were measured by the difference between total sugars and reducing sugars.

Statistical analysis: Randomized Complete Block Design (RCBD) was the experimental design with three replicates, each replicate represented by one palm which contain 8 bunches. Obtained data were analyzed by analysis of variance (ANOVA) using statistical package software Genstst. Differences between treatments were made by *F-test* and the least significant differences at *P*= 5% according to (Alex 2011).

RESULTS AND DISCUSSION

Fruit weight (gm)

The statistical analysis of data showed that there were significant differences between Potassium Sulphate (K), NAA (A) concentrations, and their interaction (**Table 1**). The superior value of fruit weight was obtained when bunches were treated with the foliar application of K3 (1.5%) which gave (10.76gm) while fewer values of fruit weight (8.67gm) were observed in control (K0). Similarly, among (A) concentrations, the maximum values of fruit weight were noticed in A2 (100 $mg.l^{-1}$) which reached (10.27gm) compared to the

Table 1. Effect of Potassium Sulphate (K) and Naphthalene Acetic Acid (NAA) and their combination on fruit weight (gm), bunch weight (kg) and yield /palm (kg) of date palm cv. Barhee

Naphthalene Acetic Acid (NAA)	Potassium Sulphate(K)				Mean
	K0 =control	K1 =0.5%	K2 =1%	K3 =1.5%	
Fruit Weight(gm)					
A0 = control	8.04	9.43	9.10	10.12	9.17
A1 = 50mg.l^{-1}	8.48	9.46	9.35	11.17	9.62
A2 =100mg.l^{-1}	9.51	9.58	10.99	11.01	10.27
Mean	8.67	9.49	9.81	10.76	
L.S.D 0.05	K	A	K × A		
	0.41	0.36	0.72		
Bunch Weight(kg)					
A0 = control	7.64	8.08	8.79	10.37	8.72
A1 = 50mg.l^{-1}	8.25	8.68	10.01	10.42	9.34
A2 =100mg.l^{-1}	8.49	8.80	11.33	10.78	9.85
Mean	8.13	8.52	10.04	10.52	
L.S.D 0.05	K	A	K × A		
	0.36	0.31	0.63		
Yield/ palm (kg)					
A0 = control	62.58	66.18	71.64	84.47	71.22
A1 = 50mg.l^{-1}	67.48	70.59	82.11	85.06	76.31
A2 =100mg.l^{-1}	69.70	71.71	92.51	89.05	80.74
Mean	66.59	69.49	82.08	86.19	
L.S.D 0.05	K	A	K × A		
	3.20	2.77	5.55		

LSD = Least significant difference at 5% probability

minimum value in control (A0) which gave (9.17gm). The interactive effect between K and A concentrations were also significantly different among treatments, the highest value (11.17gm) were noticed in K3A1 while the lowest value (8.04gm) was obtained in K0A0.

Bunch weight (kg)

From the results shown in **Table 1**, it appears that the maximum value of bunch weight was noticed in K3 spray treatment which reached (10.52 kg) compared to the minimum value (8.13 kg) which was given by K0. Regarding (A) treatment the highest bunch weight (9.85 kg) was observed in A2 treatment, while the lowest value was noticed in control (8.72 kg).According to the statistical analysis the highest interaction value (11.33 kg) was noticed in K2A2 treatment, while K0A0 gave the lowest value (7.64 kg).

Yield (Kg)

It was observed from results shown in **Table 1** that there were increases in yield when bunches treated with Potassium, the highest value has been registered when bunches spray with K3 (86.19 kg), while the lowest value was observed in K0 (66.59 kg) closely followed by K1 (69.49 kg) which have no significant difference with each other. Similarly, bunches treated with NAA showed a significant difference, A2 had achieved the highest value (80.74 kg), while the lowest value noticed in A0 which gave (71.22 kg). The interaction between treatments taking the same trend, the highest yield has been achieved in K2A2 (92.51 kg) compared to the K0A0 which gave (62.58 kg).

From the results shown in **Table 1**, it is noticed that potassium significantly increased fruit weight, it may be attributed that potassium is one of the main solvents in cells and a common factor in the swelling pressure, in addition to its effect on many physiological processes such as photosynthesis, respiration and its role in the metabolism processes through the activation of enzymes leading to the encouragement of cell division, furthermore to its important role in the movement and transfer of sugars from places of synthesis to places of storage, including fruits as well as it plays a vital role in participating in producing adenosine triphosphate (ATP) which is important in regulating the photosynthesis process(Van Brunt and Sultenfuss 1998 ; Prajapati & Modi 2012). Consequently, increasing the fruit weight will lead to an increase in the bunch weight, hence an increase in the total yield per palm. These results are in harmony with (Harhash & Abdel-Nasser 2010; Abdel El-Migeed et al 2013 and Malaka et al 2016). Regarding the effect of auxin on increasing fruit weight, this may be due to that auxins play an important role in influencing the expansion and elongation of cells, and it is believed that this effect results from the stimulation of auxin to the enzymes that degrade some components of the cell wall as well as stimulating the enzymes involved in the components of the cell wall and thus causing changes in the flexibility of the cell wall and thus causing the expansion and.

Elongation of cells (Taiz and Zeiger 2010), which causes an increase in the permeability of the cell walls and then allows large quantities of water and nutrients to enter the cell, causing it to swell as a result and increase the fruit dimensions which then increase fruit weight (Moustafa et al 1993), or it may be attributed to the reason that NAA may increase the number of cells when the spraying date coincides with the differentiation stage that the fruit cells go through, which starts from the Kimri stage until the final stages of maturity, which leads to an increase in the number of cells and then an increase in the weight of the fruit (Mohammed and Shabana, 1980). Consequently, the positive effect of NAA auxin in reducing the percentage of fruits drop (**Table 2**) and

Table 2. Effect of Potassium Sulphate (K) and Naphthalene Acetic Acid (NAA) and their combination on Fruit drop (%), Fruit ripening (%) and Total soluble solids (%) of date palm cv. Barhee

Naphthalene Acetic Acid (NAA)	Potassium Sulphate(K)				Mean
	K0 =control	K1 =0.5%	K2 =1%	K3 =1.5%	
Fruit drop (%)					
A0 = control	5.56	4.23	3.93	3.81	4.38
A1 = 50mg.l^{-1}	3.81	3.32	3.33	3.34	3.45
A2 =100mg.l^{-1}	3.22	3.44	3.31	3.09	3.26
Mean	4.19	3.66	3.52	3.41	
L.S.D 0.05	K	A	K × A		
	0.13	0.11	0.22		
Fruit ripening (%)					
A0 = control	50.87	54.13	55.82	57.26	54.52
A1 = 50mg.l^{-1}	50.80	49.17	48.77	49.37	49.53
A2 =100mg.l^{-1}	46.90	47.10	47.17	51.44	48.15
Mean	49.52	50.13	50.59	52.69	
L.S.D 0.05	K	A	K × A		
	1.01	0.87	1.75		
Total soluble solids (%)					
A0 = control	46.06	52.68	58.25	55.23	53.06
A1 = 50mg.l^{-1}	43.63	50.91	56.06	50.41	50.25
A2 =100mg.l^{-1}	42.78	51.21	48.42	48.17	47.65
Mean	44.16	51.60	54.24	51.27	
L.S.D 0.05	K	A	K × A		
	1.96	1.70	3.40		

LSD = Least significant difference at 5% probability

increasing the weight of the fruit, which is due to the increase in the rate of assimilation and moving towards the fruits, it is expected as a result to an increase in the bunch weight and hence an increase in the yield. These results are in agreement with (Abdel-Kader et al 2008; Kassem et al 2011; Ghazzawy 2013; and Merwad et al 2015) on some date palm cultivars.

Fruit drop (%)

According to the data given in **Table 2**, maximum percentage of fruit drop was noticed in control (4.19%), while the minimum fruit drop percentage was achieved by Potassium spray, K3(3.41%) closely followed by K2(3.52%) which have no significant difference with each other, in the same manner, spray bunches with NAA had a significant effect in reducing fruit drop, the lowest fruit drop was noticed in A2(3.26%), while the highest value was given by A0(4.38%). The interaction between different concentrations of Potassium and NAA was also significant; having a minimum value (3.09%) for K3A2, whereas the highest values (5.56%) was given by K0A0.

Fruit ripening (%)

Table 2 shows that the fruit ripening percentage was significantly influenced by Potassium spray, K3 had significantly more concentration of Potassium which registered the highest value (52.69%), compared to the lowest value which found in K0 and K1(49.52%, 50.13%) respectively, on the contrary, the results of statistical analysis showed that bunches sprinkling with NAA has a reducing effect in fruit ripening, the highest value was done by A0(54.52%), while the lowest value was given by A2(48.15%). The interaction between treatments had a significant effect, the highest interactive value (57.26%) was shown by K3A0 while the lowest value (46.90%) was given by K0A2.

Total soluble solids (%)

Results shown in **Table 2** proved that total soluble solids (TSS) were significantly increased by using Potassium as compared to the control treatment, K1 had achieved the highest value (54.24%) as compared to the lowest value (44.16%) at control treatment, while NAA spray led to a reduction in TSS content, the lowest value (47.65%) was given by A2 treatment, whereas the highest value (53.06%) accomplished by control treatment. The interaction among Potassium and NAA spray was also significant, the maximum value (58.25%) was given by K2A0 as compared to the lowest value (42.78%) was done by K0A2.

Total sugars (%)

Results in **Table 3** indicated that all concentrations of Potassium significantly affected total sugars content in fruits, K2 recorded the highest value which was (40.20%) compared to the control treatment at which the total sugars were (35.99%). The use of NAA has led to an obvious reduction in total sugars, A1 and A2 gave the lowest value (37.47% and 37.08%) respectively, while the highest values (39.24%) were given by control. For the interaction, it was found that K2A0 recorded the highest value (41.13%), compared to the lowest value (34.29%) at K0A2.

Reducing sugars (%)

The results in **Table 3** indicated that the use of Potassium spray caused significant differences; K2 achieved the highest value (25.18%) as compared to the control (22.96%), while NAA spray led to a reduction in reducing sugars content, the highest value (25.24%) was given by A0 treatment, whereas A2 gave the lowest value which was (23.42%). The interaction between treatments had a significant effect; the highest interactive value (26.21%) was shown by K2A0 while the lowest value (22.18%) was given by K0A2.

Table 3. Effect of Potassium Sulphate (K) and Naphthalene Acetic Acid (NAA) and their combination on Total sugars (%), Reducing sugars and, Non- reducing sugars (%) of date palm cv. Barhee

Naphthalene Acetic Acid (NAA)	Potassium Sulphate(K)				Mean
	K0 =control	K1 =0.5%	K2 =1%	K3 =1.5%	
Total sugars (%)					
A0 = control	37.90	38.57	41.13	39.36	39.24
A1 = 50mg.l^{-1}	35.78	38.33	40.50	35.26	37.47
A2 =100mg.l^{-1}	34.29	37.17	38.97	37.89	37.08
Mean	35.99	38.02	40.20	37.50	
L.S.D 0.05	K	A	K × A		
	0.85	0.73	1.47		
Reducing sugars (%)					
A0 = control	24.44	25.43	26.21	24.88	25.24
A1 =50mg.l^{-1}	22.28	25.10	25.51	23.43	24.08
A2 =100mg.l^{-1}	22.18	23.25	23.82	24.45	23.42
Mean	22.96	24.59	25.18	24.25	
L.S.D 0.05	K	A	K × A		
	0.45	0.39	0.78		
Non-reducing sugars (%)					
A0 = control	13.46	13.14	14.92	14.48	14.00
A1 = 50mg.l^{-1}	13.50	13.23	14.99	11.82	13.38
A2 =100mg.l^{-1}	12.11	13.92	15.14	13.44	13.66
Mean	13.02	13.43	15.02	13.25	
L.S.D 0.05	K	A	K × A		
	0.99	n.s	n.s		

LSD = Least significant difference at 5% probability

Non-Reducing sugars (%)

According to the data are given in **Table 3**, Potassium has a significant effect on non-reducing sugars, K2 achieved the highest value which was (15.02%), while the lowest values were given by K0, K1 and K3 (13.02, 13.43 and 13.25%) respectively, with no difference between them, while no significant differences were found as a result of NAA spray or interaction among Potassium and NAA spray.

The reason for the decrease in fruit drop as a result of spraying with NAA may be attributed to its role in preventing the formation of the separation layer by preventing the degradation of the cell walls and the middle plates of the cells of the abscission zone, as auxin works to inhibit the action of the hydrolytic enzymes that breakdown the separation layer, which is cellulase and pectinase that degrade the components of the separation layer (Yuan and Carbaugh 2007 ; Yuan and Li 2008) The findings which discussed are in line with Al-Qurashi et al 2012 and Zaen El-Daen et al 2017). The ripening process of fruits is a dynamic and effective process that is accompanied by a number of changes, including softness or tenderness, resulting from the enzymes that stimulate them (Rongcai and David, 2007), auxins work to delay the ripening of fruits, and this may be due to a decrease in total soluble solids and sugars, and the effect of auxins in the ripening process of fruits may be due to preventing the decomposition of nucleic acids present in the cell, preventing protein degradation and stopping the self-degradation that occurs in RNA as they affect the permeability of membranes Cellularity and increase the cell's control over the movement of these substances across the membranes, or the reason for delaying the ripening of fruits may be due to a remote role in delaying the senescences of fruits by regulating the production or movement of ethylene, it is known that ethylene is known as the hormone of fruit ripening. (Li and Yuan, 2008), these results are consistent with the findings of (Shabana et al, 1998; Al-Juburi et al, 2001; Al-Samaraie & Al-Falahy, 2020) on date palm cv.Khaniezy, Barhee and Braim respectively.

CONCLUSION

Results demonstrated that spray of potassium sulphate twice, after fruit set and 4 weeks after the first spray at (0.5, 1, and 1.5%), significantly reduced fruit drop and enhance fruit weight, bunch weight, yield, fruit ripening, and most of fruit quality characteristics. NAA spray at (50 and 100mg.l-1) increased fruit weight, bunch weight, yield and reducing fruit drop, fruit ripening, total soluble solids, and total sugars, than untreated treatment (control).

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