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## Saudi Journal of Biological Sciences

journal homepage: [www.sciencedirect.com](http://www.sciencedirect.com)

Original article

## Investigating the role of potassium and urea to control fruit drop and to improve fruit quality of “Dhakki” date palm

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## ARTICLE INFO

## Article history:

Received 28 November 2021

Revised 24 February 2022

Accepted 28 February 2022

Available online 4 March 2022

## Keywords:

Fruit drop

Dhakki date

Foliar application

Potassium

Urea

## ABSTRACT

Fruit drop is a key issue with date palm cultivars that can be addressed with a variety of methods and strategies. Foliar application of macronutrients can be more effective in inhibiting fruit drop and improving the quality of date fruits. The current study was carried out to investigate the possible role of potassium (K) and urea to reduce fruit drop and improve the fruit quality of “Dhakki” date palm. It was conducted in a complete randomised block design with seven treatments and three replications at Pakistan’s Agricultural Research Institute, Dera Ismail Khan. The treatments used were: (i) Control (distilled water spray); (ii) Potassium sulphate ( $K_2SO_4$ ) at 1%; (iii)  $K_2SO_4$  at 1% + Urea at 2%; (iv)  $K_2SO_4$  at 2%; (v)  $K_2SO_4$  at 2% + Urea at 2%; (vi)  $K_2SO_4$  at 3% and; (vii)  $K_2SO_4$  at 3% + Urea at 2%. All the concentrations were sprayed at Kimri stage of fruit development during two consecutive growing seasons. Twenty-one date palms of equal size and age were chosen for the assessments to measure percent fruit drop and other physicochemical variables, including fruit length, fruit diameter, fruit weight, pulp percentage, yield/bundle, pH, total soluble solids (TSS), K content in fruit, and all sugars (percent) of harvested date fruit. The results revealed that bunch spray of K significantly affected all the parameters during both seasons. Application of  $K_2SO_4$  alone and in combination with urea not only effectively reduced the fruit drop but also improved fruit quality in date where,  $K_2SO_4$  applied at 2% combined with urea was the best concentration in reducing fruit drop, enhancing other physicochemical attributes, and improving fruit quality of “Dhakki” date palm. This study may effectively contribute to reduce the fruit drop and enhance the fruit quality by using K and urea, enabling farmers to improve the date yield and increase economic growth.

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## 1. Introduction

Pakistan is the 6th largest producer of date palm globally, and dates are ranked as the 3rd most famous fruit (FOASTAT, 2019).

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Peer review under responsibility of King Saud University.



Among various cultivars grown in the country, “Dhakki” date palm is preferred for its better appearance, nutritional value, and sweeter taste (Baloch, 1999). However, the cultivar faces higher fruit drop resulting in up to 60% economic losses (Iqbal et al., 2012). Fruit drop is a serious threat in many fruiting plants, and especially in date palm cultivars, it can reduce yield drastically. Date palm is grown in hot and arid regions making it more vulnerable to various biotic and abiotic stresses that can result in fruit drop, affecting the growth and production adversely (Youssef and Awad, 2008).

Many biotic and abiotic factors have associated with premature fruit drop in different fruits crops such as deficiency of nutrients, abiotic stress and infection of virus and bacteria (Cole and

<https://doi.org/10.1016/j.sjbs.2022.02.060>

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McCloud, 1985; Mahy, 2008; Khan et al., 2012; Khan, 2015). The major causes of fruit drop can be physiological, nutritional, and pathological. Normally, it occurs at different stages of fruit development, but severe fruit drop occurs at the end of Kimri stage (the immature green stage, cell elongation), in June (also known as June drop), and its range can be around 50–70%. Sudden temperature change, high rainfalls, nutrient deficiency, improper soil moisture, and heavy crop load are also associated with fruit drop (Reuveni, 1986; Al-Shahib and Marshall, 2003; Fadel et al., 2006; Racsko et al., 2007; Robinson et al., 2010).

It is also believed that fruit drop is caused due to an imbalance between auxin and ethylene level. Ethylene triggers the system for abscission layer formation, breaks down the cell walls leading to fruit drop (Stover et al., 1998; Wood, 2011). Hence, there is a need to adopt measures and approaches to reduce fruit drop, especially in date palm cultivars. For this purpose, different plant growth regulators and applications of different chemical fertilizers have been suggested (Ahmed et al., 2013). Because of their synergistic relationship, foliar application of macronutrients, particularly potassium alone or in combination with urea, has also been found to be more effective in inhibiting the drop of fruit and improving fruit quality by strengthening fruit pedicels. This is because a deficiency or excess of these nutrients can result in a reduction in crop yield as well as inferior fruit quality (Ashraf et al., 2013; Reetika et al., 2018).

K is considered an important nutrient among the macronutrients for date palm growth and productivity. It is essential for the development of root and shoots, fruits, and leaves, as well as glucose production. It is essential for glucose generation, which is required for root and shoot development, fruit and leaf development, and nutrient absorption. Furthermore, K plays an important function in maintaining cell water content as well as the production and mobilisation of carbohydrates in plant tissues. These carbohydrates ultimately enhance vegetative growth, fruit set, yield, and fruit quality (Harhash and Abdel-Nasser 2010). K has further role in some physiological purposes, i.e. starch and sugar formation, proteins synthesis, cell division, and fruit formation to improve fruit size, shape, flavour, and color (Holzmueller et al., 2007; Abbas and Fares, 2009). It has also been reported that application of K along urea in some cases functions as growth regulators where it is found to improve growth, yield, and fruit quality of different date cultivars (Kassem et al., 1997).

Normally it is observed that when fertilizer is applied through the soil, higher doses are required because of the leaching losses. At the same time, a portion of nutrients is sometimes not available to plants due to complex chemical reactions. At the same time, in the case of foliar/bunch application, it can be useful in many fruits, especially in date palm cultivars, as these nutrients are not only required in small quantities but can be safely and easily applied on bunches in a precise concentration for absorption and supply.

Keeping in view the importance of K and urea, this work was performed to investigate these two nutrients' role in controlling fruit drop and improving fruit quality of "Dhakki" date palm.

## 2. Materials and methods

### 2.1. Experimental area and treatments

During two cropping seasons, researchers at the Agriculture Research Institute (ARI) in Dera Ismail Khan, Pakistan, investigated the role of K and urea in decreasing fruit drop and improving fruit quality in the "Dhakki" date palm. Twenty-one "Dhakki" palms with almost identical size and growth vigour were chosen for the current study. All the Agricultural practices including removal of dried leaves, application of FYM, applying lime emulsion on tree

trunk to prevent insect/pest attack were used accordingly to the local recommendations.

With seven treatments and three replications, the experiment was set up in a randomized complete block design (RCBD). The treatments used were: (i) Control (distilled water spray); (ii)  $K_2SO_4$  at 1 %; (iii)  $K_2SO_4$  at 1 % + Urea at 2 %; (iv)  $K_2SO_4$  at 2 %; (v)  $K_2SO_4$  at 2 % + Urea at 2 %; (vi)  $K_2SO_4$  at 3 %; (vii)  $K_2SO_4$  at 3 % + Urea at 2 %. All the concentrations were sprayed at Kimri stage of fruit development during the two growing seasons. The fruit at Kimri stage is immature with green color and firm texture (Hui, 2006; Ahmed et al., 2013). The spray was applied (1L) on 10 selected bunches from each tree after one month of fruit setting and second spray was applied after one month of the first spray. A tiny knapsack sprayer was used to apply the liquids on the bunch until they ran off. By cutting the palm's earliest, latest, and shortest inflorescences, the number of spathe per palm was reduced to ten bunches. The 1 % solution was made by dissolving 10 g of the needed nutrient in 1L of distilled water. Similarly, 20 and 30 g of needed nutrients per 1 L of distilled water were used to make 2 % and 3 % solutions.

### 2.2. Physicochemical analyses

In each palm tree, 10 strands were randomly selected, tagged at different positions of each bunch. Fruits were harvested, dried and processed properly for further chemical analysis. During both seasons, the fruit drop was observed three times. According to Ashraf et al. (2013), the following formula was used to calculate the percentage of fruit drop for each month.

$$\text{Fruit drop (\%)} = \frac{\text{Number of dropped fruits on strands}}{\text{Number of total fruits on strands}} \times 100$$

A Vernier calliper was used to measure the length and diameter (mm) of ten fruits per strand/bunch/palm three times. For three periods of time, the percent increase in fruit length and diameter was also observed. Using an electronic scale, the fruit weight (g) from all selected strands/bunches (ten fruit per strand) was measured. The weight of ten fruit samples was obtained using an electronic scale to determine the pulp percentage. The seed was removed, and the pulp weight and percentage were computed using the following formula:

$$\text{Pulp percentage} = \frac{\text{Total pulp weight of fruit}}{\text{Total weight of fruit}} \times 100$$

The pH was measured by the help of Jenway 3510 bench pH meter (Cole-Parmer, Staffordshire, UK). To evaluate the chemical characteristics of dates, 100 g fresh pulp from each treatment was mixed with a 200 mL distilled water and blended for 2–3 min in an electric blender to obtain a full extraction and homogeneous layer. Then 2 g of this pulp solution from each treatment was used to determine various chemical properties of dates. TSS, was measured in °Brix by using pulp solution on a prism of a digital refractometer (Krüss DR301-95; A. Krüss Optronic, Hamburg, Germany) at a temperature of 20 °C. K content in fruit (mg/g) was calculated using flame photo meter (Sherwood model 410), while, TSS (reducing and non-reducing sugars) were estimated by Fehling A and B solutions, following the Lane and Eynon methodology as mentioned in the A.O.A.C., 1995.

### 2.3. Statistical analysis

The statistical analysis was performed using the computer software Statistix-8 to analyze variance (Steel and Torrie 1980). Means were compared using the Least Significant Difference (LSD) test to

determine which treatments have a significant effect in the analysis of variance (ANOVA).

### 3. Results

#### 3.1. Fruit drop (%)

Application of  $K_2SO_4$  significantly reduced the total fruit drop during both seasons. A maximum fruit drop of 76.51 % and 70.43 % was observed in untreated trees (control). In comparison, minimum drop was recorded in bunches treated with  $K_2SO_4$  at 2 % combined with urea at 2 % presenting 47.18 % and 43.95 % of fruit drop in the first and second season, respectively by all other treatments (Figs. 1A and 1B). When the distribution of fruit drop in both seasons was examined, it was shown that the maximum fruit drop occurred in June. Spraying  $K_2SO_4$  at 2% mixed with urea at 2% considerably reduced fruit drop in June, with maximum drops (50.52 percent and 41.20 percent) in untreated palms and minimum drops (27.55 % and 18.83 %) in bunches sprayed with  $K_2SO_4$  at 2% combined with urea at 2% in both seasons (Figs. 1A and 1B).

#### 3.2. Fruit length (mm)

Significant differences were found for fruit length among the treatments during both seasons. Maximum fruit lengths of 50.70 mm and 51.26 mm after proper drying were noticed when  $K_2SO_4$  was applied at 2 % combined with urea at 2 % followed by 47.33 mm and 49.26 mm measured for fruit harvested from trees treated with  $K_2SO_4$  at 3 % alone in first and second season, respectively. However, bunches that were not sprayed with  $K_2SO_4$  or urea resulted in minimum fruit lengths of 41.60 mm and 42.26 mm during both season, respectively (Figs. 2A and 2B).

Data for fruit length was collected three times during both growing seasons and increasing in length was also calculated for each period that showed that spraying bunches with  $K_2SO_4$  boosted fruit length compared to the fruit obtained from the trees that were not sprayed (control) (Supplementary Fig. 1).

Maximum increase (45.96 % and 44.99 %) were recorded in June of first and second season, respectively, after the application of  $K_2SO_4$  at 2 % combined with urea at 2 % at Kimri stage as compared to the control that showed minimum increase of 28.73 % and 30.60 % in first and second season, respectively (Figs. 2A and 2B).

#### 3.3. Fruit diameter (mm)

For both seasons, significant differences in fruit diameter were noted among the treatments. Fruits collected from bunches sprayed with  $K_2SO_4$  at 2% mixed with urea at 2% had maximum fruit diameters of 32.40 mm and 32.20 mm, respectively, in comparison to controls, which had minimum fruit diameters of 25.16 mm and 24.70 mm in the first and second seasons, respectively (Figs. 3A and 3B).

Differences in fruit weight after complete drying were found to be statistically significant in both seasons. Fruit taken from bunches sprayed with  $K_2SO_4$  at 2 % mixed with urea had maximum weights of 14.18 g and 14.50 g, respectively, while fruit harvested from bunches left untreated had minimum weights of 10.75 g and 10.40 g in the first and second seasons, respectively (Figs. 3A and 3B) (Supplementary figure 1).

#### 3.4. Fruit weight (g)

Differences in fruit weight after complete drying were found to be statistically significant for both seasons. Fruit harvested from bunches sprayed with  $K_2SO_4$  at 2% mixed with urea had maximum weights of 14.18 g and 14.50 g, respectively, while fruit harvested from bunches left untreated had minimum weights of 10.75 g and 10.40 g (Table 1).

#### 3.5. Pulp percentage

The highest pulp percentage (91.14 % and 91.94 %) was recorded for the fruit of bunches sprayed with  $K_2SO_4$  at 2 % combined with urea at 2 % followed by 90.76 % and 90.48 %, observed for the fruits that received  $K_2SO_4$  at 2 % alone in first and second season, respectively, while untreated bunches (control) showed minimum pulp of 87.63 % and 88.16 % for the both seasons.

#### 3.6. Bunch weight (kg)

Results obtained during first year of study showed that spraying the bunches with  $K_2SO_4$  at 2 % combined with urea at 2 % or alone resulted in highest weight of 8.50 kg and 8.15 kg/bunch, respectively, whilst  $K_2SO_4$  at 3% alone and combined with urea resulted in weights of 7.99 and 7.84 kg/bunch, respectively, during the first

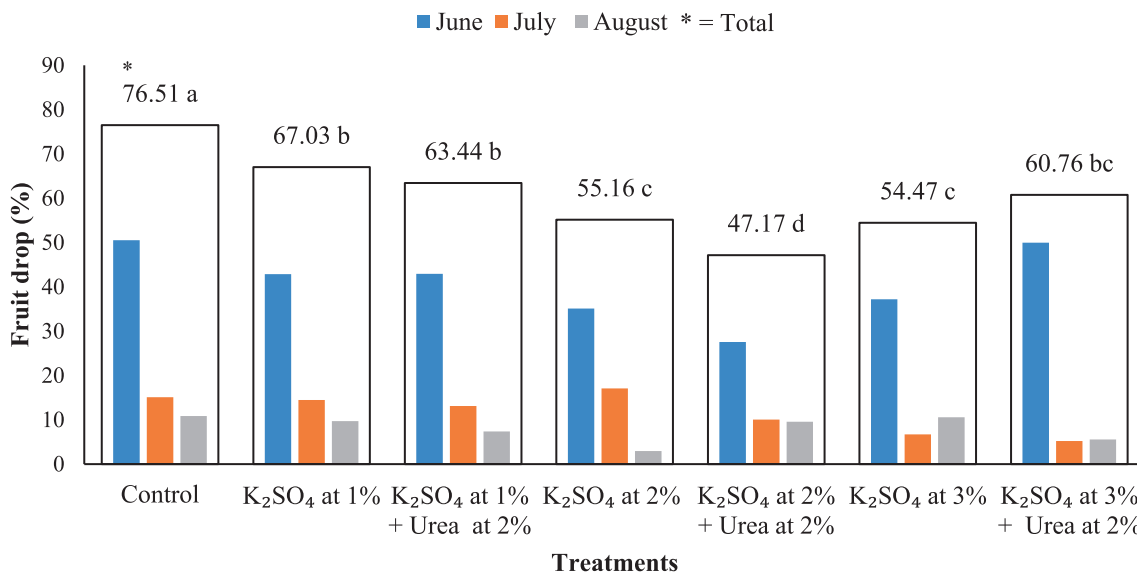


Fig. 1A. Fruit drop (%) of "Dhakki" date palm for 1st season. Means followed by different letters in columns are significant at 5% level of probability.

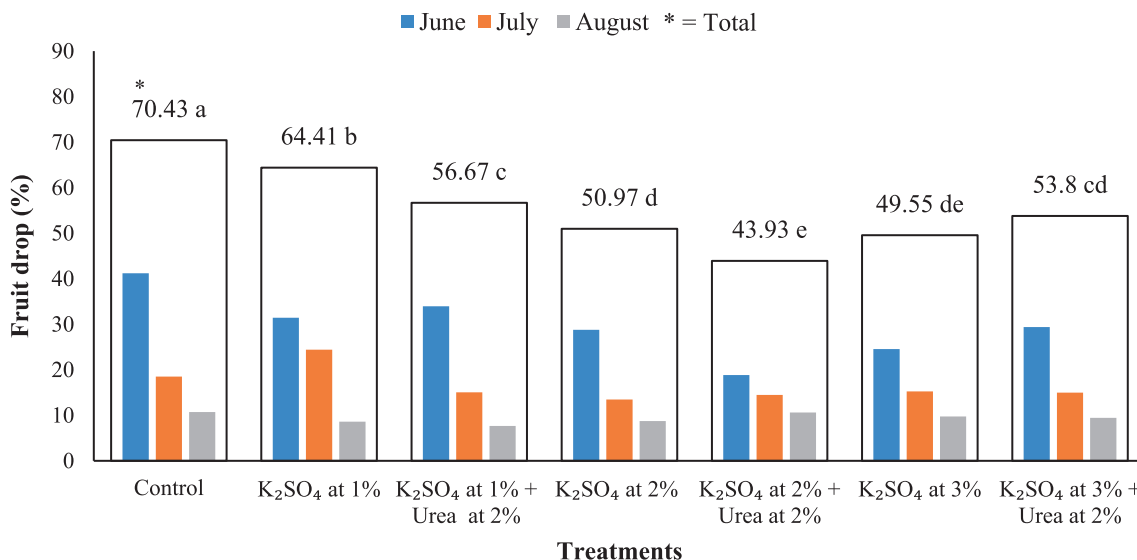


Fig. 1B. Fruit drop (%) of "Dhakkhi" date palm for 2nd season. Means followed by different letters in columns are significant at 5% level of probability.

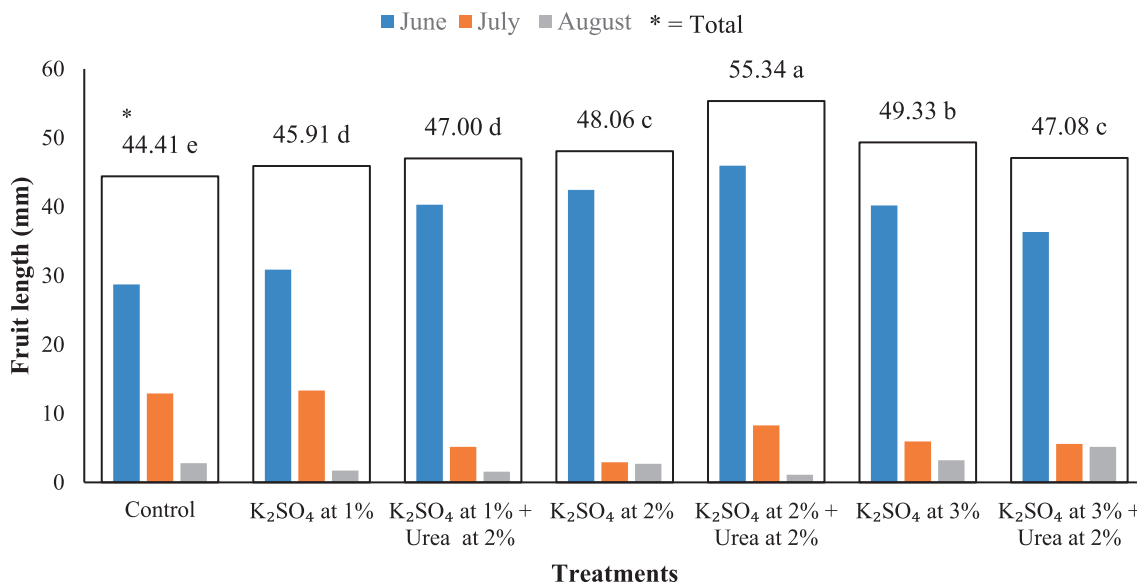


Fig. 2A. Fruit length (mm) of "Dhakkhi" date palm for 1st season. Means followed by different letters in columns are significant at 5% level of probability.

year of the study. The lowest concentration of K<sub>2</sub>SO<sub>4</sub> (1% alone) resulted in 6.72 kg/bunch, which was statistically equivalent to the 6.45 kg/bunch obtained for the untreated bunches (Table 1).

In the second season, spraying K<sub>2</sub>SO<sub>4</sub> at 2% combined with urea resulted in a maximum weight of 8.71 kg/bunch, followed by 8.48 kg/bunch from bunches sprayed with K<sub>2</sub>SO<sub>4</sub> at 3% alone and 8.41 kg/bunch from spraying the same concentration combined with urea. Spraying K<sub>2</sub>SO<sub>4</sub> at 2% alone resulted in 8.26 kg of weight/bunch, followed by spraying K<sub>2</sub>SO<sub>4</sub> at 1% coupled with urea and alone, which yielded 7.74 kg and 7.16 kg/bunch, respectively. Bunches that did not get any application (control) yielded the lowest weight of 6.73 kg/bunch during the second season of this trial (Table 1).

### 3.7. Fruit pH

Although increasing the concentration of K<sub>2</sub>SO<sub>4</sub> resulted in increased pH of the fruit, but no significant differences were found among all treatments during both seasons, and the means ranged

from 6.15 to 6.66, and 6.30 to 6.66 in first and second season, respectively (Table 2).

### 3.8. Total soluble solids (TSS)

Fruit harvested from bunches sprayed with K<sub>2</sub>SO<sub>4</sub> at 2 percent combined with urea had the highest percentage of TSS (76.20 and 76.86 °Brix), which was comparable to 75.30 and 75.56 °Brix of TSS in the fruits obtained from bunches sprayed with K<sub>2</sub>SO<sub>4</sub> at the same concentration alone in first and second season, respectively. Significantly lowest amount of TSS 73.46 and 72.83 °Brix was recorded in the fruit harvested from untreated bunches during both seasons (Table 2).

### 3.9. K Content in fruit

Increasing the concentration of K<sub>2</sub>SO<sub>4</sub> in the fruit resulted in an increase in K content in the fruit over both seasons. Fruit obtained from trees sprayed with K<sub>2</sub>SO<sub>4</sub> at 3 % mixed with with urea and it

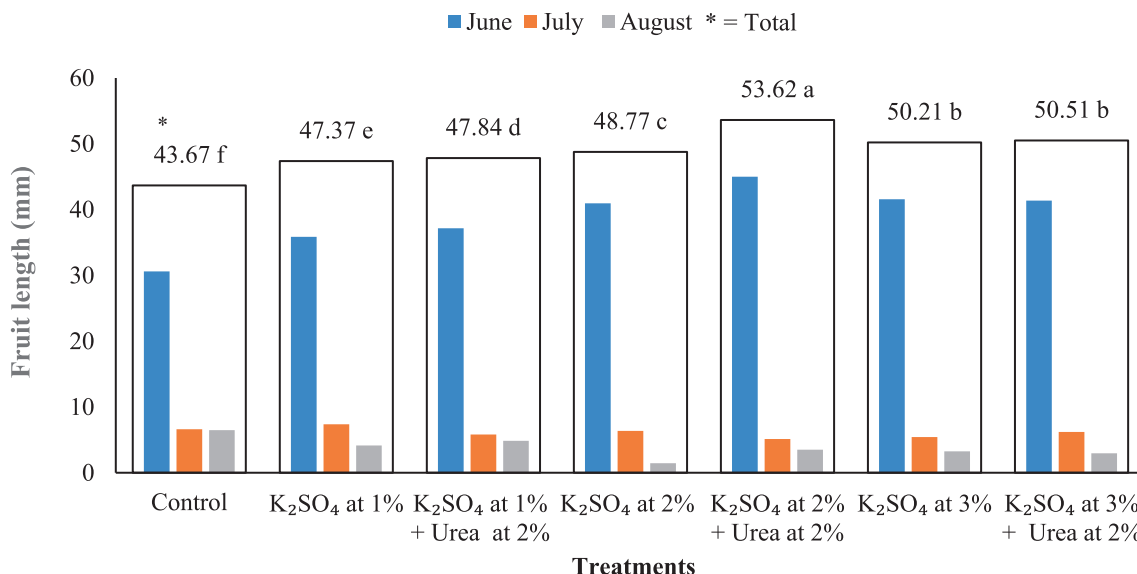


Fig. 2B. Fruit length (mm) of "Dhakki" date palm for 2nd season. Means followed by different letters in columns are significant at 5% level of probability.

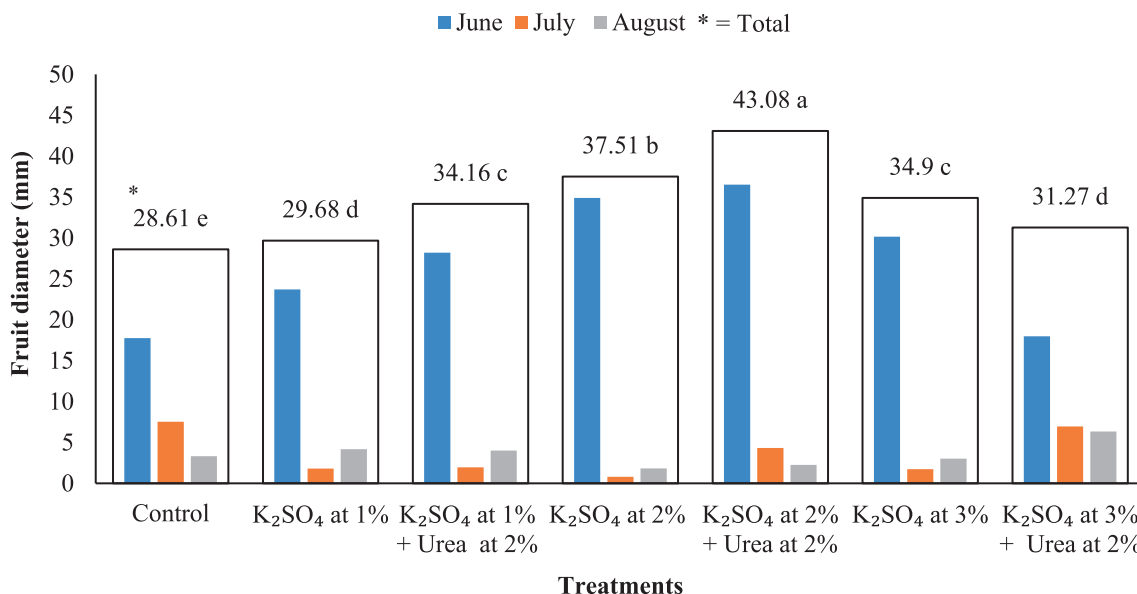


Fig. 3A. Fruit diameter (mm) of "Dhakki" date palm for 1st season. Means followed by different letters in columns are significant at 5% level of probability.

was statistically similar to 8.86 and 10.70 mg/g in the fruit treated with K<sub>2</sub>SO<sub>4</sub> at 3 % in first and second season, respectively. The fruit on the unsprayed bunches showed minimum K content of 7.53 and 7.36 mg/g in both seasons (Table 2).

### 3.10. Reducing and non-reducing sugars

K<sub>2</sub>SO<sub>4</sub> treatment of date bunches resulted in significant reductions in both reducing and non-reducing sugars. The fruit of bunches sprayed with K<sub>2</sub>SO<sub>4</sub> at 2% combined with urea had the highest reducing sugars (52.82 and 55.16 %), while the first and second season control treatments had the lowest reducing sugars (48.69 and 49.10 %, respectively) (Table 3).

However, as the concentration of K<sub>2</sub>SO<sub>4</sub> spray was reduced, non-reducing sugars increased. Fruit from bunches sprayed with 1% K<sub>2</sub>SO<sub>4</sub> had the highest level of non-reducing sugars (10.99%), which was statistically equivalent to the 10.77 and 10.99 percent

reported in fruits recovered from bunches sprayed with 1% K<sub>2</sub>SO<sub>4</sub> alone and untreated bunches, respectively. The fruit of bunches sprayed with K<sub>2</sub>SO<sub>4</sub> at 2% combined with urea had the least amount of non-reducing sugars (7.73%). (Table 3). Similarly, applying various amounts of K<sub>2</sub>SO<sub>4</sub> alone or in combination with urea during the second season had a considerable impact on non-reducing sugars. The maximum quantity of non-reducing sugars were found in K<sub>2</sub>SO<sub>4</sub> at 2 % alone or in combination with urea, at 13.06 percent and 13.33 percent, respectively. The fruit of bunches that were left untreated had the lowest proportion of non-reducing sugars, 10.26% (Table 3).

### 3.11. Total sugars

Total sugars data showed statistically non-significant differences during first season and ranged from 59.93 to 61.55 %. Spraying K<sub>2</sub>SO<sub>4</sub> at varied doses during the second season had a

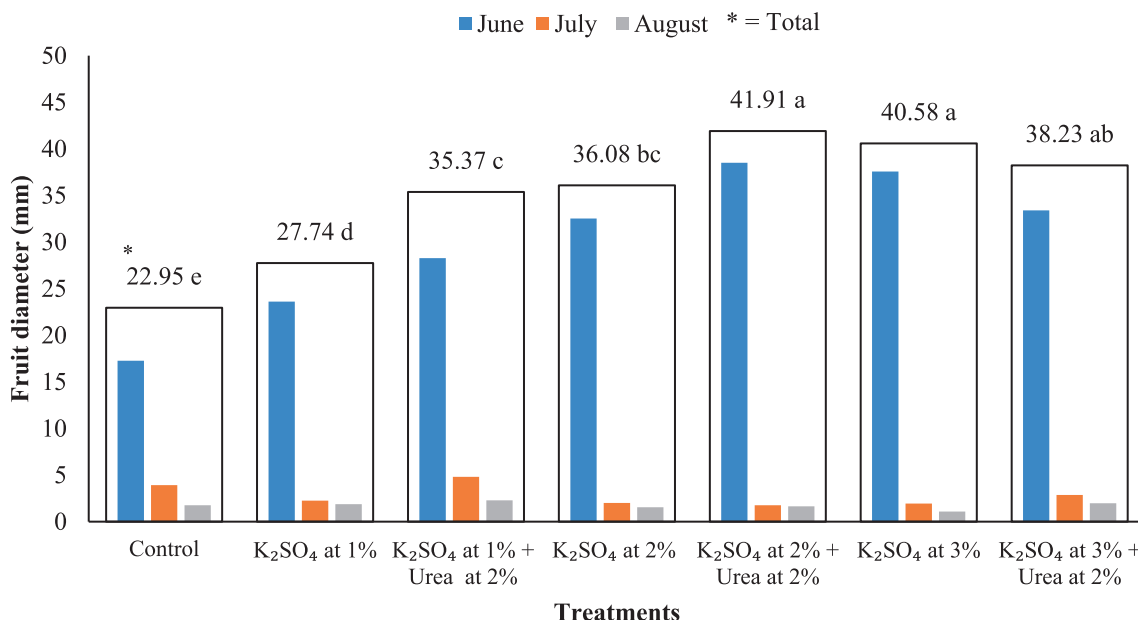


Fig. 3B. Fruit diameter (mm) of "Dhakki" date palm for 2nd season. Means followed by different letters in columns are significant at 5% level of probability.

Table 1  
Effect of K<sub>2</sub>SO<sub>4</sub> on fruit weight, pulp percentage and weight of "Dhakki" date palm for the two cropping seasons.

Treatments	Fruit weight (g)		Pulp (%)		Bunch weight (kg)	
	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
Control (water spray)	10.75 d	10.40 e	87.63 d	88.16 d	6.45 d	6.73f
K <sub>2</sub> SO <sub>4</sub> at 1%	11.20 d	11.43 d	88.19 d	89.20 cd	6.72 d	7.16 e
K <sub>2</sub> SO <sub>4</sub> at 1% + Urea at 2%	12.62c	12.06c	89.57c	89.49 bcd	7.57c	7.74 d
K <sub>2</sub> SO <sub>4</sub> at 2%	13.59 ab	12.96b	90.76 ab	90.48 abc	8.15 ab	8.26c
K <sub>2</sub> SO <sub>4</sub> at 2% + Urea at 2%	14.18 a	14.50 a	91.14 a	91.94 a	8.50 a	8.71 a
K <sub>2</sub> SO <sub>4</sub> at 3%	13.30 bc	13.43b	90.14 bc	91.05 ab	7.99 bc	8.48 bb
K <sub>2</sub> SO <sub>4</sub> at 3% + Urea at 2%	13.07 bc	13.06b	89.99 bc	91.08 ab	7.84 bc	8.41 bc
<b>LSD</b>	<b>0.728</b>	<b>0.470</b>	<b>0.979</b>	<b>1.813</b>	<b>0.451</b>	<b>0.161</b>

Means followed by different letter (s) in column are significant at 5% level of probability.

Table 2  
Effect of K<sub>2</sub>SO<sub>4</sub> on fruit pH, total soluble solids (TSS) and potassium content of "Dhakki" date palm for the two cropping seasons. Means followed by different letter (s) in column are significant at 5% level of probability.

Treatments	Fruit pH		TSS (°Brix)		Potassium Content (mg/g)	
	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
Control (water spray)	6.16 <sup>NS</sup>	6.66 <sup>NS</sup>	73.46c	72.83 e	7.53b	7.36 d
K <sub>2</sub> SO <sub>4</sub> at 1%	6.30	6.36	74.60b	73.73 d	7.60b	7.90 cd
K <sub>2</sub> SO <sub>4</sub> at 1% + Urea at 2%	6.33	6.43	74.96b	74.53c	7.66b	8.50 bc
K <sub>2</sub> SO <sub>4</sub> at 2%	6.43	6.30	75.30 ab	75.56b	7.66b	9.26b
K <sub>2</sub> SO <sub>4</sub> at 2% + Urea at 2%	6.56	6.40	76.20 a	76.86 a	7.86b	10.53 a
K <sub>2</sub> SO <sub>4</sub> at 3%	6.63	6.50	75.00b	75.06 bc	8.86 a	10.70 a
K <sub>2</sub> SO <sub>4</sub> at 3% + Urea at 2%	6.66	6.56	74.80b	74.53c	9.33 a	10.76 a
<b>LSD</b>	<b>0.14</b>	<b>0.44</b>	<b>0.762</b>	<b>0.69</b>	<b>0.531</b>	<b>0.76</b>

substantial impact on total sugars. Fruit from bunches sprayed with K<sub>2</sub>SO<sub>4</sub> at 2% mixed with urea had the largest quantity of total sugars (68.70%) compared to fruit from untreated bunches, which had the lowest amount (59.36%). (Table 3).

#### 4. Discussion

Fruit drop is a serious economic threat in many fruiting plants, and nearly 50 % of the flowers and immature fruits fell during growth under various stresses (Iqbal et al. 2009). Major causes of fruit drop can be related to genetic, physiological, and environmental phenomena (Yuan and Carbaugh, 2007; Yuan and Li, 2008; Li

and Yuan, 2008; Robinson et al., 2010; Zhu et al., 2010). Various stresses, including drought, hot weather, and nutrient deficiency or imbalance, can lead to excessive fruit drop, deteriorate fruit quality, and ultimately leads to lower production (Racsck et al., 2007; Robinson et al., 2010).

Date palm cultivar "Dhakki" is prone to severe fruit drop. Among various physiological factors, nutrient deficiency or inequity can be considered one of the most important reasons for higher fruit drop in this cultivar. The current study was designed to improve the date quality and reduce fruit drop by nutrients' application. For that purpose, various doses of K and urea were applied and their effect was studied.



**Table 3**  
Effect of  $K_2SO_4$  on reducing, non-reducing and total sugars of “Dhakki” date palm for the the two cropping seasons.

Treatments	Reducing Sugars (%)		Non-Reducing Sugars (%)		Total Sugars (%)	
	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
Control (water spray)	48.69b	49.10 a	10.90 a	10.26c	59.93 a	59.36 e
$K_2SO_4$ at 1	49.67b	50.83c	10.77 a	11.40 bc	60.44 a	62.23 d
$K_2SO_4$ at 1 % + Urea at 2%	50.34 ab	52.23 bc	10.99 a	12.33 ab	61.33 a	64.56 bc
$K_2SO_4$ at 2%	51.06 ab	53.43b	10.47 ab	13.06 a	61.53 a	66.50b
$K_2SO_4$ at 2% + Urea at 2%	52.82 a	55.16 a	7.73b	13.33 a	61.55 a	68.70 a
$K_2SO_4$ at 3%	50.68 ab	53.43b	9.88 ab	12.30 ab	60.56 a	65.73 bc
$K_2SO_4$ at 3% + Urea at 2%	50.01b	52.86b	10.04 ab	11.56 bc	60.05 a	64.43c
<b>LSD</b>	<b>1.82</b>	<b>1.47</b>	<b>2.028</b>	<b>1.37</b>	<b>2.067</b>	<b>1.98</b>

Means followed by different letter (s) in column are significant at 5% level of probability.

The current study found that  $K_2SO_4$  significantly reduced the drop, and the effect was much stronger when  $K_2SO_4$  was coupled with urea at a concentration of 2%. It has been observed that foliar treatment of  $K_2SO_4$  reduced fruit drop and increased date palm 'Hayany' yield/bunch (Salama et al., 2014). Foliar application of  $K_2SO_4$  results in improved lignin and cellulose formation as both polymers are needed to initiate synthesis of endogenous hormones process, and construction of plant structure as carbohydrates synthesis inhibits the formation of abscission layer hence results in reduced drop at premature stage (Nijjar, 1985; Jat and Kacha, 2014; Reetika et al., 2018). Furthermore, an imbalance in ethylene and auxin level in plant tissues is known to have a cause of fruit drop (Yuan and Carbaugh, 2007; Yuan and Li, 2008; Li and Yuan, 2008; Zhu et al., 2010), as ethylene initiates the formation of the abscisic layer, breaking cell wall in the system resulting in fruit drop (Stover et al., 1998; Wood, 2011). Similarly, many other fruits also showed a reduction in fruit drop when different macro and micronutrients were applied, i.e. fruit drop of 'Kinnow' mandarin was reduced when Zinc sulphate ( $ZnSO_4$ ) was applied at 0.5% (Ullah et al., 2012; Razzaq et al., 2013). Application of  $K_2SO_4$ , potassium nitrate ( $KNO_3$ ), urea, and boron (B) showed better results in reducing fruit drop in the case of persimmons as well (Kassem et al., 2010).

K is known to improve fruit quality, as its application increases water entry in the cells by an osmotic process that results in increased cell size (Bhargave et al., 1993; Ruiz, 2005). Also, an increase in length due to the combination of K and urea stimulates chlorophyll synthesis, enhances photosynthesis, helps to increase stored food in fruit tissues that ultimately results in an increased fruit size i.e. length and diameter (Jat and Kacha, 2014).  $K_2SO_4$  was found to significantly improve fruit length of date cultivars (Darwesh et al., 2015; Omar et al., 2017). Additionally, foliar application of K and B has been found to speed up sugar transport rate to actively growing regions of fruit development, improving physical attributes of the plant as these nutrients help to initiate metabolic activities (Harhash and Abdel-Nasser, 2007; Shahin, 2007; Desouky et al., 2007; Khayyat et al., 2007; Al-Obeed et al., 2013). It was also observed in the current study that foliar application of  $K_2SO_4$  at 2 % combined with urea at 2 % resulted in a significant increase in fruit length and diameter (mm) of “Dhakki” dates in both cropping seasons. After the first application of the nutrient, significant alterations were noticed. When compared to untreated plants, the length of treated plants increased shortly after the first application. Besides increasing metabolic processes of plant, K and urea are also involved in elongation and germination of pollen tube to improve fruit quality and development (Yadav et al., 2014). Active transportation of sugars to the growing regions of the plant due to the application of these nutrients can also improve the fruit size (Yasin et al., 2012).

Foliar treatment of  $K_2SO_4$  in combination with urea improved photosynthesis, resulting in increased accumulation of carbohydrate. (Gujar and Rana, 2014). It is also found that application of

$K_2SO_4$  at 1 % and 3 % resulted in increased fruit weight in lemon and sweet orange (Josan et al., 1995). Similarly, when  $K_2SO_4$  was applied to bunches of different date cultivars showed an improved fruit weight (Elsabagh, 2012; Zagzoug and Salem, 2016; Omar et al., 2017). In our study, foliar application of  $K_2SO_4$  at 2 % with urea produced date fruit with maximum fruit weight in “Dhakki” date.

Pulp is regarded as an important economic feature because large seeded types are generally disliked due to less consumable portions. In these trials, the higher pulp percentage was recorded in bunches sprayed with  $K_2SO_4$  at 2 % combined with urea at 2 %, which could be attributed to the characteristics of K in enhancing cell wall construction (Boman et al., 1998), triggering the metabolic reactions and ultimately increasing the fruit size and number (Khayyat et al., 2007). Moreover,  $K_2SO_4$  at the rate of 1.5 % on banana, and 2 % multi- K on 'Kinnow' mandarin also showed a higher peel percentage (Gill et al., 2005; Kumar 2007). K applied to the date palm cultivars, resulted in higher pulp percentage (Aboutalebi and Mohammadi, 2015), and application of  $KNO_3$  at 2 % produced increased bunch weight and pulp percentage (Khan et al., 2021). Since the application of  $K_2SO_4$  at 2 % with or without urea reduced fruit drop, increased fruit retention, improved fruit size, and weight hence, the same treatment resulted in higher weight/bunch during both the years (Desouky et al., 2007; Shahin, 2007; Elsabagh et al., 2012).

Both K and urea helped in enhanced fruit retention, ultimately resulted in increased weight /bunch. Also, their combined effect speeded upping, photosynthesis and metabolic reaction to increase fruit size and weight, resulting in increased fruit yield (Haque et al., 2000; Jat and Kacha, 2014). The highest bunch weight in both seasons with foliar application of  $K_2SO_4$  at 2 %, with or without urea, might be the effects of these nutrients availability that balanced the nutritious level. Moreover, the content of chlorophyll in leaves, translocation of metabolites in plants from source to sink resulted in improved and better fruit growth in the form of fruit size, fruit number, fruit weight, and ultimately fruit yield (Reetika et al., 2018). Many scientists have also investigated the effect of K on date fruit, concluding that K plays a critical role in enhancing date palm fruit weight and productivity (Osman, 2010; Ahmad et al., 2014; Shekofteh and Nick-Pour, 2016). The improved, reducing sugars in the fruit can be the effect of K combined with urea as both of these encouraged hydrolysis of starch to convert into sugars (Jat and Kacha, 2014).

K plays an important role in improving chemical constituents in fruits as it is involved in the transport of sugars to other parts of the plant resulting in improved fruit quality; along with this, urea also converts complex substances into simple's ones to speed up the metabolic activity of fruit to increase TSS. The TSS of date fruit is greatly improved when K is applied in any form, according to research. Spraying  $K_2SO_4$  on the fruit of “Dhakki” dates boosted the K content substantially. K content in the fruit was shown to be higher in treatments that led in higher yield, larger fruit, and

lower fruit drop, demonstrating the importance of K in improving all other measures (Harhash and Abdel-Nasser, 2010; Gill et al., 2012; Al-Obeed et al., 2013). This can be due to the role of K and urea in converting complex substances into simple's ones to speed up the metabolic activity of fruit that resulted in increased total sugars (Jat and Kacha, 2014). Application of K has been reported to increase sugar content in different date palm cultivars (Osman, 2010; Gill et al., 2012).

## 5. Conclusions

The results in this study showed significant effect of K and urea on "Dhakki" date palm. Application of  $K_2SO_4$  alone and in combination with urea not only effectively reduced the fruit drop but also improved fruit quality in date palm. All the physiochemical characteristics of date were improved by the application of these nutrients alone or in combination.  $K_2SO_4$  applied at 2 % along with 2 % urea, were proved to be most effective doses to enhance fruit quality and minimize the fruit drop in date palm cultivar. This study may help the date palm farmers to reduce the fruit drop and enhance the fruit quality by using K and urea, thus improving the date yield and economic benefit for the farming community.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Acknowledgments

The authors are thankful to the Taif University Researchers Supporting Project number (TURSP-2020/65), Taif University, Taif, Saudi Arabia.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.sjbs.2022.02.060>.

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