

(Original Article)



Effect of Spraying Nano-Nutrients on the Yield and Fruit Quality of "Barhee" Date palm

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DOI: 10.21608/AJAS.2025.415166.1528

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Abstract

During the 2022, 2023, and 2024 seasons, the study was conducted on a 20-year-old Barhee date palm that was planted on a private farm in Al-Marashda area, Al-Waqf district, Qena Governorate, Egypt. The study's goal was to find out how nano nutrients affected palm date fruiting. Eight treatments were performed on the same palm and repeated ten times using one bunch for each repetition were used in the complete randomized block design experiment. The information from the current findings summed up as follows: In comparison to spray water (control), spray nano calcium - boron or nano potassium markedly improved fruit retention, bunch weight and fruit chemical contents. The findings demonstrated that raising the spray solution's concentration had no discernible effects. Therefore, using the lower concentration makes more sense from an economic standpoint. Based on the results of the study, it is necessary to spray 1 ml/L of nano calcium - boron or 2 ml/L of nano potassium three times after one, two, and three months of fruit set in order to achieve a high return through improved fruit quality and, consequently, increased market value.

Keywords: Calcium, Date palm, Nanotechnology, Potassium, Yield.

Introduction

The cultivation of date palms (*Phoenix dactylifera* L.) is growing all throughout the world, especially in areas where this crop has just recently been introduced. Therefore, it is essential that proper practices are employed to ensure successful production date (Al-Yahyai *et al* 2023).

Dates are rich in phenolic, flavonols, carotenoids, minerals, and vitamins, among other useful bioactive and functional compounds. These substances function as potent therapeutic agents against a variety of illnesses in addition to providing the body with a substantial amount of energy (Younas *et al.* 2020).

Globally, over 9.4 million tonnes of date fruit were produced annually. The Middle East and North Africa are the two main producing regions. Egypt contributes more than 18% of the Global date production, placing it in the top 10 producers (FAO, 2022). The total cultivated area in Egypt is 186208 feddan and 14636968 palms, producing about 1703378 tons (M.A.L.R., 2023). One of Egypt's most popular soft fruit varieties is "Barhee." An estimated 45957 tons were produced by 440961 palms, or

almost 3% of all date palms cultivated. Fertilizers are important for increasing plant growth and productivity. Crop nutrition is significantly impacted when eco-friendly nano-fertilizer is used instead of conventional fertilizer (Rameshaiah *et al.* 2015). Reduced nutrient loss, either in the soil or directly on the plant, is a characteristic of environmentally friendly fertilizers (Chen *et al.* 2018).

The benefits of foliar application are rapid reaction and consistent fertilizer material division. Key physiological processes include the synthesis of proteins, the creation of sugars and starches, and the development of meristematic tissues all depend heavily on potassium. It may enhance fruit size, flavor, and color by activating a variety of enzymes involved in cell division, growth, and fruit production (Mengel 2001, Abbas and Fares 2008, Osman 2010, and Awad *et al.*, 2011).

According to Hernandez-Munoz *et al.* (2006), calcium is a useful component of a fruit's physiological resistance since it stabilizes the cell membrane and raises the turgor pressure of the cell.

According to Mengel *et al.* (2001) and El-Sheikh *et al.* (2007), the physiological metabolism of plants, which includes the metabolism of proteins, nucleic acids, natural hormone production, carbohydrates, photosynthesis, cell division, cell wall synthesis, membrane action, and water uptake, is significantly influenced by boron.

By providing essential nutrients for plant growth, fertilizers including NPK (nitrogen, phosphorus, and potassium) are now essential for increasing harvest output and fruit quality (Shareef, 2011). When sprayed to grain crops, a nanocomposite consisting of N, P, K, and micronutrients enhanced the uptake and use of additional nutrients (Abdel-Aziz *et al.* 2018). Date palm output may benefit from the application of a nano-fertilizer.

It may even be possible to use nano-fertilization to regulate fertilizer distribution such that the plant absorbs the nutrients and they are not lost to unintended soil, water, or microbes (Kopittke *et al.* 2019). The nanomaterials' high surface area to volume ratio facilitates quick reactions and, consequently, efficient plant growth (Zahedi *et al.* 2020). Increased and simpler nutrient absorption through the leaves or roots is the result of nanostructures (Amira *et al.* 2015).

It has been shown that foliar spraying macronutrients and micronutrients can increase the antagonistic effects of salt stress and is a successful method for enhancing plant salt resilience (Zouari *et al.* 2016). In date palm nutrition management, foliar nutrient spray has become widespread (Shareef, 2020).

The effects of nano-fertilizer application on date palm production have been the focus of numerous recent studies (Roshdy and Refaai 2016; Altemimy *et al.* 2019; Jubeir and Ahmed, 2019; Alebidi *et al.* 2021, El - Salhy *et al.* 2021, Shareef *et al.* 2020, and Sayed *et al.* 2024). Additionally, Roshdy and Refaai (2016) discovered that when compared to the use of conventional fertilizer, date palm growth and yield were enhanced by soil-applied nano-fertilizer. Understanding the physiological and biochemical processes that arise when date palm fruit is treated with nano fertilizer as opposed to conventional fertilizers is

therefore crucial.

Therefore, the aim of the present study was to evaluate the effects of spraying applications of nano calcium-boron, and nano-potassium compared to their conventional forms on yield and fruit quality in Barhee date palms.

Materials and Methods

The current study was conducted on a 20-year-old Barhee date palms (*Phoenix dactylifera* L.) during three seasons 2022, 2023, and 2024. The orchard, which is planted a private farm in the Al-Marashda region, Al-Waqf district, Qena Governorate, Egypt, is located at 26° 13' 41' 6" N, 32° 33' 17.64" E. Ten palms' trees were chosen are uniform in growth vigor and fruiting and given regular horticultural practices. Furthermore, pruning was done to keep the ratio of bunches to mature leaves at 1:8, by removing excess earliest, latest, and smallest inflorescences, the number of spathes per palm was reduced to eight bunches. During three study seasons, pollination was conducted using the same pollen grain source. The eight treatments in the experiment were applied to the same palm, with ten repetitions per treatment, using one bunch for each repetition, the experiments were arranged in a randomized complete block design (RCBD) as follows:

T1: spraying water (control)

T2: spraying calcium-boron (Calboron) at 3.0 ml/liter

T3: spraying nano calcium-boron (Biota calcium-boron) at 0.5 ml /liter

T4: spraying nano calcium-boron (Biota calcium-boron) at 1.0 ml /liter

T5: spraying nano calcium-boron (Biota calcium-boron) at 2.0 ml /liter

T6: spraying potassium nitrate, (Nile Pota power) at 4.0 ml/liter

T7: spraying nano potassium nitrate (Biota potassium) at 2.0 ml /liter

T8: spraying nano potassium nitrate (Biota potassium) at 4.0 ml/liter

Calboron (Cal-Bor) is a liquid fertilizer that provides plants with calcium (CaO) 15% and boron (B_2O_3) 1.2%, which used as conventional calcium-boron formula.

Biota nano calcium-boron, from Biota Egypt Company contains calcium (10%) plus boron (2%).

Nile Pota power, from Tiba Alkhadraa Company contains potassium nitrate 20% (K_2O), which is used as conventional potassium formula.

Biota nano potassium, from Biota Egypt Company contains nano potassium nitrate (KNO_3 NPs) 20% (K_2O).

The amount of each spraying compound was chosen according to producers' recommendations and previous investigations

A hand sprayer was used to thoroughly apply all spray treatments to the bunches. Three sprays of either conventional or nano nitrate compound were applied at 4, 8, and 12 weeks after fruit set. To evaluate the impact of conventional and nano formulations, the following parameters were measured.

Yield components as, fruit retention and bunch weight

At harvest, the percentage of fruit retained was determined. The following formula was used to determine the fruit retention percentage:

$$\text{Fruit retention \%} = \frac{\text{Total number of retained fruits strand}}{\text{Number of retained fruits / strand and flowers no. flower scars}} \times 100$$

When the fruits reached the Khalal stage on August 1st, bunches were picked, and the average bunch weight was measured at kilograms.

Fruit physical characteristics

Fruit weight (g), fruit dimensions (length and diameter, cm), and flesh percentage were measured.

Fruit chemical characteristics

A hand refractometer was used to measure the percentage of total soluble solids (T.S.S.). The percentage of total acidity, which is expressed as gm malic acid/100gm according to A.O.A.C., (1995). The percentages of reducing, and total sugars were calculated using the volumetric method provided by the A.O.A.C. (1995).

Statistical analysis

Analysis of variance (ANOVA) was performed on the data collected over the three growing seasons, following the methods of Snedecor and Cochran (1990). The Duncan multiple range test (1958) was used to compare means at a significance level of 0.05

Results

1. Yield component

Data in table (1), showed the effect of bunch sprayed with calcium plus boron or potassium in traditional or nano form on the fruit retention and bunch weight of Barhee date palms in the 2022, 2023 and 2024 seasons. It is obvious from the data that results took similar trend during the two studied seasons.

Results indicate that the fruit retention and bunch weight significantly increase for different conventional or nano calcium, boron and potassium sources spraying at different doses compared to water spraying (control). The maximum values of fruits retention and bunch weight were recorded due to spray nano calcium – boron at 1 or 2 ml/L (T4 or T5) followed by spraying nano Potassium at 2.0 or 4.0 ml / L water (T7 or T8), respectively.

On the other hand, the lowest values for fruit retention and bunch weight were observed in spray with water (control, T1).

The obtained fruit retention were (34.83, 37.47, 39.13, 39.76, 40.81, 37.23, 37.45 and 37.46 %) and punch weight were (11.41, 13.78, 15.25, 15.74, 16.12, 14.44, 14.65 and 14.88 kg as an av. of the three studied season) due to treat spraying (T1), calcium - boron 3.0 ml / L (T2), nano calcium - boron at 0.5 cm / L (T3), nano calcium - boron at 1.0 cm / L (T4), nano calcium - boron at 2.0 cm / L (T5), potassium nitrate at 4.0 ml / L (T6), nano potassium at 2 cm / L (T7) and nano potassium at 4 cm / L (T8), respectively.

Hence, the corresponding increment of bunch weight was (20.77, 33.65, 37.95, 41.28, 26.56, 28.40 and 30.41% as an av. of the three studied season), respectively.

In general view, the results showed that there were no significant differences due to increase the concentration of spray solution. Hence from an economic view, it is preferable to use the lower solution concentration. Also, it could be arranged the effect of spray materials in descending order is as follow nano calcium plus boron at 2 or 1 ml/L and nano potassium 4 or 2 ml/L, respectively.

Table 1. Effect of nano nutrients spraying on fruit retention and bunch weight of Barhee date palm during 2022, 2023 and 2024 seasons.

	Fruit retention (%)				Bunch weight (kg)			
	2022	2023	2024	Mean	2022	2023	2024	Mean
Control	35.28 C	34.1 C	35.11 C	34.83 C	11.63 D	11.18 D	11.42 D	11.41 D
Ca + B	38.18 B	36.56 B	37.68 B	37.47 B	14.10 C	13.46 C	13.75 C	13.78 C
Ca+B (nano1)	39.96 A	38.18 A	39.25 A	39.13 A	15.49 A	14.96 A	15.30 A	15.25 B
Ca+B (nano2)	40.58 A	38.83 A	39.86 A	39.76 A	15.96 A	15.43 A	15.83 A	15.74 A
Ca+B (nano3)	41.64 A	39.81 A	40.98 A	40.81 A	16.38 A	15.80 A	16.18 A	16.12 A
KNO₃	38.10 B	36.22 B	37.38 B	37.23 B	14.55 B	14.21 B	14.57 B	14.44 C
KNO₃ (nano 1)	38.43 B	36.39 B	37.52 B	37.45 B	14.78 B	14.45 B	14.72 B	14.65 B
KNO₃ (nano2)	38.31 B	36.48 B	37.58 B	37.46 B	15.11 B	14.63 B	14.91 B	14.88 B

The same letters make it clear that there are no significant differences (LSD) at the 0.05 level among treatments in the same column.

2. Fruit quality

- Fruit physical characteristics

Results in Tables (2 and 3) indicate that fruit weight, fruit dimensions and flesh percentage were significantly affected by different nano calcium - boron or nano potassium during three studied seasons. In general, spraying any treatment at nano formula whether calcium - boron or potassium significantly increased the previously studied traits compared to both conventional formulations and the water sprayed (control). Moreover, nano calcium - boron - at 2 ml/L achieved higher fruit weight (20.21g) and flesh % (93.79%) and fruit length (3.57 cm as av. of the three studied seasons) compared with the other treatments and control (sprayed water, T1). While the control recorded the lowest value in this respect, fruit weight (17.11 g), flesh % (90.59%) and fruit length (2.99 cm) as an av. of three studied seasons, respectively.

The recorded fruit weight was (17.11, 18.48, 19.17, 20.02, 20.21, 19.30, 19.64 and 20.00g) and flesh % (90.59, 92.19, 92.92, 93.50, 93.79, 92.82, 93.97 and 93.35 %) and fruit length (2.99, 3.22, 3.38, 3.51, 3.57, 3.40, 3.46 and 3.52 cm as an av. of the three studied seasons) due to T1 to T8, respectively.

Moreover, the increment percentage of fruit weight due to spray different nano formula compared to spray with water (control), attained (8.01, 12.04, 17.01, 18.12, 12.80, 14.73 and 16.89 %), respectively.

These results showed that no significant differences were seen due to increase the concentration of spraying nano calcium - boron, as well as nano potassium. So, from an economic standpoint it could be concluded that to spray nano calcium - boron at 1 ml/L or nano potassium at 2 ml/L, that this a lower concentration.

Table 2. Effect of nano nutrients spraying on weight and length of Barhee dates during 2022, 2023 and 2024 season.

	Fruit weight (g)				Fruit length (cm)			
	2022	2023	2024	Mean	2022	2023	2024	Mean
Control	16.25 D	17.10 D	17.98 D	17.11 D	3.01 D	3.12 D	2.83 D	2.99 D
Ca + B	17.68 C	18.83 C	18.92 C	18.48 C	3.22 C	3.41 C	3.04 C	3.22 C
Ca+B (nano1)	18.52 B	19.22 B	19.78 B	19.17 B	3.42 B	3.55 B	3.18 B	3.38 B
Ca+B (nano2)	19.18 A	20.18 A	20.69 A	20.02 A	3.55 A	3.69 A	3.30 A	3.51 A
Ca+B (nano3)	19.52 A	20.30 A	20.82 A	20.21 A	3.61 A	3.75 A	3.36 A	3.57 A
KNO₃	18.64 B	19.38 B	19.89 B	19.30 B	3.44 B	3.56 B	3.19 B	3.40 B
KNO₃ (nano 1)	18.85 A	19.82 A	20.24 A	19.64 A	3.48 A	3.63 A	3.26 A	3.46 A
KNO₃ (nano2)	19.28 A	20.11 A	20.61 A	20.00 A	3.57 A	3.68 A	3.32 A	3.52 A

The same letters make it clear that there are no significant differences (LSD) at the 0.05 level among treatments in the same column.

Table 3. Effect of nano nutrients spraying on diameter and flesh of Barhee dates during 2022, 2023 and 2024 seasons.

	Fruit diameter (cm)				Flesh (%)			
	2022	2023	2024	Mean	2022	2023	2024	Mean
Control	2.49 D	2.57 D	2.36 C	2.47 D	89.34 B	90.96 B	91.46 B	90.59 C
Ca + B	2.71 C	2.79 C	2.58 B	2.69 C	90.85 A	92.63 A	93.10 A	92.19 B
Ca+B (nano1)	2.84 B	2.93 B	2.67 B	2.81 B	91.63 A	93.38 A	93.76 A	92.92 A
Ca+B (nano2)	2.94 A	3.04 A	2.79 A	2.92 A	92.42 A	93.94 A	94.14 A	93.5 A
Ca+B (nano3)	2.99 A	3.10 A	2.85 A	2.98 A	92.78 A	94.22 A	94.36 A	93.79 A
KNO₃	2.86 B	2.93 B	2.68 B	2.82 B	91.81 A	93.17 A	93.49 A	92.82 A
KNO₃ (nano1)	2.88 A	2.98 A	2.72 A	2.86 A	92.11 A	93.22 A	93.58 A	92.97 A
KNO₃ (nano2)	2.95 A	3.02 A	2.78 A	2.91 A	92.55 A	93.65 A	93.86 A	93.35 A

The same letters make it clear that there are no significant differences (LSD) at the 0.05 level among treatments in the same column.

- Fruit chemical characteristics

It is clear from the results in Figures (1 to 4) that spraying nano calcium - boron or nano potassium significantly resulted in improving fruit chemical properties, in terms of increasing T.S.S.%, sugars content and decreasing total acidity in relative to the control treatment. As for TSS %, and total sugar, the results in Figures (1 and 2) reveal that using spray application of nano potassium at 2 or 4 ml/L followed by potassium nitrate at 4 ml/L and nano calcium - boron at 2 or 1 ml/L in descending order gave better results. The recorded TSS were (47.50, 47.60, 47.85, 47.90 and 48.69 %) and total sugars (41.84, 41.68, 41.92, 42.15 and 42.87 %) due to T4 to T8, as an av. of the three studied

seasons. On the other hand, treatment control was recorded as the lowest values in this respect (43.08 and 37.86%), respectively.

Then, the corresponding increment percentage of TSS attained (10.26, 10.49, 11.07, 11.19 and 13.02%) and total sugars (10.51, 10.62, 11.33 and 13.22) due to T4 to T8 compared to T1, respectively.

Moreover, no significant differences were found due to spraying nano calcium-boron at 1 or 2 ml/L as well as nano potassium at 2 or 4 ml/L. So, from economic view, it concluded that spraying nano calcium - boron - at 1 ml/L or nano potassium at 2 ml/L to get best dates quality.

Regarding acidity %, all spraying treatments reduced this trait as compared to the control, and lower values in this respect were obtained by nano potassium follow by nano calcium- boron. Meanwhile, control treatment gave the highest value in this respect.

In general, the lowest percentages of fruit chemical properties except for acidity were observed in the control treatment. On the other hand, spraying nano potassium at 2 or 4 ml/L followed by nano calcium - boron at 1 or 2 ml/L recorded the highest values in this respect. No significant differences were found due to spray nano calcium - boron or nano potassium at any concentration of solution. So, in general economic view, it concluded that spray nano calcium - boron or nano potassium at lower concentration to get high yield with good dates quality.

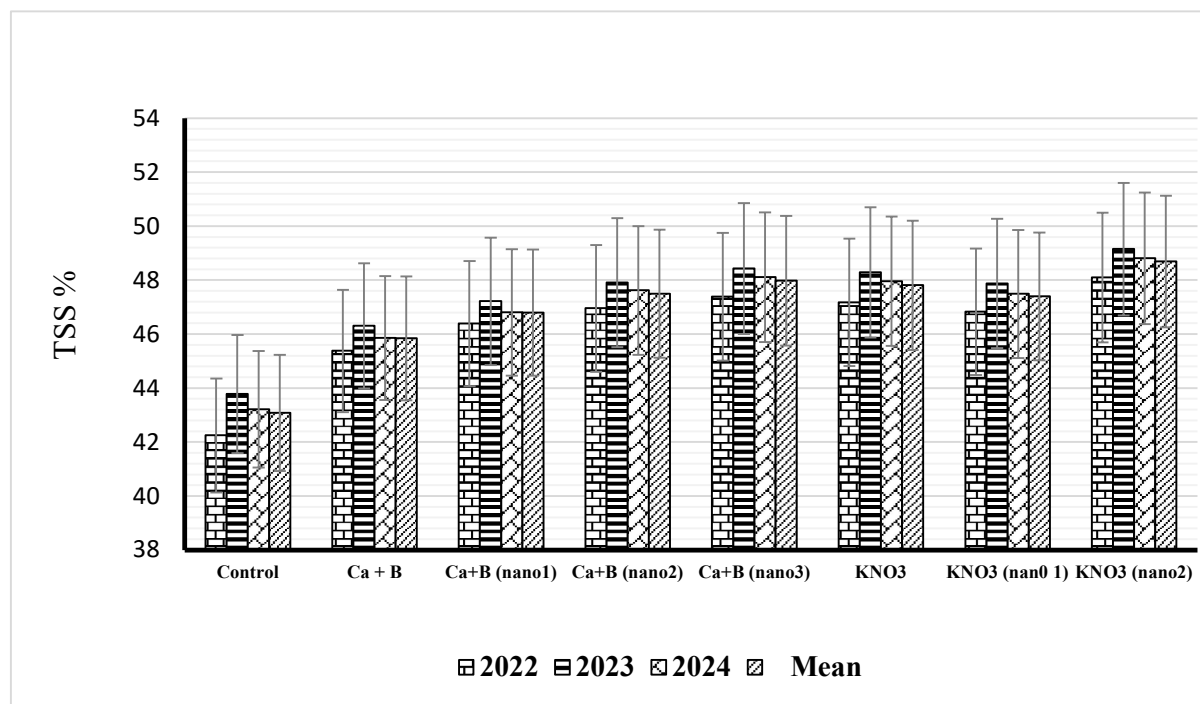


Fig 1. Effect of nano nutrients spraying on TSS of Barhee dates during 2022, 2023 and 2024 seasons.

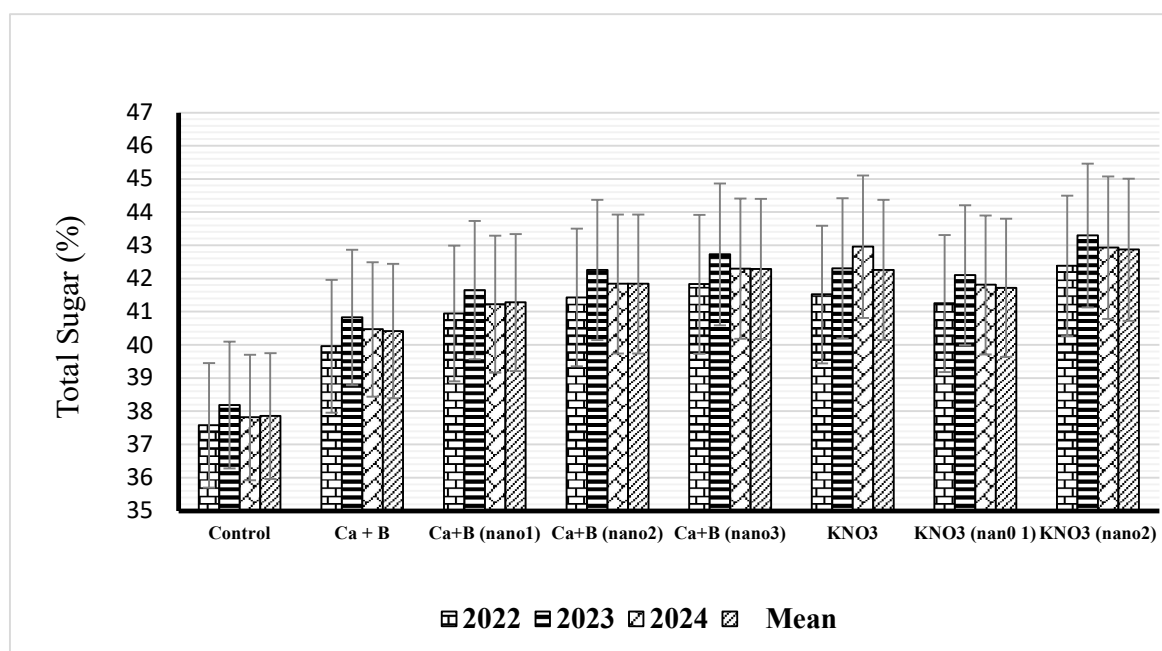


Fig 2. Effect of nano nutrients spraying on total sugars of Barhee dates during 2022, 2023 and 2024 seasons.

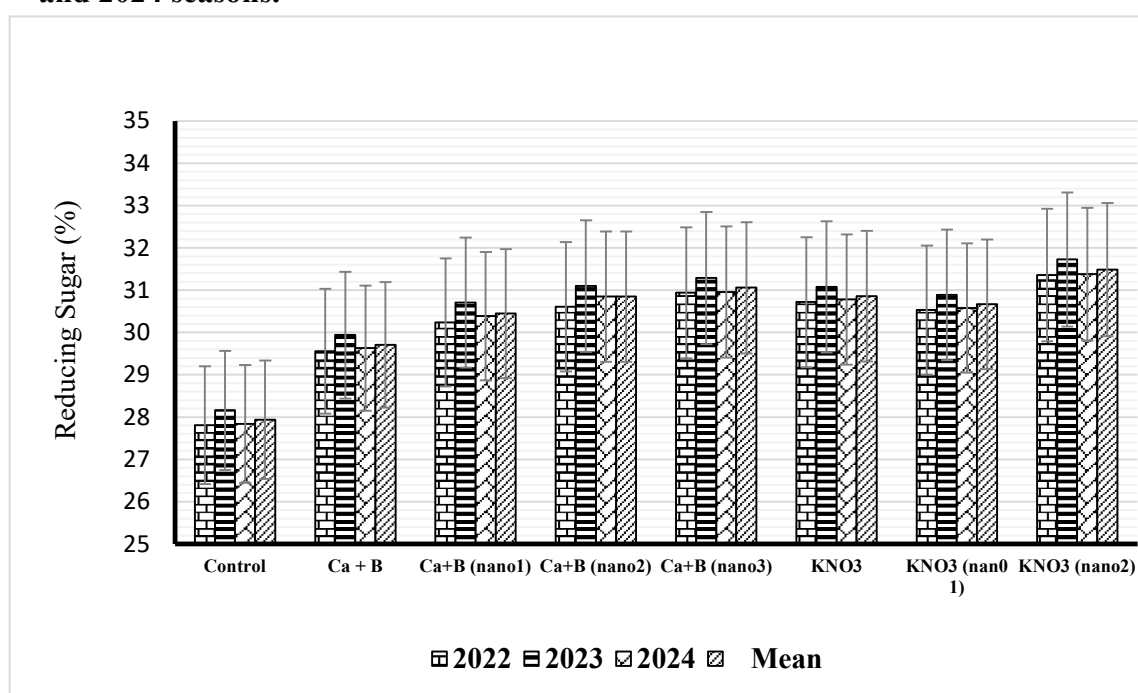


Fig 3. Effect of nano nutrients spraying on reducing sugars of Barhee dates during 2022, 2023 and 2024 seasons.

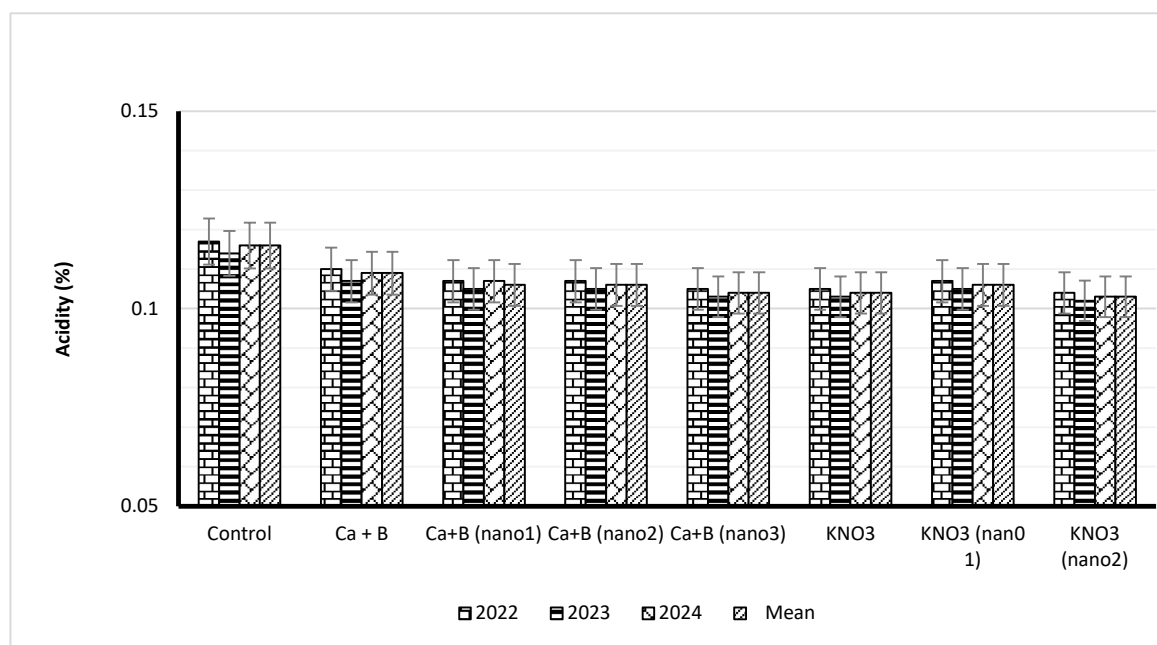


Fig 4. Effect of nano nutrients spraying on acidity of Barhee dates during 2022, 2023 and 2024 seasons.

Discussion

Potassium is essential for maintaining the balance of salts and water in plant cells as well as for the production and function of proteins, lipids, carbohydrates, and chlorophyll. Permeability, hydration, and cell structure are only a few of the physiological processes it initiates in plants (Nijjar, 1985, Marschner, 1995, and Abdel-Rahman, 2010).

A common micronutrient issue in agriculture is boron disorder, which lowers crop quality and productivity (Barker and Pilbeam, 2006). The revitalized dehydrogenase enzymes, sugar translocation, nucleic acids, and plant hormones are all indirectly attributed to boron in plants, which also has an impact on fruit set and production (El-Sheikh *et al.*, 2007). Through the crosslinking of the middle lamella's pectin chains, calcium gives cell walls their stiffness. A common sign of calcium insufficiency is the breakdown of the afflicted tissues and the disintegration of cell walls. For fruit to ripen, the amount of calcium pectate in cell walls is crucial (Glenn and Poovaiah 1990).

Fruit hardness increases as its calcium content rises, and calcium-related illnesses are avoided or delayed ripening. Additionally, calcium plays a part in controlling enzyme activity and photosynthesis, as well as inhibiting the development of an abscission zone between fruit pedicles and bearing branches. As a result, the percentage of fruit splitting may be controlled (Tony and John, 1994).

Large quantities of conventional fertilizers seem to be less necessary when date palms are treated with foliar-applied nano-fertilizer. Nano-fertilizers provide numerous benefits for agriculture, such as quicker plant absorption. A rise in fruit weight and quantity may result from increased yield brought on by boron and calcium spraying.

These results may be the result of boron synergy supporting calcium metabolism in cell wall elongation and cell division Sheikh and Manjula (2012).

The fruit's increased weight as a result of applying nano fertilizer supports the significance of nanoparticles as having special behavior and properties, such as their small size, ability to deliver nutrients, and highly active surface area, which accelerated fruit chemical reactions. These findings are in line with those of Roshdy and Refaai (2016). According to Dimkpa and Bindraban (2016), micronutrients are also essential for a number of biological processes, which is why the fruit's days to maturity decreased by promoting the growth of the cell wall required for division, potassium has a beneficial impact on the process of cell division and expansion. The plant will be pushed by all of these elements (nano-micronutrients, nano-macronutrients) to increase metabolic rates and increase the synthesis and accumulation of dry matter, which will improve the quality of the fruit.

By delivering nutrients that are not absorbed from the soil, nano-fertilizer enables the essential components to carry out a number of critical functions. We think that the majority of these nutrients were micronutrients, which promoted early maturity, increased metabolic activity, and accelerated growth. Fruit weight increased while using nano-fertilizer alone or in combination with conventional fertilizer. It is also becoming more and more associated with the beneficial effects of nutrients absorbed by the leaves on growth and yield. The procedure entails boosting photoassimilate production (source) as well as their storage and transit in fruits (sink) Semenova, *et al.*, (2024).

According to numerous studies on date palm, nano-fertilizers consistently improve date palm outcomes boosting fruit size, yield, ripening dynamics, and biochemical profiles across various cultivars and application strategies (Amiri *et al.* 2016; Roshdy and Refaai 2016; Altemimy *et al.* 2019; Jubeir and Ahmed 2019).

Conclusion

The current study declared that three spray applications of bunches with 1 ml/L nano calcium - boron or nano potassium at 2 ml/L greatly increased fruit yield as well as fruit physical and chemical attributes. The productivity and fruit quality of Barhee date palms were improved by these treatments, which were the best and most efficient.

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تأثير رش الأسمدة النانومترية على محصول وجودة ثمار نخيل البلح البرحي

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الملخص

أجريت هذه الدراسة خلال ثلاث مواسم متتالية 2022، 2023، 2024 بمزرعة خاصة بالمرشده مركز الوقف، قنا، مصر، بهدف دراسة تأثير رش البوتاسيوم او خليط الكالسيوم والبورون في الصورة التقليدية او النانومترية على إثمار نخيل البلح البرحي حيث تم رش تركيزين للبوتاسيوم او ثلاث تركيزات لخليط الكالسيوم والبورون في الصورة النانومترية لكل محلول ثلاث مرات بعد شهر وشهرين وثلاثة أشهر من عقد الثمار.

وقد أظهرت النتائج التالي:

سبب الرش بأي من البوتاسيوم او خليط الكالسيوم والبورون زيادة معنوية في نسبة الثمار الباقية ووزن السوباطة مقارنة بالرش بالصورة العادية او رش الماء (معاملة المقارنة).

سبب الرش بمحاليل النانومترية زيادة معنوية في وزن وأبعاد الثمرة ونسبة اللحم. كذلك محتواها من المواد الصلبة الذائبة والسكريات مع قلة الحموضة مقارنة بعدم الرش.

لم تظهر أي فروق معنوية نتيجة زيادة تركيز محلول الرش المستخدم ولذا من الناحية الاقتصادية يفضل استخدام التركيز الأقل.

سجلت أفضل النتائج نتيجة استخدام خليط الكالسيوم والبورون او البوتاسيوم في الصورة النانومترية.

من نتائج هذه الدراسة فإنه يوصي بأهمية رش سوبات البلح البرحي بالصورة النانومترية لخليط الكالسيوم والبورون بتركيز 1 مل/ لتر او نترات البوتاسيوم بتركيز 2 مل/ لتر ماء وذلك ثلاث مرات خلال فترة نمو الثمار وذلك لإنتاج محصول عال ذو خصائص ثمرية جيدة.

الكلمات المفتاحية: البوتاسيوم، المحصول، تكنولوجيا النانو، نخيل البلح، كالسيوم.