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Evaluation of growth and quality of tissue culture Qatari date palm cultivars by using organic nutrients in greenhouse

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Date palms are a crucial crop in Qatar and the Arabian Gulf, providing essential resources such as food and economic benefits. This study explores how organic fertilizers impact soil health and the growth of two date palm varieties, 'Shishi' and 'Nabit Saif,' specifically focusing on nutrient levels like nitrogen (N), phosphorus (P), and potassium (K). While organic fertilizers are known to improve soil quality, there has been little research on their effects in date palm cultivation. Over nine months in a greenhouse, different treatments like compost tea, humic acid, and bio-fertilizers were applied. The results showed that organic fertilizers significantly increased nitrogen levels, particularly in the T5 treatment, where levels reached 0.07%. 'Nabit Saif' absorbed more nitrogen than 'Shishi,' showing 0.06% uptake compared to 0.04%. However, phosphorus and potassium levels were similar across treatments. These findings highlight organic fertilizers' role in enhancing soil fertility and promoting sustainable agriculture, especially in regions like Qatar. Further research is needed to explore long-term impacts and improve fertilization strategies for date palm farming.

Key words: Organic nutrients, humic acid, compost tea, bio-fertilizer, tissue culture, *Phoenix dactylifera* L.

INTRODUCTION

Dates are an economically important crop in the Arabian Gulf, which provides food, shelter, and fuel to the communities. In addition, date palm fruits and their by-products are precious for their nutritional and dietetic properties and their income for oasis populations (Al-Shahib and Marshall, 2003; Chao and Krueger, 2007; Saafi et al., 2008). Date palm trees require relatively great amounts of macro- and micronutrients to achieve good growth and give reasonable economic production. Fertilization is one of the important practices that increases date production and improves fruit quality (Elamin et al., 2017). Research done on date palms showed that applying macro- and micronutrient fertilizers is necessary to increase the quantitative, qualitative, and economic output of date production in palm groves (Shaaban and Mahmoud, 2012).

Organic fertilizers have multiple benefits in balancing nutrients, increasing microbial activity, and preserving the environment compared to chemical fertilizers. Efforts to mitigate the declining mineral nutrient reserves are

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currently major research topics, but the perturbance of the global biogeochemical cycles, mainly driven by the use of mineral fertilizers, remains a serious problem (Kahiluoto et al., 2014). Compost tea application to the soil improves soil properties, decreases the need for chemical fertilizer, and promotes the growth of plants (Taha et al., 2016). Humic substances are organic compounds used as effective agents to complement synthetic or organic fertilizers. Humic acid affects a variety of soil properties and forms. The addition of organic materials increases the amount of humic acid in soil and changes its chemical structure (Chang-Chien et al., 2006; Dou et al., 2008). The quantity, composition, and nature of humus reflect certain conditions and processes of pedogenesis, and these factors are important indicators of soil fertility (Baldock and Nelson, 2000).

Biofertilizers are promising to reduce the use of chemical fertilizers (Vessey, 2003; Arora, 2013). They can fix nitrogen (N), help access nutrients such as phosphorus (P), improve drought tolerance, enhance plant health, or increase salt tolerance. However, the management of date palm wastes and the use of organic nutrients in date palm cultivation have received limited attention (Benabderrahim et al., 2017). One approach to utilizing date palm wastes is through composting.

The effect of date palm waste compost on forage alfalfa growth, yield, seed yield, and mineral uptake is promising. Composting date palm wastes along with shrimp and crab wastes results in a final compost that could serve as a good fertilizer. The compost had a moisture content of 57.1% and an organic matter content of 891 g/kg dry matter. Additionally, the compost was found to increase the germination and growth of ornamental plants (Benabderrahim et al., 2017).

The use of foliar nano-fertilization has been studied to enhance the growth, maturity, and biochemical responses of date palms. Fertilizers containing nitrogen, phosphorus, potassium (NPK), and micronutrients are crucial for improving harvest yield and fruit quality. The application of a nanocomposite fertilizer containing these nutrients improved the uptake and utilization of supplemental nutrients in grain crops, suggesting that nano-fertilizers may also be beneficial in date palm production (Shareef et al., 2021). In the Hillawi cultivar of date palm in Iraq, the addition of foliar nano-fertilizer to the annual fertilization program resulted in improved growth and increased production, indicating the positive impact of nano-fertilizers on date palm cultivation (Shareef et al., 2021).

Furthermore, research on the effect of slow-release fertilizers on the growth and fruiting of the Khalas date palm showed that the application of slow-release fertilizers had a significant effect on yield. Slow-release fertilizers provide a sustained release of nutrients, ensuring a continuous supply of essential elements for date palm growth and fruiting (Salem and Ali, 2020).

The goal of the present study is to compare organic fertilizer to chemical fertilization to improve soil qualities and increase the growth of date palm (*Phoenix dactylifera* L.) plantlets grown from tissue culture. Furthermore, it aims to achieve optimal amounts of fertilizer following plant transplantation in the greenhouse, which can be used as a strategy to protect the environment in Qatar.

MATERIALS AND METHODS

Experimental design

The experiment was designed under greenhouse conditions as follows:

1) The plantlets were produced in the Tissue Culture Laboratory of the Department of Agriculture Research in the Ministry of Municipality, located in Abu-Hamour District, Doha, Qatar.
2) The experiment was done inside the Botanical Conservation Center of the Qur'anic Botanic Garden located in Ghraffet Al-Rayyan District, Al-Rayyan, Qatar.
3) The study was carried out between 2020 and 2022 to evaluate the effects of compost tea, humic acid, and biofertilizer (effective microorganisms) and compare them with artificial fertilizer to study their effectiveness in date palm adaptation.

Plant

One-year-old date palm plants cvs. Shishi and Nabit Saif generated from tissue culture laboratory at length 20-25 cm, containing 3-5 leaves, were cultivated. Plantlets were planted into 18×25 pots filled with a 2:1:1 mixture of peat moss, sand, and perlite, supplemented with five treatments shown in Table 1. The experiment was run for 9 months, all fertilizer applications were applied one dose every two weeks.

Preparation of compost tea

In this experiment, compost extraction in the liquid phase was used which was produced from the decomposition and transformation of organic residues. Compost tea with the addition of catalyst sources and microbial food sources, was actively brewed in the compost machine. A sump pump bubbled and aerated the solution, adding a lot of much-needed oxygen.

The purpose of the brewing procedure was to extract advantageous bacteria from the compost itself, and then to increase these populations of microbes throughout the 24- to 36-h brewing period. Compost serves as a source of microbes, that enhance microbial growth and multiplication in the compost sample.

Compost tea machine

A compost tea machine was made consisting of a closed vessel/tank with a capacity of 100 L that was supported by an air pump. For every adding cycle, the following quantities have been used:

$$100\text{L Compost Tea} = 75\text{L Potable Water} + 500\text{g Dried Instant Yeast} + 2\text{L Molasses} + 5\text{L Additional Drinkable Water} + 5\text{L Fresh, High-Quality Compost}$$

The compost tea solution was produced in the device using the manufacturer's recommended formula (Figure 1).

Table 1. Treatments of organic nutrients.

Code	Treatments (ml/L)	Description
T1	NPK- control	Nitrogen, Phosphorous, Potassium
T2	CT100	Compost tea
T3	CT100+ HA 50	Compost tea + Humic acid
T4	CT100+ BF 50	Compost tea+ Bio-fertilizer
T5	CT100+HA50+BF50	Compost tea+ Humic acid + Bio-fertilizer

T = Treatment, ml/L = milliliter/Liter.

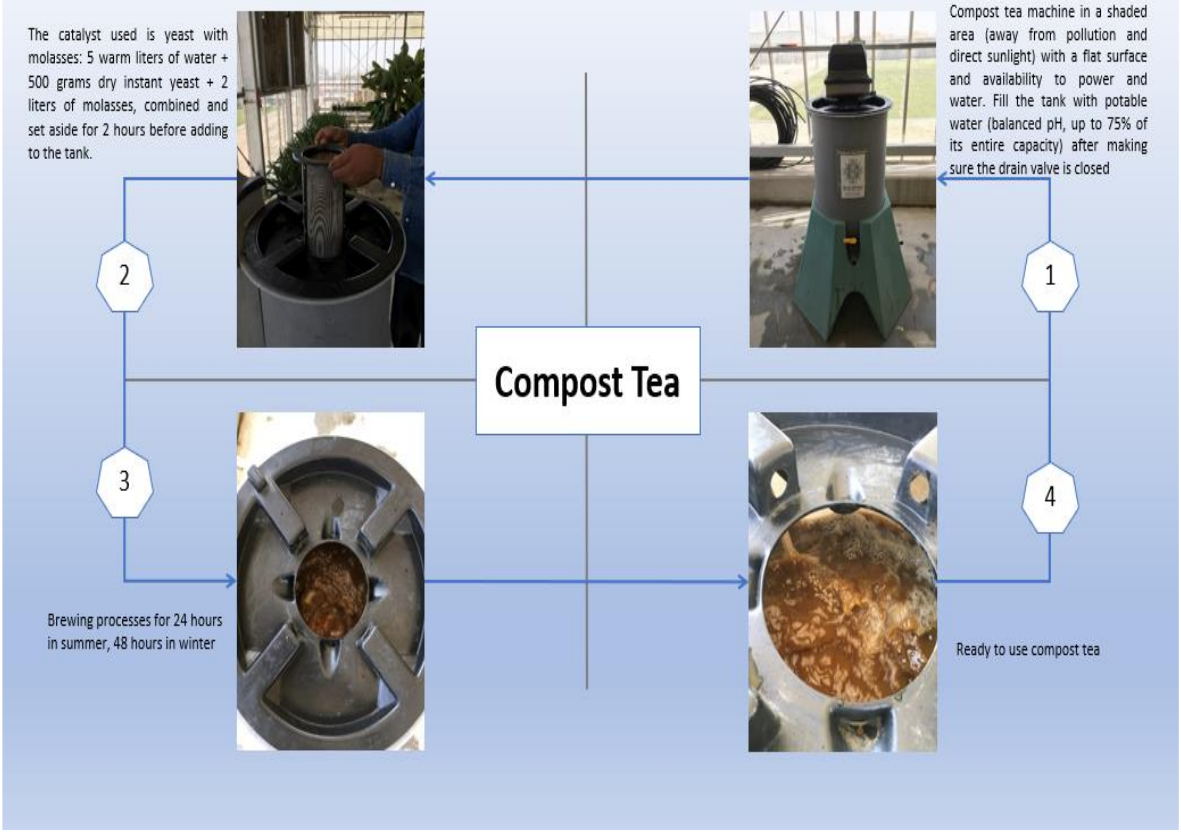

Figure 1. Compost tea preparation steps.

Preparation of the liquid organic biofertilizer

The liquid was purchased locally from the local agricultural market in Doha city, Qatar as per the supplier under the composition of the product (Table 2).

Biofertilizer application method

1) Dose: 100 mL Biofertilizer per 1000 mL (1 L) of water.
2) Method of Application: Irrigation of the plants manually using a watering can.
3) Application Rate: Applicated until the soil reaches field capacity (the point at which the soil cannot hold any more water without it running off).

Preparation of the liquid organic (Humic acid)

The humic acid has been sourced through local purchase for a product under the trade name of “Humic Power”. The composition of the liquid is provided by the manufacturer (Table 3).

Humic power application

1) Dose: 100 mL of humic power mixed with 1000 mL (1 L) of water.
2) Method of irrigation: Manual application using a watering can.
3) Application rate: Continue irrigation until the soil reaches field capacity, which is the point at which the soil is fully saturated with water and cannot absorb any more, causing excess water to run off.

Table 2. The physical and chemical characteristics of biofertilizer.

Element	Concentration (mg/L)	Chemical form
Iron (Fe)	3	Ferrous sulfate
Zinc (Zn)	3	Zinc sulfate
Manganese (Mn)	2	Manganese sulfate
Magnesium (Mg)	0.5	Magnesium sulfate
Copper (Cu)	0.3	Copper sulfate
Amino Acids	5	Seaweed extract
Boron (B)	0.004	Borax
Molybdenum (Mo)	0.002	Molybdenum (elemental)

Table 3. The physical and chemical characteristics of humic acid.

Element	Concentration (W/V) %	Source of element
Humic Acid	12	Natural rocks
Fulvic Acid	4	Natural rocks
Organic Nitrogen	4	Organic compost
Potassium	2	Natural potassium sulfate
Iron	2	Natural ferrous sulfate
Zinc	0.015	Natural zinc sulfate
Copper	0.0015	Natural copper sulfate

Plant growth metrics (determined after 9 months)

1) Plant height: Measured in centimeters (cm).
2) Stem base diameter: Measured in centimeters (cm).
3) Dry weight: Measured in grams (g).
4) Total number of leaves per plant: Count of all leaves on each plant.
5) Number of pinnate leaves per plant: Count of pinnate (feather-like) leaves on each plant.

Physical characteristic determination

Determination of nutrients N, P, and K for plants, and soil

1) The total Nitrogen in the dried samples of the leaf was determined by the modified Micro Kjeldahl Method (AOAC, 1980; Cotton, 1945).
2) The determination of phosphorus was done by using the Vanadate-Molybdate method (Jackson, 2005).
3) The Flame photometer is a double-beam internal standard instrument designed for the determination of the total amount of potassium (Jackson, 2005; Mason, 1963).

Statistical analysis

All data were subjected to analysis by using one-way ANOVA followed by Tukey's significant difference test (Harhash and Abdel-Nasser, 2010)

RESULTS

Plant growth and soil properties can be improved through an organic fertilizing regime. However, the data shown in Table 4 and Figure 2 report the effects of organic nutrient fertilizers on plant height (cm), stem base diameter (cm), and dry weight (g/pot).

Plant height (cm)

Following the nine months of application of nutrient fertilizers, the data in Table 4 and Figure 2 showed that all applications of organic nutrient fertilization treatments increased the plant height without a significant difference. However, there was an enhancement in plant height that can be attributed to using treatment T4, it gives the tallest plant height (50.20 cm) compared with other treatments. Moreover, the data indicated that when organic nutrient fertilizers were applied to the cultivars, 'Shishi' became significantly taller plants (51.08 cm) than 'Nabit Saif' (41.48 cm). Furthermore, the results showed that there was a significant difference between organic fertilization treatments and cultivars, applied T4 and T2 significantly boosted the plant height in cultivar Shishi (54.66 and 52.00 cm) compared with the chemical fertilization NPK (48.25 cm).

Stem base diameter (cm)

The results in Table 4 and Figure 2 indicated that all applications of organic nutrient fertilization treatments produced a higher positive effect on stem diameter;

Table 4. Effect of organic nutrients application on plant height, stem base diameter, and dry weight of date palm cultivars after 9 months-old in the greenhouse.

Treatment (ml/L)	Parameters								
	Plant Height (cm)			Stem base diameter (cm)			Dry weight (g/pot)		
	'Shishi'	'Nabit Saif'	Mean (B)	'Shishi'	'Nabit Saif'	Mean (B)	'Shishi'	'Nabit Saif'	Mean (B)
T1	48.25	39.25	43.75^{a}	26.27	30	28.13^{a}	61.74	41.08	51.41^{a}
T2	52	38.91	45.45^{a}	25.35	30.08	27.71^{a}	34.2	42.97	38.59^{b}
T3	50.33	39.5	44.91^{a}	29.2	28.83	29.01^{a}	38.14	42.62	40.38^{ab}
T4	54.66	45.75	50.20^{a}	27.39	31.25	29.32^{a}	37.36	41.07	39.21^{b}
T5	50.16	44	47.08^{a}	26.87	31.91	29.39^{a}	35.94	38.88	37.41^{b}
Mean (A)	51.08 ^{a}	41.48^{b}	-	27.02^{b}	30.41^{a}	-	41.48^{a}	41.32^{a}	-

Figure 2. Effect of organic nutrients application on growth and development of date palm 'Shishi' after 9 months old from acclimatization in the greenhouse.

however, T5 or T4 applied enhanced the stem diameter (29.39; 29.32 cm). Concerning cultivars, the data indicated that the application of organic nutrient fertilizers increased stem base diameter for cultivars, 'Nabit Saif' significantly had a thicker stem base (30.41 cm) when compared with 'Shishi'

Table 5. Effect of organic nutrients application on the total number of leaves and pinnate leaves of date palm cultivars after 9 months in the greenhouse.

Treatment (ml/L)	Parameters					
	Total number of leaves/plants			Number of pinnate leaves/plants		
	'Shishi'	'Nabit Saif'	Mean (B)	'Shishi'	'Nabit Saif'	Mean (B)
T1	6.66	8.83	7.75[a]	2.50	3.50	3.04[b]
T2	6.91	9.00	7.95[a]	2.60	4.25	3.45[ab]
T3	7.50	9.50	8.50[a]	3.25	3.58	3.41[ab]
T4	7.41	10.25	8.83[a]	3.25	3.91	3.58[ab]
T5	7.91	10.00	8.95[a]	3.25	4.83	4.04[a]
Mean (A)	7.28[b]	9.5[a]	-	3.00[b]	4.02[a]	-

(27.02 cm). The data showed no significant difference between organic nutrient fertilizers applied to cultivars and their interaction with treatments.

Dry weight (g/pot)

It was clear that the application of organic nutrient fertilizers significantly reduced dry weight in comparison to the NPK (T1), which produced the highest dry weight (51.41 g/pot). Dry weight expressed no major modification between the two cultivars of date palms with the treatment under study, however, 'Shishi' gave the preferable dry weight with T1 (61.74 g). it also showed the effect of organic nutrient fertilizers applied to cultivars interacting with treatments.

Total number of leaves/plants

The total number of leaves per plant assessed after the application of organic nutrient fertilizers for 9 months of acclimatization in a greenhouse is shown in Table 5 and Figure 2. Application of organic nutrient fertilizers showed no significant difference between treatments on the number of leaves per plant, even though the highest number of leaves /plants was obtained when using organic nutrient T5 as fertilizer is 8.95 leaves/plant. It was clear that the date palm cultivar is affected by the type of fertilization; the total number of leaves was significantly increased with the cultivar 'Nabit Saif' with 9.51 leaves/plant. In addition, successful new leaf growth depends on the cultivar's response to fertilizers. Data indicated that treatment T4 showed a significant number of leaves with the cultivar 'Nabit Saif' with 10.25 leaves/plant in comparison with adding other fertilizers or chemical fertilizers to the cultivar Nabit Saif.

Total Number of pinnate leaves/plants

The effect of different organic nutrient fertilizer treatments on the number of pinnate leaves and plants is shown in Table 5 and Figure 2. The data revealed that nutrient fertilizers T5 significantly increased the number of pinnate leaves per plant (4.04) compared with chemical fertilizers (3.04) pinnate leaves/plant, and experiments showed that 'Nabit Saif' gave the highest number of pinnate leaves/plant (4.02) compared with 'Shishi' (3.00) pinnate leaves/plant. It indicated that 'Nabit Saif' was affected by organic fertilization, with the highest significant response (4.83) of pinnate leaves/plant in interaction with other treatments of fertilizer. The results indicate distinct effects of organic nutrient application on nitrogen percentage amount, compost tea and humic acid play a role in increasing the nitrogen amount of the leaves. The results shown in Table 6 indicated that all tested fertilization treatments significantly increased the amount of nitrogen soluble in leaves. Both T3 and T5 (1.74 and 1.73%) had significant differences in nitrogen percentages. In addition, the most significant difference between the cultivars for nitrogen percentages was 'Shishi' (1.77%) compared with the 'Nabit Saif' (1.53%). Moreover, it was clear that T3 (1.94%) significantly increased the nitrogen percentages in the 'Shishi' compared with chemical fertilizers. A statistical analysis of the phosphorus percentages in the amount of the leaves showed that there was no significant difference among treatments. The data showed a significant difference between cultivars that applied organic nutrients, the 'Shishi' gave the highest amount of potassium (0.25 g) than the 'Nabit Saif' (0.19 g). Even though there is no significant difference between treatments and cultivars, the T5 treatment achieves a high phosphorus percentage in the leaves with the 'Shishi' cultivar (0.29 g/m^2).

In addition, data analysis does not show significant differences between organic nutrient fertilizer treatments from (T2-T5) whereas chemical fertilizers T1 gave the highest significant difference of potassium amount percentage in the leaves (2.83%**),** as well T5 treatment has a high amount of potassium percentage (2.23%) with a significant difference with the T1. The highest percentage of potassium (2.34%) was obtained with 'Shishi'.

Table 6. Effect of organic nutrients application of soluble (N, P, K) in leaves of date palm cultivars.

Treatment (ml/L)	N%			P%			K%		
	'Shishi'	'Nabit Saif'	Mean (B)	'Shishi'	'Nabit Saif'	Mean (B)	'Shishi'	'Nabit Saif'	Mean (B)
T1	1.74	1.53	1.64^{ab}	0.28	0.21	0.24^{a}	2.73	2.94	2.83^{a}
T2	1.63	1.42	1.52^{b}	0.19	0.19	0.19^{a}	2.30	1.99	2.14^{b}
T3	1.94	1.55	1.74^{a}	0.27	0.20	0.23^{a}	2.19	2.29	2.24^{b}
T4	1.68	1.54	1.61^{ab}	0.24	0.18	0.21^{a}	2.19	2.09	2.14^{b}
T5	1.86	1.60	1.73^{a}	0.29	0.19	0.24^{a}	2.31	2.15	2.23^{b}
Mean (A)	1.77^{a}	1.53^{b}	-	0.25^{a}	0.19^{b}	-	2.34^{a}	2.29^{a}	-

Table 7. Effects of application of organic nutrients fertilizers of soluble (N, P, K) in soil of date palm cultivars.

Treatment (ml/L)	N%			P%			K%		
	'Shishi'	'Nabit Saif'	Mean (B)	'Shishi'	'Nabit Saif'	Mean (B)	'Shishi'	'Nabit Saif'	Mean (B)
T1	0.06	0.04	0.05^{c}	0.27	0.22	0.25^{a}	0.79	0.65	0.72^{a}
T2	0.02	0.07	0.05^{d}	0.068	0.12	0.09^{b}	0.14	0.27	0.21^{d}
T3	0.03	0.09	0.06^{b}	0.09	0.09	0.09^{b}	0.21	0.33	0.27^{b}
T4	0.04	0.01	0.03^{e}	0.07	0.07	0.07^{b}	0.39	0.17	0.28^{b}
T5	0.04	0.10	0.07^{a}	0.07	0.13	0.10^{b}	0.19	0.27	0.23^{c}
Mean (A)	0.04^{b}	0.06^{a}	-	0.11^{a}	0.13^{a}	-	0.34^{a}	0.34^{a}	-

The data shown in Table 7 highlights the varying effects of organic nutrient fertilizers on the macronutrient levels (N, P, K) in the soil of date palm cultivars 'Shishi' and 'Nabit Saif'. The most significant finding is the increase in nitrogen (N) content, particularly under treatment T5, where the highest mean nitrogen percentage (0.07%) was recorded. Notably, the 'Nabit Saif' cultivar demonstrated a higher mean nitrogen level (0.06%) compared to 'Shishi' (0.04%), with the T5 treatment of 'Nabit Saif' yielding the highest nitrogen percentage (0.10%). This suggests that 'Nabit Saif' may be more responsive to nitrogen uptake from organic fertilizers, a finding that warrants further exploration.

In contrast, phosphorus (P) and potassium (K) levels did not exhibit significant variations across treatments or cultivars. The highest phosphorus level (0.25%) and potassium level (0.72%) were observed in the control treatment (T1), which relied on synthetic NPK fertilizer.

These results indicate that, while organic nutrient fertilizers are effective in enhancing nitrogen levels in the soil, their impact on phosphorus and potassium may be less pronounced compared to chemical fertilizers.

This could be attributed to the higher phosphorus and potassium content in the chemical fertilizer component, which provides these nutrients in more readily available forms.

DISCUSSION

In light of the study conducted on date palm cultivars and the application of various organic nutrient treatments, the results provide compelling insights that extend the findings of previous research in this field. The observed enhancements in plant height and stem diameter under treatments T4 and T5 align with the assertions by Elamin et al. (2017) and Shaaban and Mahmoud (2012),

underscoring the critical role of macro and micronutrients in promoting date palm growth and improving fruit quality. This effectiveness of organic nutrients echoes the observations of Taha et al. (2016), who highlighted the beneficial impact of organic fertilizers, such as compost tea, on soil properties and plant development.

Furthermore, the differential growth responses of 'Shishi' and 'Nabit Saif' cultivars to these treatments emphasize the need for tailored nutrient management strategies in date palm cultivation, a concept that finds support in the work of Benabderrahim et al. (2017). This study also corroborates the environmental benefits championed by Kahiluoto et al. (2014) and Vessey (2003), who advocate for the use of organic fertilizers as sustainable alternatives to reduce reliance on chemical fertilizers. Notably, the positive influence of humic substances and biofertilizers observed in this research aligns with the findings of Chang-Chien et al. (2006) and Dou et al. (2008), who noted the enhancement of soil fertility and structure with the addition of organic materials.

These results confirm the hypothesis that organic nutrient treatments can significantly influence the growth parameters of date palm cultivars, further reinforcing the potential of organic fertilizers as effective and environmentally sustainable options in date palm cultivation. This research not only supports previous findings but also highlights the necessity of customized nutrient strategies to optimize the growth and fruiting of different date palm cultivars, contributing to the overarching goal of sustainability in agricultural practices.

The data shown in Table 5 reveals the effects of organic nutrient applications (T1 through T5) on the total number of leaves and the number of pinnate leaves in date palm cultivars ‘Shishi’ and ‘Nabit Saif’, 9 months post-treatment in a greenhouse setting. The study generally demonstrates an increase in both the total number of leaves and the number of pinnate leaves across different treatments, confirming the substantial impact of organic fertilizers on date palm growth metrics.

Regarding the total number of leaves per plant, it is evident that organic treatments enhanced this attribute, with Mean A values of 7.28 for ‘Shishi’ and 9.51 for ‘Nabit Saif’. This aligns with previous literature on the role of macro and micronutrients in achieving robust growth and reasonable economic production in date palms (Elamin et al., 2017; Shaaban and Mahmoud, 2012). The increase in the total number of leaves is likely due to the well-balanced nutritional profile provided by organic fertilizers, which supports broader plant health. Similarly, the number of pinnate leaves also increased with organic nutrient treatments, most notably with T5 (Mean B of 4.04), showing a statistically significant improvement. This suggests that certain treatments may optimize nutrient uptake, including essential elements like nitrogen (N) and phosphorus (P). This result is consistent with the findings of Vessey (2003) and Arora (2013) on the role of biofertilizers in facilitating nutrient access and enhancing plant health.

The positive outcomes in leaf count might also reflect improved soil fertility due to the addition of organic materials such as compost tea and humic substances, which are known to improve soil properties and microbial activity (Taha et al., 2016; Chang-Chien et al., 2006; Dou et al., 2008). These improvements in soil structure support plant growth, as noted by Baldock and Nelson (2000).

Table 6 shows the effect of organic nutrient application on the levels of soluble nitrogen (N), phosphorus (P), and potassium (K) in the leaves of date palm cultivars ‘Shishi’ and ‘Nabit Saif’. The results indicate that organic nutrients significantly influence the macronutrient composition in these cultivars. Treatments T3 and T5 showed the highest mean concentrations of N, P, and K, with slightly higher nutrient concentrations observed in the 'Shishi' cultivar. This reinforces the view that organic fertilizers can variably influence the nutrient profile across different cultivars.

This data aligns with numerous scientific studies highlighting the benefits of organic and biofertilizers in enhancing nutrient uptake and improving plant health. For instance, Shaaban and Mahmoud (2012) emphasized that a balanced nutrient supply through proper fertilization is essential for optimal growth and economic output in date palms. Organic fertilizers, known for their ability to balance soil nutrients and stimulate microbial activity, appear to uphold these benefits, as reflected in this study. Furthermore, the use of compost and biofertilizers has been promoted as an environmentally responsible practice to enhance soil fertility and structure (Taha et al., 2016; Vessey, 2003; Arora, 2013). These treatments not only contribute to nutrient availability but also provide sustainable solutions to address the ongoing depletion of mineral nutrient reserves (Kahiluoto et al., 2014).

Conversely, these findings align with studies exploring alternative fertilization methods, such as nano-fertilizers (Shareef et al., 2021) and slow-release fertilizers (Salem and Ali, 2020). While these studies did not focus on organic nutrients, they confirm that modified nutrient delivery methods can significantly improve nutrient uptake, thereby enhancing overall plant health and productivity. Benabderrahim et al. (2017) further extend this discussion by suggesting that date palm waste itself can be a valuable organic nutrient source when composted, offering a full-circle, eco-friendly approach to date palm cultivation.

The findings on nitrogen enhancement through organic nutrient treatments align with the broader literature on the benefits of organic fertilizers in improving soil health. Shaaban and Mahmoud (2012) and Elamin et al. (2017) emphasized the importance of balanced fertilization for increasing the productivity and quality of date palms, and this study supports those conclusions, particularly in relation to nitrogen. Organic fertilizers, known for their ability to balance soil nutrients and boost microbial activity, offer a more sustainable alternative to chemical fertilizers, which are associated with negative environmental impacts such as disrupting global biogeochemical cycles

(Kahiluoto et al., 2014).

The observed increase in nitrogen content under organic treatments also resonates with the findings of Taha et al. (2016) and Chang-Chien et al. (2006), who highlighted the positive effects of compost tea and humic substances on soil properties and nutrient availability. These organic inputs increase the humic acid content in the soil, which in turn improves the soil's chemical structure and nutrient-holding capacity.

In addition, biofertilization represents a promising method for reducing the dependence on chemical fertilizers. As noted by Vessey (2003) and Arora (2013), biofertilizers can improve nitrogen fixation, enhance phosphorus uptake, and support overall plant health, making them a sustainable alternative for enriching soil nutrients. While studies such as those by Salem and Ali (2020) and Shareef et al. (2021) focus on slow-release and nano-fertilizers, their results indirectly suggest that organic fertilization techniques could also improve nutrient delivery and plant growth in date palms.

Overall, the results of this study emphasize the effectiveness of organic fertilizers, particularly in increasing nitrogen levels in the soil. This supports the broader goal of sustainable agricultural practices, especially in arid regions like Qatar, where enhancing soil fertility through organic methods is critical for long-term agricultural sustainability. These findings contribute to the understanding of how organic nutrient treatments can be strategically applied to optimize the growth and productivity of different date palm cultivars.

Conclusion

This study demonstrates the considerable potential of organic nutrient treatments in improving both soil nutrient levels and the growth of date palm cultivars, specifically ‘Shishi’ and ‘Nabit Saif’. Organic treatments, especially those combining compost tea, humic acid, and biofertilizers, significantly increased nitrogen content in the soil and leaves, with the T5 treatment being particularly effective. ‘Nabit Saif’ showed a more pronounced response to these treatments compared to ‘Shishi’, suggesting that cultivar-specific responses to fertilization are important considerations in optimizing nutrient management.

While phosphorus and potassium levels were more significantly influenced by synthetic fertilizers, the enhancement of nitrogen levels through organic treatments supports the growing body of evidence on the benefits of organic fertilization. These findings align with prior research advocating for the use of organic and biofertilizers as sustainable alternatives to chemical fertilizers, particularly in enhancing soil structure, increasing microbial activity, and promoting long-term soil fertility.

The results highlight the importance of developing customized fertilization strategies that consider the specific nutrient needs of different cultivars. Additionally, the environmental benefits of organic fertilizers, including their role in reducing the negative impacts of synthetic fertilizers on global biogeochemical cycles, make them a viable alternative for sustainable agriculture in arid environments such as Qatar.

Moving forward, this research contributes to the broader understanding of sustainable agricultural practices and emphasizes the need for continued exploration of organic fertilizers' long-term impacts on both soil health and crop productivity in date palm cultivation. This approach holds promise for promoting both agricultural sustainability and environmental conservation in regions facing climate challenges.

RECOMMENDATION

Based on the study results, it is recommended to expand the use of organic fertilizers, particularly compost tea, humic acid, and biofertilizers, for improving soil fertility and promoting sustainable date palm cultivation. The differential responses between 'Shishi' and 'Nabit Saif' cultivars suggest the need for cultivar-specific nutrient management to optimize growth and nitrogen uptake. Further research should explore the long-term effects of these organic fertilizers on soil health and productivity, particularly in arid environments. Additionally, integrating these organic treatments into existing agricultural practices could reduce reliance on chemical fertilizers and enhance environmental sustainability.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ABBREVIATION

CT, Compost tea; **HA,** humic acid; **BF,** bio-fertilizer.

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