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Comparative Study of the Effects of Biological Fertilizer, Mycorrhizal, and Organic Fertilizer (Classical) on the Vegetative and Chemical Characteristics of Tissue Culture Offshoots of Date Palm PHOENIX Dactylifera L. (BARHI cv.)

Omar Ali Dahham[1], Ali Adil Abdulkareem[2], Ahmed alsabte[3], Y. S. Sekhi[4], Samara Alzuhairi[5]

[1]Tikrit University, Iraq. E-mail: omarali@tu.edu.iq Orcid 0009-0006-7883-4314
[2]Date Palm Research Unit, College of Agricultural Engineering Sciences, University of Baghdad, Iraq.
E-mail: ali.adel1005@coagri.uobaghdad.edu.iq.
[3]Iraq. E-mail: ahmed.ali@coagri.uobaghdad.edu.iq. Orcid 0000-0001-8672-6088
[4]University of Anbar, College of Agriculture. yassirsayel@Uoanbar.edu.iq
[5]College of Science, Al-Farahidi University, Iraq samaramahdi1991@gmail.com Orcid 0000-0003-3553-4515

ABSTRACT

This study was done during the 2024 and 2025 seasons at the Date Palm Orchard of the College of Agricultural Engineering Sciences, University of Baghdad, to test the individual and interactive effects of arbuscular mycorrhizal fungi (AMF) and organic liquid fertilizer on vegetative growth and mineral nutrient accumulation of in vitro–derived date palm (Phoenix dactylifera L.) offshoots cv. Barhi. Three levels of AMF inoculation (0, 10, and 20 g offshoot^{-1}) and three concentrations of organic fertilizer (0-, 1.5-, and 3-mL L^{-1}) were applied in a factorial experiment arranged in a randomized complete block design (RCBD). Growth parameters, including leaflet number, offshoot length, leaf area, and root number, were assessed, along with leaf mineral contents of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and sodium (N). The results presented that AMF inoculation significantly enhanced all vegetative and chemical traits, with the highest level (20 g) producing superior performance across both seasons. On the same side, organic fertilization at 1.5- and 3-mL L^{-1} significantly improved growth attributes and nutrient accumulation compared with the control. Notably, the interaction between high AMF inoculation and organic fertilizer application exhibited a pronounced synergistic effect, resulting in the highest values for most studied parameters. The interaction of AMF and organic fertilizer significantly increased nutrient uptake efficiency, promoted root development, and improved overall plant vigor. These improvements are likely associated with enhanced rhizosphere activity, increased nutrient bioavailability, and improved physiological performance. In conclusion, integrating arbuscular mycorrhizal fungi with organic fertilization represents a sustainable and effective strategy to develop the growth and nutritional status of tissue-cultured date palm offshoots, thereby accelerating their transition to maturity and potentially reducing reliance on chemical fertilizers.

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Date palm; Tissue culture, Biofertilizer, liquid Organic fertilizer, Nutrient absorption.

1. Introduction

In the last two decades, the world has turned to the use of clean agriculture methods through the use of organic and bio-fertilizers, which are a haven for achieving food security in line with the direct increase in population numbers, and also reducing the use of chemical mineral fertilizers to about 50%, ultimately obtaining a safe and healthy product. Bio- and organic fertilizers play a positive role in improving soil properties, in addition to increasing the availability of nutrients such as N, K, S and iron in the soil, and increasing the availability of phosphorus by dissolving the deposited phosphor compounds and releasing them to the soil in the form of H2PO4, in addition to secreting plant hormones and acids that act as plant growth regulators (Neina, 2019 and Chukwuka et al. 2020; Abdulkareem & Hussien,2022). Biofertilizers secrete antibiotics that increase plant resistance to soil-dwelling pathogens and pests, and they also secrete enzymes that stimulate plant growth (Hamid et al., 2021; Victorino et al., 2021). Among the most important biofertilizers is the mycorrhizal fungus, which is characterized by its ability to fix atmospheric nitrogen and increase the surface area for absorption through the presence of hyphae within plant roots. It has an important role in increasing the availability of elements, especially phosphorus, improving water relations, and increasing the resistance of the host plant to drought. Inoculation with mycorrhizal fungi is also important for root growth in the early stages of plant growth, as mycorrhizal fungi increase the amount of growth regulators, such as auxin, gibberellins, and cytokinins, released from the tissues,

increasing the weight of the roots, and also activating the growth and effectiveness of root hairs. In the same direction, organic fertilizers are added to plants. They are produced from animal or plant waste because they are a source of nutrients, humic acids, and organic materials that are effective in improving the biological and physical properties of the soil and are an important medium for the growth of microorganisms (Silva and 2016, Bras chetani and Sharma, 2017; Chukwaka et al., 2020), (2015, Garcica Puschel, 2016; Macik et al., 2020; Adetunij et al., 2022; Abdulkareem,2023). These fertilizers are important for supplying elements such as phosphorus and potassium, as well as trace elements, which promote root growth and positively affect plant growth (Kranz et al., 2020). Organic fertilizer is also rich in humic and fulvic acid, which consist of nitrogen, sulfur, oxygen, hydrogen, and carbon, in addition to major and minor elements. Humic acid is considered a source of energy for microorganisms, which increases their ability to increase the availability of elements and improve soil properties. Al-Rubaye et al. (2019) concluded that the use of fungal biofertilizer led to an increase in the dry and wet weight of the plant, and Hussien et al. (2019) concluded that the addition of mycorrhizal fungi increased all vegetative growth traits and yield of the corn plant. As Awasthi et al. (2019) showed, the use of organic fertilizers led to increased production and reduced environmental pollution compared to chemical fertilizers. Aziz et al. (2010) observed increased chlorophyll, plant height, and dry matter in yellow corn plants treated with organic fertilizer compared with untreated plants. Jeong, Etesami, and Nacoon et al. (2021) also concluded that inoculation with mycorrhizal fungi led to an increase in soil phosphorus availability. Anil et al. (2020) concluded that the use of bio- and organic fertilizers represented by Seaweed extract and mycorrhizal fungi led to an improvement in the physical and chemical properties of date palms represented by NPK and leaf area. In a study comparing the effects of biofertilization with mycorrhizal fungi and chemical fertilizer, Khalifa (2015) reported a significant increase in NPK content in plant leaves and other vegetative characteristics. On the other hand, Shamsi and others (2018) showed that inoculation of new palm seedlings with mycorrhizal fungi increased the number of fronds compared to chemical fertilizer, The researcher Al-Karki 2013 concluded that the use of mycorrhizae in the growth of date palms led to improving the soil texture and reducing its need for water, which was positively reflected in the growth of palm seedlings represented by the trunk diameter and plant length. In the same way, El-Salhy (2021) showed that biological and organic fertilization improved the fruit growth characteristics of Sakkoty date palms by 35% compared to mineral fertilizer, with an increase in leaf area, bunch weight, number, and weight. Al-Tamimi et al. (2017) showed that treating palm leaves with humic acid increased the percentage of chlorophyll and increased NPK and protein in the leaves at a concentration of 18 ml/L. In a study conducted to compare the effect of organic fertilizer Tekamin Max and chemical fertilizer on the growth of two palm varieties, Maktoum and Sukkari, between Al-Hamdani and Al-Janabi, the organic fertilizer treatment led to an increase in vegetative characteristics, including the number and length of leaves, the number and length of roots, and the chlorophyll content of leaves at a concentration of 60 ml/L. The objective of this research is to enhance vegetative growth and increase the concentrations of chemical elements to accelerate the transition of offshoots to maturity, flowering, and subsequently fruiting.

2. Material and methods

This study was carried out at the Palm orchard of the College of Agriculture during the 2024 and 2025 seasons. Twenty-seven offshoots of the Date palm *Phoenix dactylifera* L. Barhi variety, produced from a tissue culture laboratory, 6 months of age, and grown in pots, were selected. Offshoots homogeneous in size and service operations were used; three levels of mycorrhizal fungus were used (0, 10, and 20 g) and are symbolized M1, M2, and M3. Different concentrations (0, 1.5, and 3) mL-1 of liquid organic fertilizer were used, denoted C1, C2, and C3. Called (Classical), which consists of fulvic and humic acids, micro- and macro-elements, besides amino acids. A Randomized Complete Block Design (RCBD) was used, and the Least Significant Difference (LSD) test was used to compare the means of the different treatments at a significance level of 0.05. The following characteristics were measured.

1- Plant height (cm): The height was measured using a measuring tape, from the soil surface to the highest point of the plant.

2- Leaf area (cm^2) = (length × maximum width × 0.84) according to Shabana and Anton (1980).

3- Leaflet number: The average number of newly developing leaflets and their length was calculated at the end of the growing season.

4- The ratio of nitrogen, phosphorus, and potassium in the leaflet: The leaves were washed with tap water, then with distilled water, furthermore air-dried, and finally dried evenly at 70°C until a constant weight was achieved. The dried material was then ground in a stainless-steel vessel, and 0.2 g of each sample was digested overnight with concentrated sulfuric acid and 30% hydrogen peroxide. The nitrogen, phosphorus, and potassium contents (on a dry-weight basis) in the digested solution were determined. According to the method of Wilde et al. (1985)

Measurement of potassium and sodium using a Atomic Absorption spectrophotometer according to the method described by Momen et al. (2006) and Rohman A and Gandjar (2007).

3. Result and discussion

Table (1) Influence of Mycorrhizal fungi and organic fertilizers on leaflet number of Date palm Offshoots over two growing seasons (2024-2025).

2024					2025				
O / rg	1 org	2 org	o rg3	m ean	O / rg	1 org	2 org	o rg3	m ean

M					M				
M 1	1 .0	1 .03	2 .0	1 .34	M 1	2 .0	3 .3	3 .03	2 .77
M 2	2 .0	2 .0	4 .0	2 .66	M 2	2 .73	4 .0	4 .0	3 .57
M 3	4 .0	4 .1	3 .0	3 .7	M 3	4 .0	6 .33	5 .0	5 .11
M ean	2 .33	2 .37	3 .0		m ean	2 .91	4 .54	4 .01	
L SD 5%	Myco × Org . 0.5524 Org 0.31 0.31 Myco				L SD 5%	Myco × Org . 0.9431 Org 0.54 0.54 Myco			

The results in Table (1) indicate that there were significant differences between the levels of mycorrhizal fungus in 2024 and 2025 in their effect on leaflet number , where level 3 giving the highest results (3.7 and 5.11) leaf let compared with level 1 and 2 gave lowest numbers (1.34 and 2.66)in 2024 and (2.77 and 3.57) leaflet in 2025 respectively, regarding the organic fertilizer concentration the data was clear that concentration 3 in 2024 and level 2 in 2025 achieved maximum number reached to 3 and 4.54 leaf in comparison with lowest number (2.37 and 2.91) for concentration 1 for two seasons respectively , in the same way the interaction treatments between mycorrhizal fungus and organic fertilizer achieved significant differences were the results revealed that the interacted treatments (2 myco + 3 org), (3 myco + 1 org) and (3 myco + 2 org) in 2024 and (3 myco + 2 org) in 2025 gave highest number was (4.0 ,4.0, 4.1) leaflet in 2024 and (6.33) leaflet in 2025 compared with control treatment(1 myco + 1 org) gave minimum number was (1.0 and 2.0) leaflet for two season respectively .

Table (2) Influence of Mycorrhizal fungi and organic fertilizers on length of Date palm Offshoots over two growing seasons (2024-2025).

2024					2025				
Org / M	1 org	2 org	o rg3	m ean	O rg / M	1 org	2 org	o rg3	m ean
M1	7 .5	9 .0	9 .7	8 73.	M 1	9 .2	1 1.0	1 8.0	1 2.73
M2	8 .2	7 .9	9 .9	8 66.	M 2	1 7.8	1 9.0	1 8.2	1 8.33
M3	1 0.2	1 3.8	1 2.3	1 2.1	M 3	1 8.9	2 3.83	1 9.6	2 0.77
Me an	8 63.	1 0.23	1 0.63		m ean	1 5.3	1 7.94	1 8.6	
L SD5%	Myco × Org 1.2747 0.73			Org 0.73 Myco	L SD 5%	Myco × Org=1.1667 Org 0.067 Myco 0.067			

The results in Table 2 showed differences in offshoot length as affected by mycorrhizal fungal levels, organic fertilizer concentrations, and their interaction across two growing seasons (2024–2025). Increasing mycorrhizal levels resulted in a marked improvement in offshoot length, where treatment 3 noted the greatest mean values in both seasons, arriving at 20.77 cm in 2024 and 18.33 cm in 2025, compared with the minimum values obtained at level 1. In the same direction, organic fertilizer application significantly enhanced offshoot length, with concentration 3 giving superior growth compared to control level 1 in both seasons. Regarding the interaction treatments, the data showed significant differences between mycorrhizal fungi and organic fertilizers in both seasons. In 2024, treatment of 3 Myco + 3 Org recorded the highest length (23.83 cm), followed by 3 Myco + 2 Org (19.6 cm), whereas the lowest length was obtained from the control treatment 1 Myco + 1 Org (7.5 cm). Likewise, in 2025, the maximum offshoot length was observed under 3 Myco + 3 Org (20.77 cm), while the minimum length (9.2 cm) was recorded in the control treatment.

Table (3) Influence of Mycorrhizal fungi and organic fertilizers on leaf area of Date palm Offshoots over two growing seasons (2024-2025).

2024					2025				
Org / M	1 org	2 org	org3	mean	Org / M	1 org	2 org	org3	mean
M1	1 2.22	1 4.33	1 6.2	1 4.25	M 1	1 9.6	2 1.3	2 3.7	2 1.53
M2	1 9.3	1 5.4	1 5.7	1 6.8	M 2	2 2.4	2 5.7	2 4.3	2 4.13
M3	1 7.4	2 1.2	1 9.0	1 9.2	M 3	2 6.1	3 0.1	2 6.0	2 7.4
Mean	1 6.3	1 6.97	1 6.96		mean	2 2.7	2 5.7	2 4.6	
L SD5%	Myco × Org = 0.748 Org 0.43 Myco 0.43				L SD 5%	Myco × Org =0.5689 Org 0.32 Myco 0.32			

Data in Table 3 demonstrate that leaf area was significantly influenced by mycorrhizal fungi, organic fertilizer, and their interaction across both seasons. The highest leaf area was consistently recorded under mycorrhizal level 3, with mean values of 27.4 cm² in 2024 and 24.13 cm² in 2025, whereas the lowest values were observed at level 1. Organic fertilizer application also had a clear impact, as higher concentrations resulted in increased leaf area compared with lower concentrations. Regarding the interaction between treatments, the results showed that in 2024, the interaction 3 Myco + 3 Org produced the highest leaf area (30.1 cm²), whereas the lowest value (12.22 cm²) was recorded under 1 Myco + 1 Org. A similar trend was observed in 2025, with 3 Myco + 3 Org yielding the maximum leaf area (27.4 cm²), whereas the control treatment yielded the minimum (19.6 cm²).

Table (4) Influence of Mycorrhizal fungi and organic fertilizers on root number of Date palm Offshoots over two growing seasons (2024-2025).

2024					2025				
Org / M	1 org	2 org	org3	mean	Org / M	1 org	2 org	org3	mean
M1	2 .0	2 .0	2 .0	2 0.	M 1	3 .0	3 .0	3 .0	3
M2	3 .0	3 .0	3 .0	3 0.	M 2	4 .0	4 .0	4 .0	4
M3	3 .0	5 .0	3 .0	3 66.	M 3	5 .0	7 .0	5 0.	5 66.
Mean	2 66.	3 33.	2 66.		mean	4	4 66.	4	
L SD5%	Myco × Org = 0.6885 Org 0.39 Myco 0.39				L SD 5%	Myco × Org =0.6741 Org 0.38 Myco 0.38			

The data in Table 4 demonstrate that the number of roots was significantly affected by mycorrhizal fungi, organic fertilizer levels, and their interaction during 2024-2025. Mycorrhizal level 3 had the highest number of roots, reaching 5.66 in 2024 and 5.0 in 2025, compared with the minimum recorded at level 1. Organic fertilizer application also gave results to root development positively, with increasing concentrations promoting a greater number of roots. The interaction between mycorrhizal and fertilizers resulted in superior root proliferation, especially at high levels. This increase in root number can be attributed to the stimulatory effect of mycorrhizal fungi on root branching and nutrient uptake, as well as to the role of organic fertilizers in improving soil properties and stimulating microbial activity.

Table (5). Influence of Mycorrhizal fungi and organic fertilizers on nitrogen content of Date palm Offshoots over two growing seasons (2024-2025).

2024					2025				
Org / M	1 org	2 org	org3	mean	Org / M	1 org	2 org	org3	mean
M 1	0.12	0.16	0.27	0 18.	M 1	0.15	0.19	0.3	0 21.
M 2	0.29	0.33	0.41	0 34.	M 2	0.33	0.36	0.46	0 38.
M 3	0.51	0.75	0.62	0 62.	M 3	0.55	0.8	0.65	0 66.
M ean	0 3.	0 41.	0 43.		m ean	0 34.	0 45.	0 47.	
L SD 5%	Myco × Org = 0.0489 Org 0.02 Myco 0.02				L SD 5%	Myco × Org =0.0577 Org 0.033 Myco 0.033			

The data in Table 5 revealed significant differences in nitrogen content of date palm offshoots due to mycorrhizal fungi, organic fertilizers, and their interaction in both seasons. The highest nitrogen content was observed at level 3 of mycorrhizal, with values reaching 0.66% in 2024 and 0.62% in 2025, while the lowest values were recorded at level 1. So, organic fertilizer concentration significantly increased nitrogen accumulation, particularly at concentration 3. Interaction treatments showed that combining high mycorrhizal levels with high organic fertilizer levels resulted in the highest nitrogen content. This improvement may be attributed to boosted nitrogen uptake efficiency due to mycorrhizal colonization and increased mineralization of organic nitrogen sources in the soil.

Table (6). Influence of Mycorrhizal fungi and organic fertilizers on phosphorus content of Date palm Offshoots over two growing seasons (2024-2025).

2024					**2025**				
Org / M	**1 org**	**2 org**	**org3**	**mean**	**Org / M**	**1 org**	**2 org**	**org3**	**mean**
M 1	0.19	0.21	0.24	0 21.	M 1	0.22	0.22	0.27	0 23.
M 2	0.27	0.28	0.28	0 27.	M 2	0.29	0.29	0 31.	0 29.
M 3	0.28	0.38	0.29	0 31.	M 3	0.33	0.41	0.35	0 36.
M ean	0 24.	0 29.	0 27.		m ean	0 28.	0 3.	0 31.	
L SD5%	Myco × Org = 0.0402 Org 0.02 Myco 0.02				L SD 5%	Myco × Org = 0.0613 Org 0.035 Myco 0.035			

Table 6 shows that phosphorus content was significantly influenced by the interaction between mycorrhizal fungi and organic fertilizers. In 2024, the highest phosphorus content (0.41%) was recorded in the 3 Myco + 3 Org treatment, while the lowest value (0.19%) was obtained from the control treatment. Similarly, in 2025, 3 Myco + 3 Org yielded the highest phosphorus content (0.36%), whereas 1 Myco + 1 Org yielded the lowest (0.22%). The superior phosphorus uptake under high interaction levels highlights the well-known role of mycorrhizal fungi in enhancing phosphorus availability and translocation within plant tissues .The data in the same table show that phosphorus content was significantly affected by mycorrhizal fungal levels and organic fertilizer concentrations. Mycorrhizal at level 3 recorded the highest phosphorus content in both seasons, 2024 and 2025, reaching 0.36% and 0.31%, respectively, compared with the minimum values at level 1 .Organic fertilizer application significantly increased phosphorus concentration, particularly at higher application

rates. Concerning the interaction data revealed that treatments combining high mycorrhizal inoculation with high organic fertilizer concentrations achieved the highest phosphorus content. This result is expected, as mycorrhizal fungi are well known for enhancing phosphorus uptake through their extensive hyphal networks, especially in soils with limited phosphorus availability.

Table (7) Influence of Mycorrhizal fungi and organic fertilizers on potassium content of Date palm Offshoots over two growing seasons (2024-2025).

2024					2025				
Org / M	1	2	3	Mean	Org / M	1	2	3	Mean
M1	0.13	0.15	0.15	14.0	M1	0.14	0.16	0.18	16.0
M2	0.15	0.17	0.16	16.0	M2	0.18	0.18	0.19	18.0
M3	0.19	0.23	0.16	19.0	M3	0.22	0.27	0.19	22.0
Mean	15.0	18.0	15.0		Mean	18.0	2.0	18.0	
LSD5%	Myco × Org = 0.0425 Org 0.02 Myco 0.02				LSD 5%	Myco × Org =0.0465 Org 0.02 Myco 0.02			

Table 7 demonstrated that mycorrhizal fungi had a significant effect on potassium content during both seasons. The maximum value was recorded at mycorrhizal level 3, particularly when combined with organic fertilizer concentration 3, while the lowest values were observed at level 1. In the same way, organic fertilizer application also increased potassium content compared with the control treatment. Regarding the interaction treatments, the results show a synergistic effect, suggesting that mycorrhizal fungi enhance potassium uptake efficiency when sufficient organic nutrients are available. Improved root growth and increased soil nutrient availability may explain these findings.

Table (8) Influence of Mycorrhizal fungi and organic fertilizers on calcium content of Date palm Offshoots over two growing seasons (2024-2025).

2024					**2025**				
Org / M	1	2	3	Mean	Org / M	1	2	3	Mean
M1	0.38	0.39	0.41	39.0	M1	0.42	0.42	0.44	42.0
M2	0.4	0.43	0.45	42.0	M2	0.45	0.47	0.51	47.0
M3	0.44	0.51	0.43	46.0	M3	0.59	0.42	0.44	48.0
Mean	4.0	44.0	43.0		Mean	48.0	43.0	46.0	
LSD 5%	Myco × Org = 0.0384 Org 0.022 Myco 0.022				LSD 5%	Myco × Org = 0.0457 Org 0.026 Myco 0.026			

The results in Table 8 indicate a direct relationship between fertilizer application and the increase in calcium content. Mycorrhizal and organic fertilizers showed positive effects on calcium content; at level 3, these generally produced higher calcium content, whereas lower levels in both seasons did not yield high results .Organic fertilizer application also contributed to an increase in calcium concentration in the same direction. The interaction between mycorrhizal fungi and organic fertilizers resulted in enhanced calcium uptake, which may be related to improved root surface area and increased nutrient mobility in the rhizosphere.

Table (9). Influence of Mycorrhizal fungi and organic fertilizers on sodium content of Date palm Offshoots over two growing seasons (2024-2025).

2024					2025				
O rg / M	1 org	2 org	o rg3	m ean	C rg / M	1 org	2 org	o rg3	m ean
M 1	0 .21	0 .21	0 .18	0 2.	N 1	0 .22	0 .23	0 .22	0 22.
M 2	0 .24	0 .27	0 .27	0 26.	N 2	0 .27	0 .29	0 .29	0 28.
M 3	0 .24	0 .38	0 .26	0 29.	N 3	0 33.	0 .43	0 .31	0 35.
m ean	0 23.	0 28.	0 23.			0 27.	0 28.	0 27.	
L SD 5%	Myco × Org =0.041 Org 0.02 Myco 0.02				LSD 5% = 0.449 Org 0.02 Myco 0.02				

As presented in Table 9, sodium content varied significantly among treatments. Higher mycorrhizal levels generally resulted in increased sodium accumulation, particularly when combined with higher organic fertilizer concentrations. In all cases, the increase in sodium content remained within acceptable limits and did not adversely affect plant growth .The interaction effects suggest that mycorrhizal fungi may influence ion balance in plant tissues, potentially reducing sodium stress by improving nutrient selectivity and enhancing uptake of beneficial elements. Organic fertilizers may also help regulate sodium availability by improving soil structure and cation exchange capacity. The increase in nutrients using mycorrhizal fertilizer is attributed to the fact that the fungal hyphae secrete specific organic acids and growth regulators such as cytokinins, gibberellins, auxins, and some enzymes, which in turn increase the activity of nitrogen-fixing bacteria. As for phosphorus, this is due to an increase in the phosphatase enzyme, which works to dissolve phosphate compounds and convert them into readily available forms. On the other hand, there is an increase in the activity of phosphate-solubilizing microorganisms due to the symbiotic relationship between mycorrhizae and plant roots. Hyphae also work through their secretions to dissolve potassium-containing compounds and improve the growth conditions of microorganisms, thus increasing their concentration. Organic fertilizer also increases nutrients, possibly because it increases biological activity in the soil, which in turn increases the ability of nitrogen-fixing organisms to convert organic nitrogen into mineral nitrogen. (Kareem and Al-Dahan, 2020; Farida and Wangiyana,2023; Yooyongwech et al., 2022).

4. Conclusion

The application of mycorrhizal fungi at a level of 20 g is considered one of the best treatments for improving the vegetative and chemical growth of tissue-cultured date palm offshoots. The interaction between mycorrhizae and organic fertilizer showed an apparent synergistic effect, achieving the highest values for most of the studied traits compared to the individual treatments. These treatments contribute to accelerating the transition of palm offshoots resulting from tissue culture to the stage of maturity, which positively impacts the acceleration of entry into the flowering and fruiting stages. The study recommends adopting mycorrhizal biofertilization with organic fertilization as a sustainable partial or total alternative to chemical fertilizers in date palm nurseries, due to its role in improving growth and reducing environmental impact. Biofertilization and organic fertilization improved nutrient uptake, particularly of nitrogen, phosphorus, and potassium, due to increased microbial activity and enhanced root system growth. Liquid organic fertilization, particularly at concentrations of 1.5 and 3 ml/L, effectively contributed to promoting vegetative growth and increasing nutrient accumulation in the leaves.

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