Colegio de Postgraduados

Response to chemical and organic fertilization in date palm (*Phoenix dactylifera* L.) Mejhoul variety in Northwestern Mexico

Morales-Maza, Antonio[1]; Mendoza-Gómez, Aurelia[2*]; Cabada-Tavares, Carlos A.[1]; Beleño-Cabarcas, Mary T.[2]; Torres-Ramos, Ricardo[2]; Cervantes-Díaz, Lourdes[2]

[1] Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, Campo Experimental Valle de Mexicali (CEMEXI), Baja California, México. C.P. 21700.
[2] Universidad Autónoma de Baja California, Instituto de Ciencias Agrícolas (ICA), Mexicali, Baja California, México. C.P. 21705
* Correspondence: aurelia.mendoza@uabc.edu.mx

ABSTRACT

This research was conducted to determine the effect of chemical, organic, and combined fertilization on the fruit yield of the Mejhoul date palm variety in Northwestern of Mexico. The variables measured were polar diameter, equatorial diameter of the fruit, roundness index, number of clusters, number of leaves per palm, number of leaves per cluster, fruits with separated skin, dried fruits and commercial yield. The design used was complete randomized blocks with five replicates, where each palm tree was the experimental unit. The results indicate that chemical fertilization 262N-138P_2O_5-540K_2O alone or in combination with compost application (three or six tons per hectare) increases polar and equatorial diameter, promoting the oval growth of dates. Fruits with separated skin continue to occur regardless of the origin of the fertilizers. The number of fruits increases with chemical fertilization, but the total yield of dates remains consistent across the treatments evaluated. In conclusion, date palms respond favorably to the combination of chemical and organic fertilization, but date yields did not increase.

Keywords: Dates, chemical fertilizers, organic fertilizer, yield.

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INTRODUCTION

The date palm (*Phoenix dactylifera* L.) is one of the oldest cultivated fruits and is increasing its cultivation area worldwide. It is known as the "tree of life" due to its resilience, its ability to adapt to limited water supply, its long-term productivity, and its multipurpose anthropocentric qualities. Additionally, it is the most common fruit tree grown in warm, semi-arid, and arid regions (Marzouk, 2011). Dates are rich in numerous therapeutic, bioactive, and functional compounds such as polyphenols, dietary fiber, carotenoids, vitamins, amino acids, carbohydrates, and minerals, making them one of the most nutritious natural foods (Ibrahim *et al.*, 2021; Noutfia and Ropelewska, 2022).

Currently, around 9.61 million tons of dates are produced worldwide on 1.25 million hectares of land (FAO, 2024). From 2021 to 2022, the cultivated area of date palm in Mexico grew by 8.12 percent, reaching 3,268 hectares that produced 19,465 tons of this fruit. Mexico ranks third in the world as a producer, after Israel and the United States, of the Mejhoul date, which is recognized for its high nutritional quality and its contribution to territorial development in these regions of the country, with social inclusion and justice. The main date producers are San Luis Río Colorado, Sonora, with 55 percent of the total national volume, followed by Mexicali, Baja California, with 41 percent. In 2022, these regions exported just over seven thousand tons.

The yield and quality of date palm fruit largely depend on the cultivar, nutrition, water relations, soil type, type of fertilizers, and the fertilization program, which determine the efficiency of the production system in relation to the previous year's yield and the quality of the dates. It is common to supplement the nutritional requirements of date palms mostly with chemical or synthetic fertilizers. However, the continuous use of chemical products leads to the deterioration of soil characteristics and fertility (Shimbo *et al.*, 2001).

Organic fertilizers have been used in agriculture to improve soil fertility, promote plant growth and protection, which enhances crop productivity. According to Ghouili *et al.* (2022), the application of organic amendments such as compost could be considered a good strategy for environmentally sustainable management. Cultivating date palms in organic systems represents the optimal solution for sustainable production through the use of organic fertilizers (compost), biofertilizers (nitrogen-fixing bacteria, phosphate-solubilizing microorganisms, and potassium-solubilizing biological microorganisms), as well as biocontrol agents (Safwat, M.S.A. 2007).

Magdoff (1998) suggests that organic matter from manure is an excellent source of macro and micronutrients such as nitrogen, phosphorus, and potassium (N, P, and K), and its incorporation into the soil increases the availability of P and exchangeable contents of K, calcium, and magnesium. The application of shredded organic matter or compost in date palms provides additional benefits by reducing water evaporation from the soil surface, helping to control weed invasion, suppressing dust, preventing soil erosion from wind or water, and providing thermal stabilization by keeping the soil cooler in hot climates and warmer in cold climates (EL-Mously *et al.*, 2023).

Similarly, the application of organic fertilizers improves soil structural stability and decreases bulk density, increasing moisture retention, water infiltration rate, and soil hydraulic conductivity (Tisdale *et al.*, 1990; Young, 1997).

The recommended doses of N, P, and K conventionally applied to date palms vary widely among farmers in the region, possibly due to limited knowledge of the actual nutritional needs of date palms, soil variations, climatic conditions, irrigation systems, tree age, and the lack of research related to fertilization. In this regard, research conducted on Iraqi and United Arab Emirates date palms recommends approximately 2.3 kg of N, 1.2 kg of P, and 1.4 kg of K per tree (Al-Rawi, 1998).

On the other hand, the FAO calculated a global average application of 0.65 kg of N $tree^{-1}$ 20 years ago (Klein and Zaid, 1999). However, more recent research suggests that the optimal application rate of N could range from 0.4 to 3.6 kg $tree^{-1}$ $year^{-1}$,

depending primarily on the type of fertilizer, application method, and the presence of other micronutrients (Al-Qurashi *et al.*, 2015; Hesami *et al.*, 2017; Ibrahim *et al.*, 2013; Saleh, 2009). In Israel, nitrogen fertilization recommendations range from 1.5 kg of N tree^{-1} year^{-1} for three-year-old trees, up to 3.6 kg of N tree^{-1} year^{-1} by the sixth year, for palms grown in sandy soil with drip irrigation (Wright, 2012). This is because research in Israel has shown that the estimated annual nitrogen consumption of a mature date palm is around 2 kg of N (MOAG, 2019).

However, the most recent fertilization recommendations suggest a concentration of 35 mg N L^{-1} of fertilizer in fertigation (fertilization and irrigation) throughout a year (MOAG, 2015). As a result, this would lead to a triple dose of 6 kg of N mature tree^{-1}, and with 123 trees planted per hectare, a total fertilization of 732 kg N ha^{-1} year^{-1} would be achieved.

According to Kassem (2012), in Zaghloul date palms, fertilization with 1000 grams per palm of ammonium sulfate increased fruit yield, weight, length, and color compared to ammonium nitrate or urea. Additionally, potassium and sulfur fertilization improved the physicochemical characteristics of the fruit. Poultry manure (PM) and cow manure (CM) resulted in the best fruit weight, pulp weight, and fruit length in twenty-six-year-old Zaghloul palms grown in clay loam soil (Kassem and Marzouk, 2010).

Plants require nutrients such as N, P, K, Ca, Mg, S, Fe, Mn, Zn, and other trace elements for their growth and development, which can be supplied through organic and inorganic sources. Nutrients from organic sources decompose more slowly, and plants take longer to absorb them, whereas inorganic fertilizer sources are readily available (Nyamangara, 2020; Chen, 2023). Inorganic mineral fertilizers combined with organic manures have been shown to have a positive impact on global food production and are an essential part of many agricultural production systems (Hernández, 2019).

The use of fertilization, based on the application of both compost and chemical fertilizers, can improve the yield of date palms and increase farmers' income, while also restoring soil fertility. This research was conducted to determine the effect of applying chemical, organic, and combined fertilization on the fruit yield of the Mejhoul date palm variety in Northwestern Mexico.

MATERIALS AND METHODS

The experiment was conducted during the 2023 season in a 26-year-old plantation located in Ejido Tula, Mexicali Valley, Baja California, Mexico (32.56453167449391, −115.20770875361818). The variety was Mejhoul. The trees were planted at 8 meters between palms and 8 meters between rows. The palms were grown in sandy loam soil with a localized irrigation system using tubing and gravity irrigation. Pollination was done manually by obtaining pollen from male flowers and subsequently placing it on female flowers. After five weeks, fruit thinning was performed at the "Hababouk" stage, with a spacing of 2.5 cm between fruits and 8 to 10 fruits per bunch.

The physical and chemical characteristics of the soil are as follows: loam texture, bulk density of 1.04 g/cm^3, hydraulic conductivity of 4.80 cm hr^{-1}, pH of 8.07, carbohydrates at 9.36%, 3.66 dS m^{-1}, 0.92% organic matter, 19.6 ppm N, 23.1 ppm P_2O_5, 192 ppm K_2O,

3323 ppm Ca, 463 ppm Mg, 239 ppm S, 442 ppm Na, 5.16 ppm Fe, 0.42 ppm Zn, 5.48 ppm Mn, 0.63 ppm Cu, and 1.76 ppm B.

The palms were fertilized with inorganic and organic products either alone or in combination, according to the treatments. The inorganic fertilizer used was ammonium nitrate (33.5% N)+phosphoric acid (54% P_2O_5)+potassium nitrate (12.66% N+43.3% K_2O+3.05% S) and heptahydrated magnesium sulfate (13.8% S+10% Mg).

The organic fertilizer was compost made from bovine manure, with 21.91% organic matter, pH 8.89, EC less than 1.4 dS m^{-1}, CEC less than 40 cmol l^{-1}, 1.08% N, 0.02% P_2O_5, 1.40% K_2O, 0.26% Ca, 0.78% sulfate, 0.5% humic acids, 0.5% fulvic acids, beneficial microorganisms, a C/N ratio of 11.5, moisture content less than 25%, and a physical appearance of granulated powder less than 10 mm.

The treatments were as follows: T1-COMPOST (38.46 kg of compost per palm), T2-FERQUIM with chemical fertilization (262 N-138 P_2O_5-540 K_2O), T3-CP50%+FQ50% (chemical fertilization 131 N-69 P_2O_5-270 K_2O plus 19.23 kg of compost per palm), T4-CP100%+FQ100% (chemical fertilization 262 N-138 P_2O_5-540 K_2O plus 38.46 kg of compost per palm), and T5-FERCONV (conventional fertilization 456 N-162 P_2O_5-252 K_2O). The application of the fertilization doses was distributed across the months as follows: February (5%), March (10%), April (12%), May (20%), June (21%), July (14%), August (8%), September (5%), and October (5%).

Yield Estimation: The fruits were harvested at the Tamer stage, characterized by less than 25% fruit moisture. Harvesting began in September and continued until the end of October. The average yield and weight of the bunches were recorded in kilograms. Samples of 50 fruits from each palm were randomly taken (as a sample for each replicate) to determine fruit quality characteristics.

Fruit Weight (g): From the 50 fruits, samples of 20 fruits from one bunch per palm were taken. The weight was obtained using a digital electronic scale (Scout Pro SP 602, Ohaus®, USA), with a capacity of 0.6 kg and a sensitivity of 0.01 g.

Polar and Equatorial Diameter (mm): Samples of 20 fruits from one bunch per palm were taken. Measurements were made with a caliper (CAL-6MP, Truper®, Mexico) along the polar and equatorial planes of the fruit.

Roundness Index (dimensionless): Using the polar and equatorial diameter data, this index was calculated using Mohsenin's (1986) formula, where Ra is the roundness or sphericity, Ap is the projected area of the fruit corresponding to the polar diameter in mm, and Ac is the projected area of the fruit corresponding to the equatorial diameter in mm.

$$Ra = \frac{Ap}{Ac}$$

Fruits with separated skin and dry: Samples of 20 fruits from a bunch per palm were taken and classified by comparing the total area of fruits with more than 10% of separated skin, known as "pouchy" fruits.

Experimental design: The design used was a completely randomized block design with five replications, with one palm as the experimental unit.

Statistical analysis: All data were tested to determine the effects of the treatments using analysis of variance (ANOVA) and multiple mean comparisons using Tukey's test ($P \leq 0.05$), with the assistance of Statistical Analysis Software (SAS Institute, 2002).

RESULTS AND DISCUSSION

Polar diameter and equatorial diameter of the fruit

In this study, the application of compost alone for date palm nutrition showed significant differences ($P \leq 0.05$) in polar diameter and equatorial diameter, with values of 25.99 mm and 39.44 mm, respectively. This is in comparison to treatments involving chemical fertilization or a combination of chemical and organic fertilizers (Table 1).

In general, it is observed that fertilizing with chemical sources and their combinations with organic fertilizers increases both the polar diameter and the equatorial diameter of the fruit, with the polar diameter always being greater. This results in the fruit maintaining an elliptical or elongated shape. These results regarding the polar and equatorial diameter of the fruit are consistent with general opinions and trends reported in various cultivars (Idris *et al.*, 2014; Mahawar *et al.*, 2017; Metwally *et al.*, 2019).

Roundess index

The relationship between the equatorial and polar diameter, expressed as the roundness index, was significant ($P \leq 0.05$) for T1-COMPOSTA, with a value of 1.76. In general, the fruits that had a larger equatorial diameter were from T1-COMPOSTA (25.99 mm), but with a smaller polar diameter (39.44 mm), resulting in a higher roundness index (1.76). However, in the other treatments, the fruits were elongated, which is a characteristic of the Mejhoul variety (Table 1), with the characteristic "elongated" pattern, meaning those fruits had a greater polar diameter than equatorial diameter (Montoya-Holguin *et al.*, 2014).

Although for tomatoes (*Solanum lycopersicum*) Becvort-Azcurra *et al.* (2012) mention that this characteristic shows a stronger correlation with genotype than with environmental and agronomic management factors. However, in the case of the present study, it was found that for date fruits, this characteristic is related to the number of fruits per bunch, the number of bunches per palm, and the total number of fruits per bunch per palm. This suggests a source-demand relationship where a greater number of fruits leads to more rounded growth.

Table 1. Equatorial diameter, polar diameter, and roundness index in date fruits with chemical, organic, and combined fertilization.

Treatment	Repetitions	Equatorial diameter of the fruit (mm)	Polar diameter of the fruit (mm)	Roundness index
T1-COMPOST	5	25.99 a	39.44 b	1.76 b
T2-FERQUIM	5	21.84 b	44.69 a	2.07 a
T3-CP50%+FQ50%	5	21.27 b	43.55 a	2.06 a
T4- CP100%+FQ100%	5	22.02 b	44.52 a	2.04 a
T5-FERCONV	5	20.95 b	43.67 a	2.09 a

*Means with the same letter within each column are statistically equal (Tukey, $p \leq 0.05$).

The above is corroborated by the research of Mahawar *et al.* (2017), who found that in dates c.v. Khadrawy and Medjool or Mejhoul, the roundness or sphericity of c.v. Khadrawy and Medjool were 0.60±0.03 and 0.71±0.024, respectively, determining that the fruits of date palm c.v. Medjool, being larger, achieved greater roundness, which resulted in higher sphericity values. However, according to Noutfia and Ropelewska (2022), this is due to the determination of the elliptical shape factor (W1) of 1.000 and the circular shape factor (W2) of 0.110, which confirmed the elliptical shape of the "Mejhoul" fruit.

Number of clusters, number of leaves, and number of leaves per cluster

No statistically significant differences were found for the number of clusters and the ratio of the number of leaves per cluster among the treatments evaluated. However, for the number of leaves, there were significant differences in the combinations of chemical fertilization with organic fertilizer, with values ranging from 72.8 to 74.8 leaves per palm. The highest values were observed in T2-FERQUIM (84.0 leaves per palm), T1-COMPOSTA (83.6 leaves per palm), and T5-FERCONV (74.8 leaves per palm), as shown in Table 2.

The leaves are very important for maintaining a balance between source and demand in date palms; according to Said *et al.* (2002), the distance from the fiber at the base of the leaf to the base of the leaflets is 28% of the entire leaf, where only the spines occupy around 4%, and the leaflets around 62%. Al-Sekhan (2009) suggests that maintaining a higher number of clusters may affect the source-demand balance in palms, ultimately negatively impacting fruit size and quality, as well as reducing the plant's growth and yield in subsequent years.

Panchal *et al.* (2021) found that increasing the number of leaves per cluster proportionally increases the final yield of the palm, with a leaf-to-cluster ratio of 4:1 compared to an 8:1 ratio, the latter resulting in the highest yield. Similarly, fruit characteristics also improved with a higher leaf-to-cluster ratio. Hegazi *et al.* (2008) found that retaining 9-11 leaves per cluster is adequate for the date cultivar Oreabi, while a ratio of 5 leaves per cluster resulted in lower yield and poorer fruit quality under the conditions of the Lower Delta region of Egypt.

In general, the production capacity and fruit quality of the Mejhoul date palm variety are proportional to the number of leaves and, consequently, to the leaf area. An excess of fruit relative to the leaf area of the palm reduces fruit size and quality and also promotes alternate production.

Table 2. Number of bunches, number of leaves, and the leaf-to-bunch ratio in the Mejhoul variety. Mexicali Valley, Baja California, Mexico. October 2023.

Treatment	Repetitions	Number of clusters	Number of leaves per palm	Ratio of the number of leaves per bunch
T1-COMPOST	5	15.8 a	83.6 a	5.34 a
T2-FERQUIM	5	16.2 a	84.0 a	5.26 a
T3-CP50%+FQ50%	5	17.6 a	72.8 b	4.26 a
T4- CP100%+FQ100%	5	16.1 a	71.6 b	4.55 a
T5-FERCONV	5	14.4 a	74.8 ab	5.23 a

*Means with the same letter within each column are statistically similar (Tukey, $p \leq 0.05$).

Yield

According to Table 3, there were no statistically significant differences in fruit weight and average fruit weight. However, the number of marketable fruits was higher with conventional fertilization (T5-FERCONV, 338.8 fruits), but these were smaller in size. It was observed that when analyzing other variables, the total weight of marketable fruits was statistically similar in T3-CP50%+FQ50% (1924.8 g), T4-CP100%+FQ100% (2563.2 g), and T5-FERCONV (4138.3 g).

This is consistent with the findings of Mahawar *et al*. (2017), who observed that in dates of the c.v. Khadrawy and Medjool, the weight of 100 fruits was 860.45±4.64 g for Khadrawy and 2199.6±13.30 g for Medjool. They noted an approximate 155% increase in the weight of 100 fruits for the Medjool variety compared to the Khadrawy variety, attributed to the proportional increase in fruit size in Medjool compared to Khadrawy. The responses to this combination were better than the independent application of each of them.

In this regard, Elamin *et al*. (2017) observed similar responses in the Khenazi cultivar with the application of N, P, K combined with organic matter concerning fruit pulp weight, pulp-to-seed ratio, fruit length, fruit width, fruit volume, ripeness, number of fruits per strand, number of fruits per cluster, and fruit yield. This is due to the fact that the application of macro and micronutrients increases date production and improves fruit quality (Al-Rawi, 1998; Yahia and Kader, 2011).

Fruits with Skin Separation and Dryness

Skin separation (appearance of swelling or peeling of the fruit's skin) in date palm fruits is a critical physiological disorder that significantly reduces the visual appeal and quality of the fruit. Skin separation (swelling) typically occurs when the date's skin is dry, hard, and brittle. According to Table 4, there were no statistically significant differences in the number, weight, and average weight of fruits with separated skin, nor in the number of dry fruits. Physiological disorders associated with skin separation potentially reduced the visual quality of the fruit and therefore caused economic losses for the producer by lowering its commercial value. The price range for fruit with 30-50% skin separation (swelling) is approximately 80% lower than that of fruit with intact and normal skin (without swelling).

Table 3. Weight of fruits, average fruit weight, number of commercial fruits, and total weight of commercial fruits with chemical, organic, and combined fertilization in Mejhoul date palm in the Mexicali Valley, Baja California, Mexico. October 2023.

Treatment	Fruit weight (g)	Average fruit weight (g)	Number of commercial fruits	Weight of commercial fruits (g)
T1-COMPOST	263.18 a	13.16 a	94.4 b	1270.4 b
T2-FERQUIM	263.14 a	13.15 a	49.75 b	712.1 b
T3-CP50%+FQ50%	292.60 a	14.63 a	163.60 b	1924.8 ab
T4- CP100%+FQ100%	319.10 a	15.96 a	160.80 b	2563.2 ab
T5-FERCONV	296.20 a	14.81 a	338.80 a	4138.3 a

* Means with the same letter within each column are statistically similar (Tukey, $p \leq 0.05$).

Table 4. Number, total weight, average weight of fruits with separated skin, and number of non-commercial dry fruits with chemical, organic, and combined fertilization in Mejhoul date palm in the Valley of Mexicali, Baja California, Mexico. October 2023.

Treatment	Number of fruits with separated skin	Weight of fruitswith separated skin (g)	Average weight of fruit with separated skin (g)	Number of dried fruits
T1-COMPOST	31.4 a	309.4 a	11.01 a	33.02 a
T2-FERQUIM	46.5 a	1133.5 a	25.94 a	20.75 a
T3-CP50%+FQ50%	58.4 a	676.1 a	12.95 a	33.41 a
T4- CP100%+FQ100%	54.4 a	739.1 a	13.79 a	25.81 a
T5-FERCONV	82.1 a	1125.8 a	13.25 a	37.81 a

* Means with the same letter within each column are statistically similar (Tukey, $p \leq 0.05$).

Dry and total fruits

No significant statistical differences were found for dry fruit weight, average weight of a fruit, and total fruit weight. However, there were significant differences ($p \leq 0.05$) for the total number of fruits, where T5-FERCONV (458.6 fruits) and T3-CP50%+FQ50% (255.4 fruits) were superior to the other treatments. Al-Hajjaj and Ayad (2018) found that foliar boron (1600 ppm) significantly affected yield, bunch weight, fruit set, physical fruit characteristics, and fruit quality. Kassem and Marzouk (2010) found that in twenty-six-year-old Zaghloul date palms on clay-loam soil, application of organic fertilizer, whether alone or combined with mineral fertilizers, increased palm yield and improved fruit color compared to mineral fertilization alone. On the other hand, Tagelsir *et al.* (2012) found that in Barakawi date palms, the combination of N and P resulted in the most pronounced increases in foliage growth, average fruit size, and total yield. Similarly, El-Mously *et al.* (2023) concluded that using compost from date palm residues could provide a viable ecological and sustainable alternative to conventional fertilizers. According to Kassem and Marzouk (2010), micronutrient contents were significantly higher in fruits with the application of organic fertilizer alone compared to organic fertilizer combined with NPK or mineral fertilization alone. Ghazzawy *et al.* (2023) found that in Sukary date palms with 12 clusters, there were negative effects on most of the attributes of date yield and quality; however, applying potassium sulfate at doses of 5 and 7.5 kg per palm allowed the palm to retain 8 to 10 fruit clusters per palm with significantly positive results.

Table 5. Individual weight, number of dry and total fruits with chemical, organic, and combined fertilization in Medjool date palms in the Mexicali Valley, Baja California, Mexico. October 2023.

Treatment	Weight of dried fruits (g)	Average weight of a dried fruit (g)	Number of total fruits	Total fruit weight (g)
T1-COMPOST	72.6 a	2.42 a	158.8 b	1625.4 a
T2-FERQUIM	56.8 a	2.71 a	117.1 b	1402.5 a
T3-CP50%+FQ50%	117.36 a	3.71 a	255.4 ab	2718.3 a
T4- CP100%+FQ100%	165.78 a	7.21 a	241.01 b	3468.1 a
T5-FERCONV	462.32 a	12.61 a	458.6 a	5166.5 a

*Means with the same letter within each column are statistically similar (Tukey, $p \leq 0.05$).

CONCLUSIONS

Chemical fertilization with 262N-138P_2O_5-540K_2O alone or in combination with compost at three or six tons per hectare increased the polar and equatorial diameters, promoting the oval growth of dates. Application of either compost alone or chemical fertilization results in a higher number of leaves per palm compared to their combination. Fruits with separated skin continue to be present regardless of the source of the fertilizers. The number of fruits increases with chemical fertilization, but the total yield of dates remains consistent across the evaluated treatments.

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