Standardization of pit size and organic filling mixture for tissue cultured cultivar Barhee of date palm in hot arid region of western Rajasthan

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Sharma BD, Meena RK, Bhargava R, et al. Standardization of pit size and organic filling mixture for tissue cultured cultivar Barhee of date palm in hot arid region of western Rajasthan. AGBIR.2024;40(1):767-771.

The study aims to provide comprehensive guidelines for optimizing pit size and the composition of filling mixtures, thereby fostering the growth, root development, and overall health of tissue-cultured Barhee date palm cultivars. The experiment was undertaken in 2019-2021 at the ICAR-Central Institute for Arid Horticulture research farm located in Bikaner, Rajasthan, India. Fully hardened tissue-cultured saplings of the Barhee cultivar of date palm were planted with a spacing of 5 × 5 m in the month of July. Different planting pit sizes (1.00 m × 1.00 m × 1.00 m, 0.75 m × 0.75 m × 0.75 m, and 0.50 m × 0.50 m × 0.50 m) and filling mixtures of field soil, clay, and FYM (1.0: 1.0:1.0, 2.0:0.5:0.5, 0.5:2.0:0.5, and 0.5:0.5:2.0) were used as treatment combinations for evaluating the tree growth potential of plants. The experiments were laid out in a factorial randomized block design with three replications. The obtained results indicated that tissue-cultured plants of the Barhee cultivar grown under a pit size of 1 m^3 with a filling mixture of 0.5 parts field soil, 0.5 parts clay, and 2.0 parts FYM performed better. Thus, the research confirms that improvement of the pit size and filling mixtures can have positive results on date palm establishment.

Key Words: *Date palm; FYM; Pits; Filling mixture*

INTRODUCTION

The date palm (*Phoenix dactylifera* L.) is a member of the Arecaceae (Palmae) family and stands as one of the earliest cultivated fruit plants in human history. According to archaeological findings, Iraq is recognized as the source of origin date palm [1]. In India, the cultivation of date palms is primarily concentrated in the western parts of Rajasthan the Rann of Kutchand the semi-arid regions of Gujarat and Punjab area known for its harsh, hot, and arid climatic conditions [2]. Rajasthan occupies almost 60% of the total of these regions. However, this region is known for its unforgiving environment characterized by harsh climatic conditions, arid soil with high salinity, minimal rainfall, extreme temperature fluctuations, and challenging soil fertility. The Rajasthan canal system represents the major irrigation scheme. With the construction of the Indira Gandhi Canal, Jaisalmer District has an area of 677,000 ha and Barmer District 3,100 ha of irrigation facilities. This facility has led to making this region a garden of date palms as it grows well under extreme temperatures and saline soil, although requiring a proper water supply. The government of Rajasthan has taken a visionary step to transform this arid terrain into a thriving date palm oasis, importing tissue-cultured planting material to realize this ambitious endeavor.

Tissue culture has revolutionized date palm cultivation by providing disease-free and genetically consistent plantlets, offering a promising solution to strengthen date palm production in this region. Among the various imported tissue-cultured date palms, the Barhee cultivar has emerged as a prominent choice. Nevertheless, the success of tissue-cultured Barhee date palms in Western Rajasthan hinges on several critical factors. At the forefront of these factors are the size of the planting pit and the composition of the filling mixture, both of which are indispensable for ensuring optimal growth, root development, and overall plant health.

The size of the planting pit directly influences root development, moisture retention, and nutrient accessibility, while the composition of the filling mixture significantly impacts soil structure, aeration, and moisture-holding capacity [3]. Therefore, addressing these factors is crucial to ensuring the long-term success of date palm plantations in this challenging environment.

However, one of the major factors affecting the growth of tissue culture plants is improper planting pits size, unreliable rainfall, low soil productivity and low fertilizer management [4]. Pitting size and filling mixtures has been one of the most important aspects of tree planting programs that are crucial for tree survival [5]. Different pitting size and filling mixture are important in improving root soil contact, improves soil aeration and water infiltration [6]. Therefore, this study aimed at the successful tree sapling establishment in arid and semi-arid regions of Rajasthan based on the planting pit sizes and filling mixtures.

This research will delve into the methodology employed to explore the optimal pit size and filling mixture for tissue-cultured Barhee date palms. It will provide a comprehensive analysis of the findings, encompassing the growth and nutrient status of the date palms. Our study aspires to offer practical recommendations for date palm growers in Western Rajasthan, enabling them to refine their practices and optimize the cultivation of Barhee date palms in this demanding environment. By standardizing pit size and filling mixture, we aim to contribute to the sustainability and enhanced yield of Barhee date palm cultivation in Western Rajasthan. In the challenging environment of the hot arid region of Western Rajasthan, this standardization will be pivotal in fostering improved growth, and overall plant health, ultimately leading to increased yields and sustainable agriculture practices.

MATERIALS AND METHODS

The experiment was conducted during 2019-2021 at ICAR-Central Institute for Arid Horticulture, Bikaner, Rajasthan, India. The experimental site was situated on 28° N latitude, 73°18° E longitude and at an altitude of 234.84 m above sea level. The soil of the experimental site was sandy, desertic, poor in fertility and water-holding capacity. The soil nutrient content was analyzed at three different depths (30-90 cm depth) using Auger-Auger for soil profiling system and samples were analyzed and recorded. The average rainfall of this region was about 230 mm/annum. May-June was the hottest month (mean maximum temperature 42.9°C and mean minimum temperature 29.6°C) and December-January was the coldest month of the year (mean maximum temperature 23.7°C and mean minimum temperature 8.9°C). Occasional frost was also experienced during January and February.

Experimental site

To see the effect of pit size and filling mixture, the following experiment was undertaken in July 2020 at the ICAR-Central Institute for Arid Horticulture research farm located in Bikaner, Rajasthan, India. This site was chosen due to its suitability for simulating the arid conditions prevalent in the region. The detailed soil properties are given in Table 1.

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Received: 05-Dec-2023, Manuscript No. AGBIR-23-122050; **Editor assigned:** 07-Dec-2023, Pre QC No. AGBIR-23-122050 (PQ); **Reviewed:** 25-Dec-2023, QC No. AGBIR-23-122050; **Revised:** 03-Jan-2024, Manuscript No. AGBIR-23-122050 (R); **Published:** 11-Jan-2024, DOI:10.35248/0970-1907.24.40.767-771

TABLE 1
Physico-chemical properties of experimental site

S. No.	Characteristics	Mean value	Reference
1	Particle size analysis		Bouyoucos 1962
	Sand (%)	89.5	
	Silt (%)	6.5	
	Clay (%)	4	
	Textural class	Loamy sand	
2	Bulk density (Mg/m^{-3})	1.6	Black 1965
3	Particle density (Mg/m^{-3})	2.65	Black 1965
2	Water holding capacity (%)	5.6	Black 1965
3	Infiltration rate mm hr^{-1})	24	Johnson 1963
4	pH (1:2)	8.5	Jackson 1979
5	Electrical conductivity (dSm^{-1}) (1:2)	1.1	Jackson 1979
6	Organic carbon (g kg^{-1})	0.09	Walkley and Black 1934
7	Available nitrogen (kg ha^{-1})	130	Subbiah and Asija 1956
8	Available phosphorus (kg ha^{-1})	15	Olsen 1954
9	Available potassium (kg ha^{-1})	164	Jackson 1973
10	DTPA extractable iron (mg kg^{-1})	29.6	Lindsay and Norvell 1978
11	DTPA extractable zinc (mg kg^{-1})	0.35	Lindsay and Norvell 1978
12	DTPA extractable copper (mg kg^{-1})	2.6	Lindsay and Norvell 1978
13	DTPA extractable manganese (mg kg^{-1})	13.54	Lindsay and Norvell 1978

Experiment details

The treatment consisted of three pit sizes and four filling mixtures (Table 2). The experiments were laid out in a factorial randomized block design with three replications. Fully hardened tissue-cultured saplings of the Barhee cultivar of date palm, each possessing 2-3 leaves, were planted with the spacing of 5 × 5 m.

TABLE 2
Experiment details

Pit sizes (P)	1.00 m × 1.00 m ×1.00 m	P1
	0.75 m × 0.75 m × 0.75 m	P2
	0.50 m × 0.50 m × 0.50 m	P3
Filling mixtures (M)	1.0 : 1.0 : 1.0 (Field soil: Clay: FYM)	M1
	2.0 : 0.5 : 0.5 (Field soil: Clay: FYM)	M2
	0.5 : 2.0 : 0.5 (Field soil: Clay: FYM)	M3
	0.5 : 0.5 : 2.0 (Field soil: Clay: FYM)	M4

Data collection

Vegetative parameters: Parameters like plant height, number of leaves and plant spread were recorded after 12 and 24 months after planting. The plant growth parameters like height, plant spread were recorded with the help of steel tape and the number of leaves by manual counting method.

Leaf nutrient status: For petiole analysis to be meaningful as a diagnostic tool, the collection of particular parts of leaves at the right stage for analysis. For date palm middle part of the physiologically mature leaves was taken for analysis of N, P, K, zinc and iron determination. One-gram oven-dried grounded sample was taken in a digestion tube to which 1 m mL of diacid mixture (nitric acid: perchloric acid=5:2) zinc and iron analysis and 10 mL were added and triacid mixture (nitric acid: perchloric acid: sulphuric acid=9: 4: 1) for P and K analysis were added. The contents were kept overnight for pre-digestion. The tubes were loaded into the digester and then heated the digestion chamber. The temperature was raised to 200 degrees centigrade for 2-3 hours till the solution turned colorless with cessation of emission of white dense fumes from the digesting samples. The tubes were kept for cooling down. The digested material was then filtered and volume made up to 100 mL with distilled water and stored for further estimation. The determination of total N and P content were carried out by using the modified micro Kjeldahl method and vanadomolybdate yellow color method, respectively. The zinc and iron were determined by using atomic absorption spectrophotometer. Petiole samples were prepared with a laboratory homogenizer using about 0.5 g of fresh material. 80% acetone was used as an extraction solvent. Analytical determination of total chlorophyll (a+b) was performed with a spectrophotometer at 662 nm and 644 nm, respectively, and then formulae as given by Witham et al., [7] for calculating the total chlorophyll.

Statistical analysis

Data obtained on various characters were analyzed statistically according to the analysis of variance techniques as suggested by Gomez and Gomez [8]. The Critical Difference (CD) was calculated to understand the significance or non-significance of difference between treatment means at 5% level of significance.

RESULTS AND DISCUSSION

Vegetative parameters

Results revealed that the plant vegetative growth was significantly affected by the different treatments. After 12 and 24 months after planting the highest plant height, number of leaves i.e., 118.00 cm and 169.15 cm, (7.38 and 11.40) were observed in plants under the pit size of 1m^3, respectively. Whereas, the highest plant height (120.45 and 160.20 cm), number of leaves (7.33 and 10.57) were recorded under filling mixture M4 (Table 3). The interaction effect of the studied pit sizes and filling mixture showed significant differences and found maximum plant height (130.85 and 185.60 cm), number of leaves (8 and 13.5) in P1M4 (Tables 3 and 4). Furthermore, data presented in Table 5 reveals that, plants growing under filling mixture M4 produced maximum plant spread (93.3 × 91.7 and 170.0 × 171.7) after 12 and 24 months after the planting, respectively. The maximum plant spread (95.0 × 96.0 and 178.8 × 181.2) was found in plants under the pit size P1 after 12 and 14 months after planting, respectively. The interaction effect of pit size and filling mixture was significant and found maximum plant spread under P1M4. The findings of this study align with previous research, as observed in the study conducted by Amanullah et al., [9]. Their research indicated that the performance of planted seedlings, specifically in terms of height, is positively affected by an increased application of manure. Vincent and Davies further elucidate that larger planting pit sizes have been associated with several advantages for seedlings. These advantages include a reduction in soil compaction within the rooting zone, enhanced water infiltration, and increased water availability during the critical early stages of establishment, all of which collectively influence tree growth positively. These results are consistent with earlier studies conducted by Ghafoor and Gopan [10], Abdel-Hameed and Ragab [11], Mohamed and Gobara [12], Mansour et al., [13], and Diab [14] documented favorable effects on vegetative growth and leaf nutrient composition when different date palm cultivars received annual applications of organic fertilizers.

Among the different filling mixtures, M4 provides more FYM to the plant. FYM provides a slow-release source of nutrients, including nitrogen, phosphorus, and potassium, which are crucial for plant growth [15,16]. Moreover, FYM enhances the soil's physical properties. It improves soil structure, increases water-holding capacity, and promotes better aeration. This improved soil environment is conducive to root development, which is a fundamental component of vegetative growth. A healthy and well-developed root system can efficiently absorb water and nutrients from the soil, providing the necessary support for above-ground vegetative growth.

TABLE 3

Effect of pit sizes and filling mixtures on the plant height (cm) of tissue cultured date palm cv. Barhee

Pit size	After 12 of planting					After 24 months of planting				
	M1	M2	M3	M4	Mean	M1	M2	M3	M4	Mean
P1	125.25	105.4	110.5	130.85	118	175.5	155	160.5	185.6	169.15
P2	110	105	115	120.5	112.63	150.5	135.4	140.5	155	145.35
P3	100.8	90	95	110	98.95	135.5	125.3	132.2	140	133.25
	112.01	100.13	106.83	120.45		153.83	138.57	144.4	160.2	

After 12 of planting		After 24 months of planting	
SEm ± Pit size	1.235	SEm ± Pit size	2.114
Filling mixture	2.546	Filling mixture	3.213
Pit size x Filling mixture	1.980	Pit size x Filling mixture	2.876
LSD (0.05) Pit size	2.964	LSD (0.05) Pit size	5.074
Filling mixture	6.110	Filling mixture	7.895
Pit size x Filling mixture	4.951	Pit size x Filling mixture	6.902

TABLE 4

Effect of pit sizes and filling mixtures on the number of leaves of tissue cultured date palm cv. Barhee

Pit size	After 12 of planting					After 24 months of planting				
	M1	M2	M3	M4	Mean	M1	M2	M3	M4	Mean
P1	7.5	7	7	8	7.38	12.6	10	9.5	13.5	11.4
P2	6.6	6.2	6.8	7	6.65	9.8	7.8	7.5	10.2	8.28
P3	6.5	6	6	7	6.38	8.2	7.8	7.5	8	7.88
	6.87	6.4	6.6	7.33		10.2	8.53	8.17	10.57	

After 12 of planting		After 24 months of planting	
SEm ± Pit size	0.465	SEm ± Pit size	0.362
Filling mixture	0.785	Filling mixture	0.386
Pit size x Filling mixture	0.643	Pit size x Filling mixture	0.354
LSD (0.05) Pit size	NS	LSD (0.05) Pit size	0.969
Filling mixture	NS	Filling mixture	0.947
Pit size x Filling mixture	NS	Pit size x Filling mixture	0.885

TABLE 5

Effect of pit sizes and filling mixtures on the plant spread (cm) of tissue cultured date palm cv. Barhee

Filling mixture	Pit size							
	After 12 month				After 24 months			
	P1	P2	P3	Mean	P1	P2	P3	Mean
M1	95 × 100	90 × 90	80 × 82	88.3× 90.7	190 × 185	155 × 150	140 × 145	160.7 × 160.0
M2	90 × 94	85 × 85	80 × 78	85.0 × 85.7	160 × 165	135 × 140	135 × 130	143.3 × 145.0
M3	95 × 90	85 × 82	75 × 75	85.0 × 83.3	165 × 170	135 × 125	135 × 130	145.0 × 141.7
M4	100 × 100	95 × 90	85 × 85	93.3 × 91.7	200 × 205	165 × 160	145 × 150	170.0 × 171.7
Mean	95.0 × 96.0	88.8 × 86.0	85 × 85		178.8 × 181.2	147.5 × 143.8	138.8× 138.8	

After 12 month		After 24 months	
SEm ± Pit size	0.465	SEm ± Pit size	0.362
Filling mixture	0.785	Filling mixture	0.386
Pit size x Filling mixture	0.643	Pit size x Filling mixture	0.354
LSD (0.05) Pit size	NS	LSD (0.05) Pit size	0.969
Filling mixture	NS	Filling mixture	0.947
Pit size x Filling mixture	NS	Pit size x Filling mixture	0.885

Leaf nutrient content

The maximum values of the leaf nitrogen (1.69 and 1.70%) and phosphorous content (0.28 and 0.28%) of the leaf were obtained on the palm that growing under P1 and filling mixture M4, respectively. The interaction effect between both factors was found significant and maximum leaf nitrogen and phosphorous content was found maximum under P1M4 i.e., 1.80 and 0.30% respectively (Table 6). Moreover, the highest potassium content was exhibited by plants growing under the pit size P1 (2.08%) and filling mixture M1 and M2 (2.02%) compared to the other treatments. Both the factors showed significant interaction and the highest potassium content was found under P1M4 (2.10%) and P1M1 (2.10%). However, the zinc content was maximum (77.16 and 77.50 ppm) in plants growing under the pit size P1 and filling mixture M4, respectively. The interaction between both factors was found significant and the maximum zinc content was under P1M4 (80.00 ppm) (Table 7).

Data in Table 8 show that the leaf chlorophyll content was significantly affected by both the factor and maximum chlorophyll content (2.23 and 2.26 mg g^{-1} FW) exhibited by the plants growing under the pit size P1 and filling mix M4, respectively. The interaction effect of both the parameters was found significant and maximum chlorophyll content (2.50 mg g^{-1} FW) was found under P1M4.The highest leaf iron content (170.25 and 168.08 ppm) was recorded with pit size P1 and filling mixture M4, respectively, the interaction of pit size with the filling mixture was significant for leaf iron content, and the highest leaf iron content was recorded under P1M4 (179.00 ppm) followed by P1M1 (172.00 ppm). The results are in agreement with the findings of Mauki and Kilonzo [3] who proposes larger pit size to be highly considered especially in dryland regions for the survival of various plant species.

TABLE 6

Effect of pit sizes and filling mixtures on the nitrogen and phosphorus in leaves of tissue cultured date palm cv. Banshee

Pit size	Nitrogen (%)					Phosphorus (%)				
	M1	M2	M3	M4	Mean	M1	M2	M3	M4	Mean
P1	1.75	1.6	1.6	1.8	1.69	0.29	0.27	0.27	0.3	0.28
P2	1.68	1.6	1.61	1.68	1.64	0.27	0.26	0.25	0.28	0.27
P3	1.6	1.58	1.6	1.62	1.6	0.26	0.26	0.26	0.27	0.26
	1.68	1.6	1.6	1.7		0.27	0.26	0.26	0.28	

Nitrogen (%)			Phosphorus (%)		
SEm ±	Pit size	0.021	SEm ±	Pit size	0.036
	Filling mixture	0.031		Filling mixture	0.045
	Pit size x Filling mixture	0.026		Pit size x Filling mixture	0.040
LSD (0.05)	Pit size	0.051	LSD (0.05)	Pit size	0.090
	Filling mixture	0.078		Filling mixture	0.110
	Pit size x Filling mixture	0.064		Pit size x Filling mixture	0.885

TABLE 7

Effect of pit sizes and filling mixtures on the potassium, zinc, and status in leaves of tissue cultured date palm cv. Barhee

Pit size	Potassium (%)					Zinc (ppm)				
	M1	M2	M3	M4	Mean	M1	M2	M3	M4	Mean
P1	2.1	2.05	2.05	2.1	2.08	78.25	75.4	75	80	77.16
P2	1.98	1.98	1.95	1.98	1.97	76.65	75	75.35	76.5	75.87
P3	1.98	1.98	1.97	1.98	1.98	75	75	75.25	76	75.31
	2.02	2	1.99	2.02		76.63	75.13	75.2	77.5	

Potassium (%)			Zinc (ppm)		
SEm ±	Pit size	0.026	SEm ±	Pit size	0.362
	Filling mixture	0.037		Filling mixture	0.386
	Pit size x Filling mixture	0.031		Pit size x Filling mixture	0.354
LSD (0.05)	Pit size	0.071	LSD (0.05)	Pit size	0.969
	Filling mixture	0.088		Filling mixture	0.947
	Pit size x Filling mixture	0.074		Pit size x Filling mixture	0.885

TABLE 8

Effect of pit sizes and filling mixtures on the iron and total chlorophyll content in leaves of tissue cultured date palm cv. Barhee

Pit size	Total chlorophyll (mg g^{-1} FW)					Iron (ppm)				
	M1	M2	M3	M4	Mean	M1	M2	M3	M4	Mean
P1	2.3	2.05	2.05	2.5	2.23	172	166	167	179	170.25
P2	2.15	2	1.95	2.25	2.09	166.5	165	165	167.25	165.94
P3	1.98	1.98	1.95	2.02	1.98	155	155.25	155.7	158	155.99
	2.14	2.01	1.98	2.26		164.5	162.08	162.56	168.08	

Total chlorophyll (mg g^{-1} FW)			Iron (ppm)		
SEm ±	Pit size	0.046	SEm ±	Pit size	0.682
	Filling mixture	0.067		Filling mixture	0.836
	Pit size x Filling mixture	0.063		Pit size x Filling mixture	0.644
LSD (0.05)	Pit size	0.115	LSD (0.05)	Pit size	1.637
	Filling mixture	0.164		Filling mixture	2.090
	Pit size x Filling mixture	0.154		Pit size x Filling mixture	1.610

A larger pit size offers a more root growth has the opportunity to access a broader spectrum of nutrients in the soil. The extensive root network, nurtured by a larger pit, increases the plant's capacity to absorb nutrients, potentially leading to higher leaf nutrient content. This is particularly advantageous when aiming for a rich nutrient profile in plant leaves. Furthermore, larger pits can store more moisture, ensuring that the plant has consistent access to water. Adequate moisture availability is pivotal for efficient nutrient uptake through the roots. FYM is a reservoir of vital nutrients, such as nitrogen, phosphorus, potassium, and micronutrients. When integrated into the soil, it significantly enriches the nutrient pool available to plants [17]. As plants draw these essential elements through their roots, the heightened nutrient availability can result in elevated nutrient content within the leaves. The influence of FYM extends to improved nutrient retention and enhanced soil structure. By promoting favorable conditions for nutrient storage and release through enhanced soil structure and microbial activity, FYM facilitates efficient nutrient uptake by plant roots [18]. This, in turn, results in greater nutrient content in plant leaves. The influence of FYM also extends to the enhancement of photosynthesis. Improved nutrient availability, soil structure, and moisture retention collectively bolster the photosynthetic capacity of plants [19]. This heightened photosynthetic activity leads to increased nutrient assimilation and storage in the leaves, resulting in higher leaf nutrient content [20-28].

CONCLUSION

In this arid region, date palm cultivation plays a pivotal role in sustaining livelihoods and enhancing food security. By determining the ideal pit size and filling mixture, this research can vastly improve agricultural productivity, ensuring that farmers can make the most efficient use of their limited resources such as water and soil. The results we obtained suggest that the barhee cultivar tissue-cultured plants showed superior growth when cultivated in pits measuring 1 m^3 and filled with a mixture comprising 0.5 parts of field soil, 0.5 parts of clay, and 2.0 parts of FYM. This study supports the idea that optimizing pit size and the composition of the filling mixture can have a beneficial impact on the establishment of date palm trees.

ACKNOWLEDGMENTS

We are grateful to the Govt. of Rajasthan for providing the tissue culture planting material and ICAR-CIAH for the necessary facilities to conduct research.

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