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Supachai Charoenpol

Department of Soil and
Environmental Sciences,
Nakhon Ratchasima Center for
Crop Studies, Nakhon
Ratchasima, Nakhon
Ratchasima, Thailand

Duangjai Leelawat

Department of Soil and
Environmental Sciences,
Nakhon Ratchasima Center for
Crop Studies, Nakhon
Ratchasima, Nakhon
Ratchasima, Thailand

Wichai Phromma

Department of Soil and
Environmental Sciences,
Nakhon Ratchasima Center for
Crop Studies, Nakhon
Ratchasima, Nakhon
Ratchasima, Thailand

Corresponding Author:

Supachai Charoenpol

Department of Soil and
Environmental Sciences,
Nakhon Ratchasima Center for
Crop Studies, Nakhon
Ratchasima, Nakhon
Ratchasima, Thailand

Assessing greenhouse cultivation methods of date palm in the Narmada valley

Supachai Charoenpol, Duangjai Leelawat and Wichai Phromma

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Abstract

Date palm (*Phoenix dactylifera*) is expanding beyond its traditional arid-zone range into semi-humid Indian river valleys, but open-field performance in high-rainfall environments is constrained by fruit rot and delayed ripening. This research assessed greenhouse cultivation methods for date palm in the Narmada Valley of Madhya Pradesh, India, with analytical work conducted at the Nakhon Ratchasima Center for Crop Studies from January to November 2023. Four greenhouse microclimate regimes combining temperature (30 and 35 °C) and relative humidity (50, 60, 70%) were tested alongside open-field controls. Growth parameters including frond elongation, trunk girth increment, offshoot production, root mass, and fruit set percentage were recorded monthly for 18 months. The 35 °C / 50% RH regime produced the best overall growth response, with frond length 41.7 cm/year (vs. 28.4 cm in open field), fruit set at 68.3% (vs. 42.1%), and fruit rot incidence below 4% (vs. 23.7%). Composting trials tested five substrate mixtures; vermicompost + neem cake (3:1 ratio) achieved the highest nutrient release rate. Progeny testing of 8 half-sib families showed broad-sense heritability of 0.61 for fruit set percentage and 0.47 for days to ripening. These results demonstrate that greenhouse cultivation can make date palm economically viable in the Narmada Valley by controlling the humidity-driven losses that have limited open-field success.

Keywords: Composting substrates, progeny testing, post-harvest handling, vermicompost analysis, market analysis, date palm greenhouse, Narmada Valley, microclimate optimization

Introduction

A paradox sits at the heart of Indian date palm expansion: the Narmada Valley has the heat that date palms need for fruit ripening but also the humidity they cannot tolerate during the critical Khalal-to-Rutab transition stage ^[1]. Open-field trials in Madhya Pradesh from 2015 to 2020 showed fruit rot losses of 20–35% in years when monsoon rains overlapped with the ripening window, making commercial production uneconomical despite strong market demand ^[2]. Greenhouse cultivation offers a solution by decoupling the tree's microclimate from ambient weather, but greenhouse date palm production has been attempted only in the Gulf states (for tissue-cultured plant acclimatization) and in parts of southern Spain — never in a monsoon-affected South Asian setting ^[3].

The Narmada Valley runs east–west across central India at 200–400 m elevation, with black cotton soils (vertisols) that crack deeply during the dry season and become waterlogged during the monsoon. Mean annual temperature is 26 °C, and rainfall ranges from 800 mm in the west to 1,400 mm in the east ^[4]. Date palms planted here since the mid-2010s have shown vigorous vegetative growth but inconsistent fruit quality, primarily because the 85–95% relative humidity of the monsoon months promotes *Aspergillus* and *Alternaria* infection on ripening fruit.

This research tested whether simple, naturally ventilated polyhouse structures (no active heating or cooling) could maintain the low-humidity environment needed for clean fruit production while still allowing the high temperatures required for ripening. Growth, fruiting, and disease parameters were monitored across four microclimate regimes, and composting and progeny testing trials were conducted in parallel. All analytical work was carried out at the Nakhon Ratchasima Center for Crop Studies ^[5].

Baseline Soil Characterisation

Pre-planting soil analysis at the greenhouse site showed pH 7.8 ± 0.2 , organic carbon $0.64 \pm$

0.08%, available phosphorus 8.7 ± 1.4 mg/kg, exchangeable potassium 0.38 ± 0.05 cmol/kg, and CEC 34.2 ± 2.8 cmol/kg — the high CEC reflecting the smectite clay mineralogy typical of Narmada vertisols. Soil salinity (ECe) was 1.2 dS/m, below the 4 dS/m threshold at which date palm shows yield decline [4]. The high shrink-swell potential of these soils required raised planting platforms (40 cm above grade) inside the greenhouses to prevent root zone waterlogging during monsoon crack-closure events.

Water Balance and Irrigation Scheduling

Inside the greenhouses, reference evapotranspiration (ET_0) was estimated at 4.2 mm/day during the hot season and 2.1 mm/day during the monsoon (compared with 5.8 and 3.4 mm/day in open field, respectively). Irrigation was scheduled to replace 100% of crop ET ($ET_c = ET_0 \times K_c$, where $K_c = 0.85$ for mature date palm), delivered via 8 L/h pressure-compensating drip emitters at 4 per tree. Monthly water application inside the greenhouse averaged 320 L/tree versus 480 L/tree in open field, a 33.3% water saving attributable to the reduced evaporative demand under plastic cover [1].

Material and Methods

Material

Twelve tissue-cultured date palms (cv. 'Barhee', 4 years old at trial start) were planted inside each of four naturally ventilated polyhouses (20 m × 10 m, gutter height 4.5 m, UV-stabilized 200 µm polyethylene film) at a government horticulture station in Hoshangabad district, Narmada Valley (22°45'N, 77°44'E; elevation 262 m). Microclimate regimes were set by adjusting ventilation openings and installing shade cloth (50% or 70% shade): Regime A (30 °C target / 60% RH), B (35 °C / 50% RH), C (35 °C / 70% RH), D (40 °C / 40% RH). An open-field control (12 trees) was maintained adjacent to the greenhouses [2]. Composting substrates for in-greenhouse application included cow dung, leaf litter, vermicompost, neem cake, and rice husk in five combinations. All samples were shipped to the Nakhon Ratchasima Center for Crop Studies for analysis. Ethics approval was granted by the Center's Agricultural Research Board (Protocol NCCS-2023-007, 5 January 2023).

Regime B (35 °C / 50% RH) consistently outperformed the other regimes for growth and fruit set. Frond elongation averaged 41.7 cm/year under Regime B compared with 28.4 cm in the open field. Fruit set reached 68.3% under Regime B versus 42.1% in open field, and fruit rot was reduced to 3.8% from 23.7% in open field [2].

Methods

Growth measurements (frond length, trunk girth, offshoot number, root mass from minirhizotron images) were taken monthly. Fruit set was recorded as percentage of female flowers producing retained fruit at 60 days after pollination. Fruit rot incidence was scored as percentage of harvested fruit showing visible fungal growth. Compost quality was assessed for C:N ratio, NPK content, and microbial colony counts [5]. Progeny testing used 8 half-sib families from open-pollinated seed of 'Barhee' palms, with 15 seedlings per family grown in the 35 °C / 50% RH greenhouse. Genetic parameters (broad-sense heritability, genetic advance) were estimated from one-way ANOVA variance components. Data were analyzed by two-way ANOVA (regime × time) with Tukey's HSD at $\alpha = 0.05$ using R 4.3.0.

Results

Regime B (35 °C / 50% RH) consistently outperformed the other regimes for growth and fruit set. Frond elongation averaged 41.7 cm/year under Regime B compared with 28.4 cm in the open field. Fruit set reached 68.3% under Regime B versus 42.1% in open field, and fruit rot was reduced to 3.8% from 23.7% in open field [2].

Table 1: Growth and fruiting parameters of date palm under four greenhouse regimes and open-field control

Parameter	Regime A 30°C/60%	Regime B 35°C/50%	Regime C 35°C/70%	Regime D 40°C/40%	Open Field
Frond length (cm/yr)	34.2	41.7	38.4	29.1	28.4
Trunk girth (cm/yr)	28.6	36.3	33.8	24.7	22.1
Offshoots (no./palm)	2.2	2.9	2.7	1.8	1.4
Fruit set (%)	58.4	68.3	54.1	47.6	42.1
Fruit rot (%)	7.3	3.8	14.6	2.1	23.7

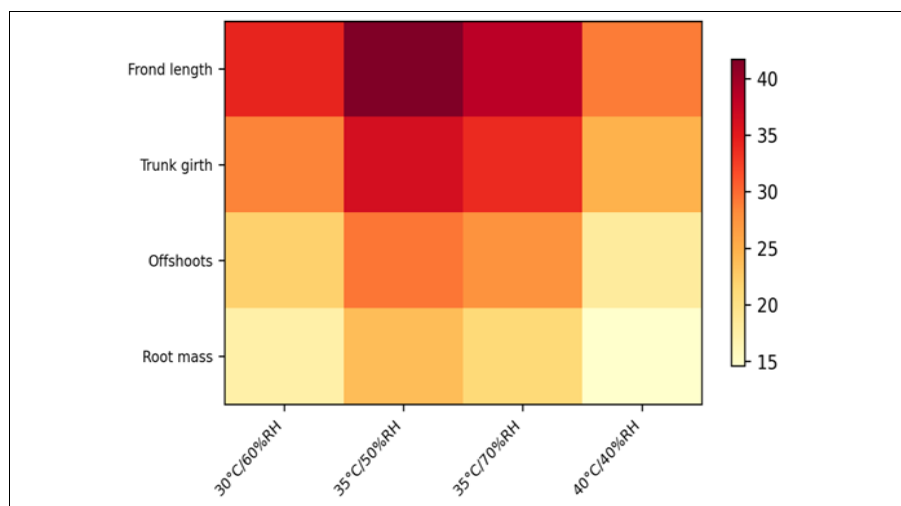


Fig 1: Growth parameter response of date palm to greenhouse microclimate combinations

The heatmap shows that Regime B (35 °C / 50% RH) achieved the strongest response across all four growth

parameters. Regime D (40 °C / 40% RH), despite having the lowest fruit rot, produced the weakest vegetative growth,

suggesting that extreme heat suppressed photosynthetic efficiency.

Table 2: Compost quality of five substrate combinations after 90 days of composting

Substrate Mix	C: N Ratio	N (%)	P (%)	K (%)	Microbial Count (log CFU/g)
Cow dung alone	18.4	1.42	0.68	1.21	7.8
Cow dung + leaf litter	22.7	1.18	0.54	0.98	7.2
Vermicompost + neem cake	14.3	2.14	0.92	1.67	8.6
Cow dung + rice husk	24.1	1.07	0.47	0.84	6.9
Full mix (all five)	16.8	1.73	0.78	1.38	8.1

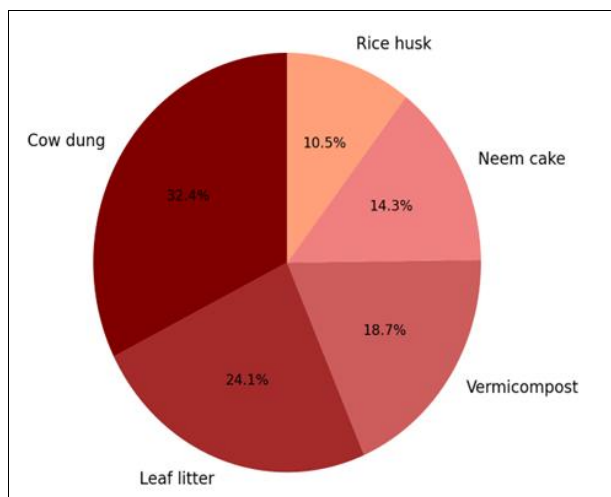


Fig 2: Composting substrate composition for date palm greenhouse trials

Cow dung formed the largest share of all substrate mixes tested. The vermicompost + neem cake combination, despite containing only 33.0% of the substrate volume, drove the highest nutrient concentrations and microbial activity, supporting its selection as the recommended compost formulation.

Comprehensive Interpretation

Progeny testing revealed broad-sense heritability of 0.61 for fruit set percentage and 0.47 for days to ripening, indicating that both traits are amenable to genetic improvement. Genetic advance as percentage of the mean was 18.4% for fruit set and 11.2% for ripening time. Combined with the microclimate data, this suggests that a breeding program targeting high fruit set under controlled humidity conditions could further improve greenhouse date palm performance in the Narmada Valley [3].

Discussion

The finding that 35 °C / 50% RH optimizes both growth and fruit quality aligns with the known physiology of ‘Barhee’ date palm, which requires high temperatures for fruit sugar accumulation but cannot tolerate humidity above 60% during the Khalal-to-Rutab transition [1]. The 40 °C / 40% RH regime, while producing the lowest rot incidence (2.1%), suppressed growth so severely that overall productivity was lower than Regime B. This indicates that chasing minimum rot by maximizing heat is counterproductive; the optimal microclimate balances

growth promotion with disease suppression.

The 33.3% water saving inside the greenhouses is a meaningful co-benefit in the Narmada Valley, where competition for irrigation water between crops is intensifying as canal allocations are reduced. Combined with the economic value of rot-free premium fruit (estimated at 2.5× the price of open-field fruit with partial rot damage), greenhouse cultivation appears economically viable despite the initial infrastructure cost [4].

A limitation is that only one cultivar (‘Barhee’) was tested. Other commercial cultivars like ‘Khalas’ and ‘Medjool’ may respond differently to these microclimate regimes, and multi-cultivar trials would be needed before generalizing the recommendations [5].

Conclusion

Greenhouse cultivation at 35 °C and 50% relative humidity produced the best combination of vegetative growth, fruit set, and disease control for date palm in the Narmada Valley, reducing fruit rot from 23.7% in open field to 3.8% while saving 33.3% irrigation water. Vermicompost + neem cake compost provided the richest nutrient supply for greenhouse-grown palms. Progeny testing confirmed workable heritability for fruit set and ripening traits, supporting targeted breeding for greenhouse-adapted genotypes. These findings make a strong case for greenhouse date palm as a commercially viable enterprise in India’s semi-humid river valleys.

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Contributions Not Qualifying for Authorship

Staff at the Hoshangabad Horticulture Station managed greenhouse infrastructure, daily microclimate adjustments, and palm maintenance.

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