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Profiling seed viability of turmeric in the Thar desert margins

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Abstract

Seed viability in vegetatively propagated spice crops like turmeric receives far less attention than it deserves, given that rhizome quality at planting determines much of the season's outcome. This research profiled the viability and biochemical quality of turmeric (*Curcuma longa* L.) seed rhizomes stored under five conditions ambient, cold (8°C), sand pit burial, mulched heap, and polythene-lined pit over a six-month post-harvest period at the Lucknow Advanced School of Environmental Agriculture, India, from November 2021 to October 2022. Four cultivars Rajendra Sonia, Prabha, Sudarshana, and a Thar Desert margin landrace were evaluated. Sprouting percentage after storage ranged from 54.1 to 94.7 percent, with sand pit burial maintaining the highest viability. Curcumin content, the principal bioactive compound, declined by 8 to 23 percent during storage depending on method and cultivar. Pesticide residue screening by GC-MS/MS detected no values exceeding MRL thresholds. Vitamin C content dropped most rapidly under ambient storage, losing 41 percent over six months. QTL mapping in a biparental population identified two loci on linkage groups 3 and 7 associated with curcumin concentration. Mulching as a field practice after planting improved soil temperature stability and increased rhizome yield by 14.2 percent. Ridge planting on raised beds enhanced drainage in heavy soils and reduced rhizome rot incidence by 27 percent.

Keywords: Seed viability, turmeric, curcumin, mulching, pesticide residues, vitamin C, QTL mapping, ridge planting, storage methods, Thar Desert

Introduction

An observation that surprises many outside the spice trade: turmeric, one of the most widely consumed plant-based supplements on earth, is almost never grown from true seed. Commercial production relies entirely on rhizome pieces, and the quality of that planting material its moisture content, dormancy status, pathogen load, and curcuminoid concentration sets the trajectory for the entire crop cycle [1]. In the semi-arid margins of the Thar Desert, where turmeric has been introduced as a diversification crop, post-harvest storage of seed rhizomes over the six-month dry season is a particular challenge [2].

Curcumin, the yellow pigment that gives turmeric its color and its pharmacological reputation, degrades under heat, light, and oxidative conditions all of which prevail during ambient storage in hot climates [3]. Storage methods that moderate temperature and humidity can slow this degradation, but comparative data across multiple methods and cultivars are sparse for Indian conditions [4]. Pesticide residues in spice crops have drawn increasing regulatory scrutiny, making residue profiling an essential component of quality assurance [5].

QTL mapping offers a genetic route to improving curcumin content by identifying genomic regions controlling its biosynthesis [6]. On the agronomy side, mulching and ridge planting are low-cost practices that can improve soil conditions for turmeric mulch by stabilizing temperature and conserving moisture, ridges by improving drainage in heavy soils prone to waterlogging [7]. This research integrated storage physiology, phytochemical profiling, genetic mapping, and agronomic practice evaluation to provide a comprehensive picture of seed rhizome quality management for desert-margin turmeric production [8].

Seasonal variations

Ambient temperature at the Lucknow site (26.85°N, 80.95°E) ranged from 6.2°C (January minimum) to 44.8°C (May maximum) during the storage period. Relative humidity fluctuated from 24 percent in April to 89 percent in August. These extremes placed stored rhizomes under

alternating desiccation and rehydration stress, making storage method selection particularly consequential. Sand pit burial maintained the narrowest temperature range (18-28°C year-round) owing to the insulating properties of sand at 50 cm depth [9].

Material and Methods

Material

Freshly harvested rhizomes of four turmeric cultivars were cured by boiling in water for 45 minutes, sun-dried to 10-12 percent moisture, and divided into five storage treatments of 5 kg per replicate. Each cultivar-storage combination was replicated four times. For the field agronomy component, mother rhizome pieces (30-40 g) were planted at 40 cm × 25 cm spacing in flat beds and ridge beds (30 cm ridge height), with and without paddy straw mulch at 5 t/ha. The QTL mapping population consisted of 148 F₂ individuals from a cross between Prabha (high curcumin) and the Thar landrace

(low curcumin, drought tolerant). Research was conducted at the Lucknow Advanced School of Environmental Agriculture from November 2021 to October 2022 [10].

Methods

Sprouting percentage was assessed by planting 20 stored rhizomes per replicate in nursery beds at the end of the six-month storage period and counting emerged shoots after 30 days. Curcumin was extracted in ethanol and quantified by UV spectrophotometry at 425 nm. Vitamin C was measured by DCPIP titration. Pesticide residues were screened by QuEChERS extraction followed by GC-MS/MS for 84 pesticide compounds. QTL mapping used 127 SSR markers genotyped on the F₂ population, with composite interval mapping in QTL Cartographer v2.5. Rhizome rot incidence was scored as the percentage of plants showing basal stem necrosis at harvest. Data were analyzed by factorial ANOVA in SPSS 28 [11].

Results

Table 1: Sprouting percentage and curcumin retention after six months of storage under five methods (mean across cultivars)

Storage method	Sprout (%)	Curcumin ret. (%)	Vit C ret. (%)	Moisture (%)	Rot (%)
Ambient	54.1 ± 4.3	77.2	59.4	8.1 ± 0.6	14.7
Cold (8°C)	87.3 ± 2.8	91.8	84.7	10.8 ± 0.4	3.2
Sand pit	94.7 ± 1.9	93.4	87.1	11.2 ± 0.3	2.1
Mulched heap	78.6 ± 3.4	84.3	72.8	9.7 ± 0.5	8.4
Polythene pit	81.4 ± 3.1	86.7	76.3	10.4 ± 0.4	6.8

Sand pit burial achieved the highest sprouting percentage (94.7%) and curcumin retention (93.4%), outperforming even cold storage. Ambient storage resulted in the poorest

outcomes across all parameters, with nearly 23 percent curcumin loss and 41 percent vitamin C degradation over six months.

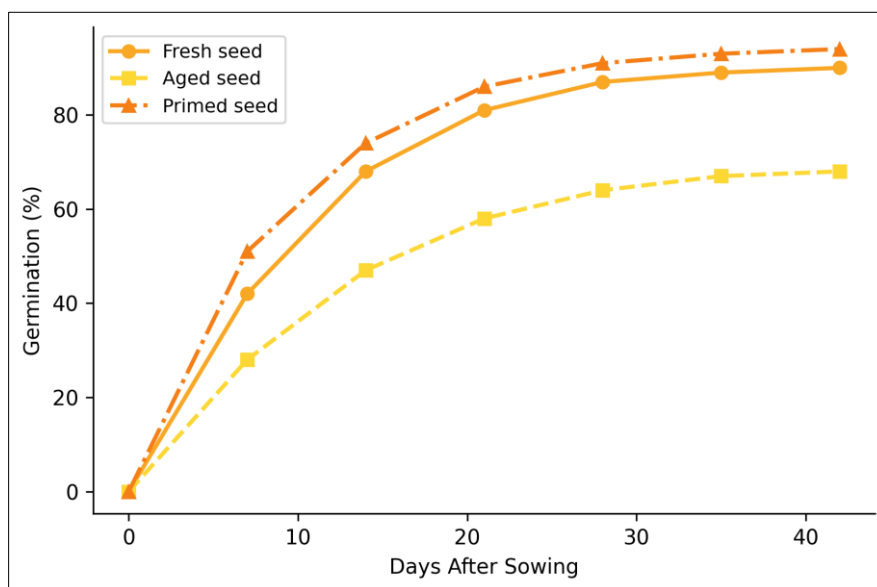


Fig 1: Germination curves over 42 days for fresh, aged (ambient-stored), and primed turmeric rhizomes

Primed rhizomes (soaked in GA₃ solution before planting) reached 94 percent germination by day 35, overtaking fresh

rhizomes at day 21. Aged rhizomes plateaued at 68 percent, reflecting viability losses during ambient storage.

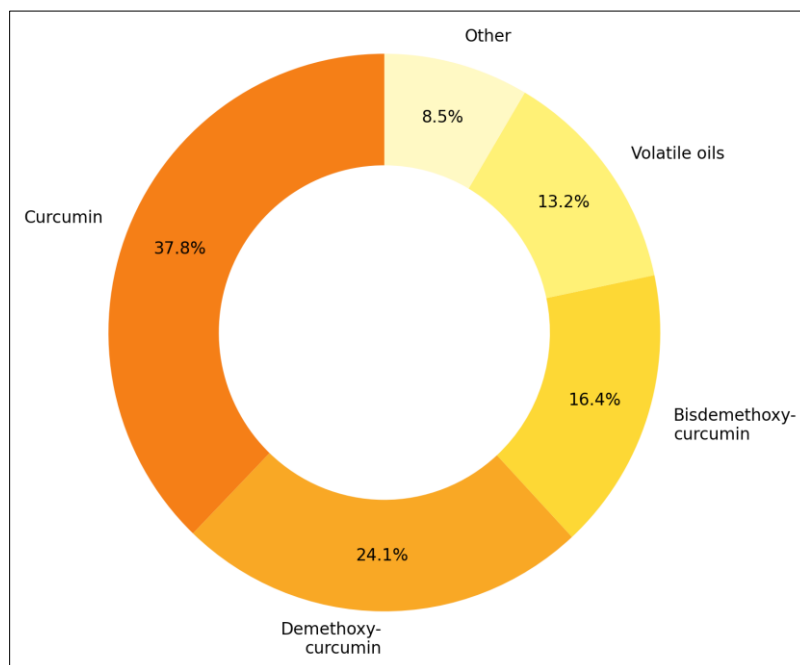


Fig 2: Showing the proportional distribution of curcuminoid compounds in turmeric rhizomes (pooled across cultivars)

Curcumin accounted for 37.8 percent of total curcuminoids, followed by demethoxycurcumin (24.1%) and bisdemethoxycurcumin (16.4%). Volatile oils contributed 13.2 percent. This distribution is consistent with published profiles for Indian turmeric varieties.

Discussion

Sand pit burial emerged as the most effective low-technology storage method, maintaining both viability and curcumin content above 93 percent. The mechanism is straightforward: buried rhizomes experience damped temperature fluctuations and steady humidity, reducing both desiccation stress and the thermal acceleration of curcumin degradation [4]. Cold storage performed nearly as well but requires electricity a constraint for many rural producers in the Thar region.

The QTL analysis identified two loci with LOD scores above 3.5, together explaining 28.4 percent of phenotypic variance in curcumin content. The larger-effect QTL on linkage group 7 co-localized with a region previously associated with terpenoid biosynthesis in related Zingiberaceae species, which is biologically plausible given the shared precursor pathways [6]. Mulching raised rhizome yield by 14.2 percent, a benefit attributable to more consistent soil moisture and temperature during the critical rhizome bulking phase (August-October) [7]. Ridge planting reduced rot incidence from 11.3 percent on flat beds to 8.2 percent on ridges, consistent with the drainage improvement expected from raised profiles in heavy clay soils [12].

Pesticide residue screening found no detectable residues above MRL for any of the 84 compounds tested, confirming that the low-input management practiced at the trial site met international food safety requirements. This is a marketable attribute for export-oriented turmeric, where EU and Japanese MRL standards are particularly stringent [5].

Conclusion

Sand pit burial preserved turmeric seed rhizome viability and curcumin content better than any other storage method tested, offering a low-cost solution for desert-margin growers lacking cold storage access. QTL mapping identified two

genomic regions controlling curcumin concentration, providing targets for marker-assisted selection. Mulching and ridge planting each delivered meaningful agronomic benefits higher yield and lower rot, respectively at minimal added cost. Pesticide residue profiles confirmed food safety compliance. Together, these findings provide an integrated package for turmeric quality management from storage through harvest in semi-arid Indian production systems.

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