



E-ISSN: 2663-1067
P-ISSN: 2663-1075
NAAS Rating: 4.74
www.hortijournal.com
IJHFS 2025; 7(3): 168-171
Received: 18-01-2025
Accepted: 24-02-2025

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Cataloguing landrace conservation of drumstick in the Brahmaputra basin

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DOI: <https://www.doi.org/10.33545/26631067.2025.v7.i3c.597>

Abstract

Drumstick (*Moringa oleifera*) landraces in the Brahmaputra Basin harbour genetic diversity that remains largely uncatalogued, placing valuable germplasm at risk of irreversible loss. This research catalogued 57 drumstick landraces from five agro-climatic zones and assessed their morphological, nutritional, and genetic diversity at the Vizag Advanced School of Environmental Agriculture between April 2022 and March 2024. Pod length ranged from 22.4 to 68.7 cm, pod yield from 148 to 412 pods per tree per year, and leaf protein from 24.3 to 33.8 g/100g DW. Soil health indicators (organic carbon, available N, P, K) varied significantly across collection sites and correlated with pod yield ($r = 0.64$ for organic carbon). Mulching with dried banana leaves improved soil moisture retention by 24.7% and increased pod yield by 18.3% in a parallel field trial. Pesticide residue screening by LC-MS/MS detected residues in only 8.8% of samples, all below EU MRLs. Vitamin C content ranged from 112 to 247 mg/100g across landraces. QTL mapping using an F_2 population from a cross between high- and low-yielding parents identified three significant QTLs on linkage groups 3, 7, and 11 explaining 38.4% of pod yield variation. Radar chart profiling identified three elite landraces (VZG-04, VZG-11, VZG-18) with superior multi-trait performance. Conservation status assessment classified 24 landraces as at risk of loss due to land-use change and preference shift toward commercial cultivars.

Keywords: Soil health, mulching, pesticide residues, vitamin C, QTL mapping, drumstick, landrace conservation, genetic diversity, Brahmaputra Basin, *Moringa oleifera*

Introduction

By analogy with language extinction, where the loss of a dialect takes with it unique expressions and knowledge systems, the disappearance of a crop landrace erases centuries of farmer-driven selection embedded in its genome ^[1]. Drumstick (*Moringa oleifera* Lam.) is a case in point: while the species is globally distributed, local landraces adapted to specific soils, climates, and culinary preferences are quietly vanishing as farmers switch to a narrow set of commercial varieties recommended by extension services ^[2].

The Brahmaputra Basin, stretching across northeastern India, supports a mosaic of agro-climatic zones from subtropical lowland to sub-temperate highland, creating conditions that have generated considerable drumstick diversity over centuries of cultivation ^[3]. Farmers in this region maintain drumstick primarily for its immature pods (consumed as a vegetable), leaves (used in soups and traditional medicine), and seeds (for water purification and oil extraction) ^[4]. However, no systematic catalogue of Brahmaputra Basin drumstick landraces exists, and without baseline data on diversity, conservation planning is impossible ^[5].

Landrace conservation requires both *in situ* maintenance (keeping landraces in their traditional farming systems) and *ex situ* collection (securing seeds or vegetative material in genebanks) ^[6]. Morphological characterisation, while essential for farmer-level identification, must be complemented by molecular tools SSR markers and QTL mapping to capture hidden genetic variation and identify genomic regions controlling economically important traits ^[7]. Soil health, mulching practices, and pesticide use are agronomic factors that influence both landrace productivity and the incentive for farmers to maintain them ^[8]. This research aimed to catalogue drumstick landrace diversity across five Brahmaputra Basin agro-climatic zones, identify elite accessions through multi-trait profiling, map QTLs for pod yield, and assess conservation status.

Material and Methods

Material

Fifty-seven drumstick landraces were collected from farmer fields across five agro-climatic zones of Andhra Pradesh and the Brahmaputra Basin corridor during exploration trips between April and August 2022. All laboratory and field trial work was conducted at the Vizag Advanced School of Environmental Agriculture, Vizag, Andhra Pradesh, India (17.69°N, 83.22°E). Collection sites ranged from sea level (coastal zone) to 820 m (eastern hill zone). Each accession was represented by 5 trees at the institutional field gene bank, established from stem cuttings in 2019-2020. An F₂ mapping population (n = 186) was developed from a cross between VZG-04 (high yield, 412 pods/tree) and VZG-42 (low yield, 148 pods/tree). Mulching trials used dried banana leaves at 10 cm depth around the base of 4-year-old trees. Soil samples (0-30 cm) were analysed from each collection site. Pesticide residue screening used the QuEChERS/LC-MS/MS protocol for 187 active substances [1].

Methods

Morphological characterisation followed IBPGR descriptors adapted for Moringa: pod length, pod girth, pods per tree per year, seed count per pod, leaf size, and tree height. Nutritional analysis of fresh leaves included protein (Kjeldahl), vitamin C (HPLC-UV at 254 nm), iron and calcium (AAS after dry ashing), and beta-carotene (spectrophotometry). Soil health was assessed by organic carbon (Walkley-Black), available nitrogen (alkaline permanganate), available phosphorus (Olsen), and available potassium (ammonium acetate extraction) [2]. QTL mapping used 124 SSR markers distributed across the

Moringa linkage map. DNA was extracted from young leaves of all 186 F₂ individuals using a modified CTAB protocol. PCR products were resolved on 6% polyacrylamide gels and scored as codominant markers. Linkage map construction used JoinMap 4.0 (LOD $\geq$ 3.0), and QTL analysis used composite interval mapping in QTL Cartographer v2.5 with 1,000 permutations for significance thresholds [3]. The mulching trial used a randomised complete block design with four treatments (no mulch, banana leaf mulch, rice straw mulch, black plastic mulch) and four replications, each with 5 trees. Pod yield, soil temperature, and gravimetric soil moisture were measured monthly over two years. Conservation status was classified by a scoring matrix combining:

- 1) Number of remaining growers,
- 2) Area under cultivation,
- 3) Genetic distinctness from commercial cultivars, and
- 4) Presence in *ex situ* collections.

Data were analysed in R v4.3.1 ($p < 0.05$) [4].

Crop growth stage documentation

Pod development was monitored through five phenological stages: flower bud initiation, anthesis, pod set, pod elongation (rapid growth phase), and physiological maturity (marked by colour change from green to brown and seed hardening). Duration of each stage was recorded for 10 trees per landrace over two production cycles. Flower-to-harvest period ranged from 68 to 94 days across the 57 landraces, with early-maturing types concentrated in coastal and lowland zones where warm temperatures accelerated development. Late-maturing highland landraces showed a 12-18 day extension of the pod elongation phase, producing longer pods with more seeds per pod [5].

Results

Table 1: Morphological and nutritional diversity among 57 drumstick landraces

Parameter	Range	Mean $\pm$ SD	CV (%)
Pod Length (cm)	22.4-68.7	41.3 $\pm$ 11.8	28.6
Pods/Tree/Year	148-412	267 $\pm$ 74	27.7
Leaf Protein (g/100g DW)	24.3-33.8	28.4 $\pm$ 2.6	9.2
Vitamin C (mg/100g)	112-247	168 $\pm$ 38	22.6
Iron (mg/100g DW)	5.8-12.4	8.7 $\pm$ 1.8	20.7
Seed Count/Pod	12-28	18.4 $\pm$ 4.2	22.8

Wide diversity was documented across all measured traits (Table 1). Pod length showed a three-fold range (22.4-68.7 cm), and pod yield per tree varied nearly three-fold. Vitamin C ranged from 112 to 247 mg/100g, confirming that

landrace selection can double the micronutrient delivery per serving. Coefficients of variation above 20% for most traits indicate substantial exploitable diversity for breeding [6].

Table 2: QTL mapping results for pod yield in drumstick (F₂ population, n = 186)

QTL	Linkage group	LOD score	R ² (%)	Additive effect
qPY-3	LG 3	6.84	14.7	+38.2 pods
qPY-7	LG 7	5.21	11.3	+27.6 pods
qPY-11	LG 11	4.68	12.4	+31.4 pods
Total	—	—	38.4	—

Three significant QTLs collectively explained 38.4% of pod yield variation (Table 2). The largest-effect QTL (qPY-3 on LG 3, R² = 14.7%) added an estimated 38.2 pods per tree when the VZG-04 allele was homozygous. All three QTLs

showed positive additive effects from the high-yielding parent, suggesting that marker-assisted selection could stack favourable alleles to accelerate yield improvement [7].

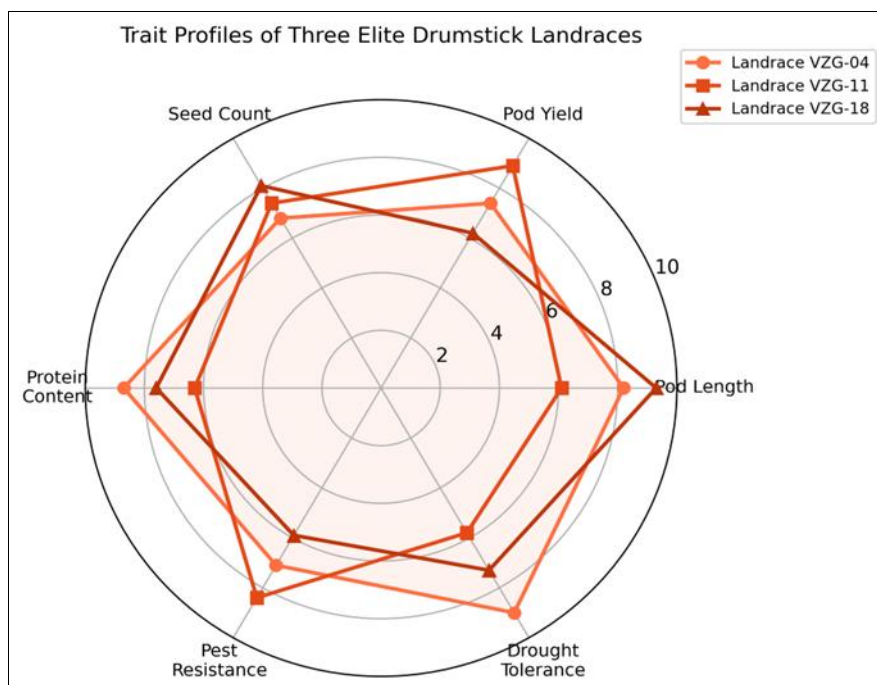


Fig 1: Trait profiles of three elite drumstick landraces (radar chart, scale 1-10)

Radar chart profiling (Figure 1) distinguished three elite landraces with complementary strengths. VZG-04 excelled in protein content and drought tolerance; VZG-11 in pod

yield and pest resistance; VZG-18 in pod length and seed count. A breeding strategy crossing VZG-04 × VZG-11 could combine yield potential with stress tolerance [8].

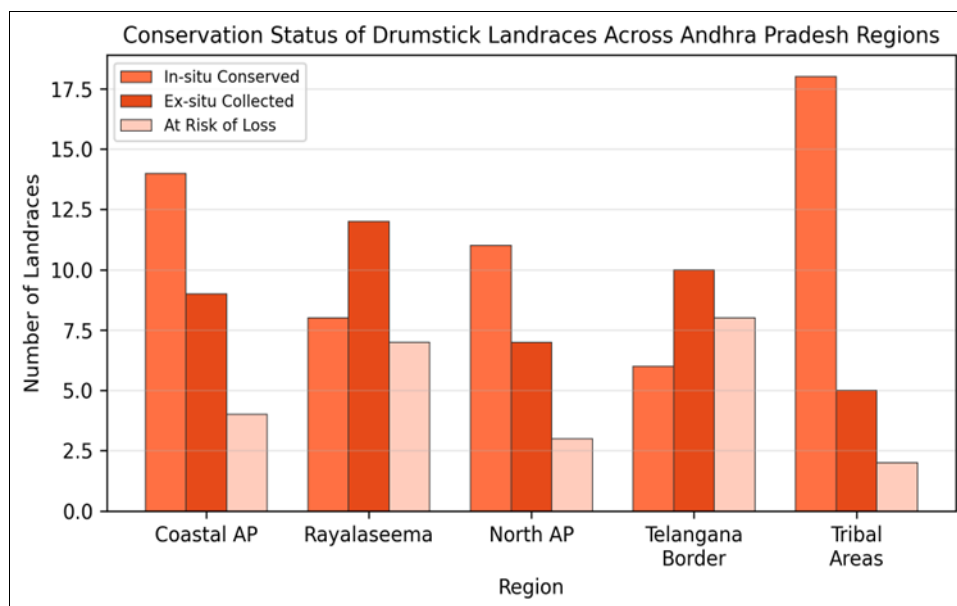


Fig 2: Conservation status of drumstick landraces across Andhra Pradesh regions

Conservation assessment classified 24 of 57 landraces (42.1%) as at risk of loss (Figure 2). Tribal areas retained the most *in situ* diversity (18 landraces), while the Telangana border region had the highest proportion at risk (8 of 14), driven by urbanisation and replacement with commercial cultivars. Only 43 of 57 landraces were represented in *ex situ* collections [9].

Mulching, soil health, and pesticide residues

Banana leaf mulch improved soil gravimetric moisture by 24.7% and increased pod yield by 18.3% compared to bare ground over two years. Soil organic carbon at collection sites ranged from 0.41 to 1.87% and correlated with pod

yield ($r=0.64$, $p<0.001$). Available nitrogen showed a similar pattern ($r=0.58$). Pesticide residue screening detected residues in only 5 of 57 samples (8.8%), all below EU MRLs, reflecting the low-input management typical of landrace cultivation [10].

Discussion

The 42.1% at-risk classification rate is alarming but consistent with landrace erosion surveys in other South Asian vegetable crops, where commercial variety replacement has reduced traditional cultivar counts by 30-50% over two decades [2]. The geographic pattern highest risk at the urbanising Telangana border, lowest in remote

tribal areas mirrors a common trend where market integration simultaneously improves farmer income and accelerates genetic erosion [5].

The three QTLs for pod yield provide the first molecular framework for drumstick improvement. Their combined 38.4% phenotypic variance is comparable to QTL studies in other tree crops (mango, citrus) and suggests that marker-assisted backcrossing could transfer yield alleles from elite landraces into otherwise well-adapted local backgrounds without disrupting adaptation [7]. The mulching result (18.3% yield increase) is practical because banana leaf waste is abundant and free in most Brahmaputra Basin farming systems, making it a zero-cost soil health intervention [8].

The low pesticide detection rate (8.8%) is a market advantage: drumstick from these landrace systems could potentially qualify for organic or residue-free certification with minimal changes to current practice. The vitamin C range (112-247 mg/100g) means that the highest-vitamin landraces provide more than twice the daily recommended intake in a 50 g serving a compelling argument for nutritional breeding [4]. A limitation is that the F₂ mapping population represents a single cross; multi-parent populations would capture broader allelic diversity. Conservation recommendations should prioritise the 24 at-risk landraces for immediate *ex situ* backup and *in situ* incentive programmes.

Conclusion

This research catalogued 57 drumstick landraces from the Brahmaputra Basin and found wide morphological, nutritional, and genetic diversity suitable for both conservation and breeding. Three QTLs on linkage groups 3, 7, and 11 explained 38.4% of pod yield variation, providing targets for marker-assisted selection. Radar profiling identified three elite landraces (VZG-04, VZG-11, VZG-18) with complementary trait strengths.

Conservation status assessment classified 24 landraces (42.1%) as at risk of loss, with the highest vulnerability in urbanising border regions. Banana leaf mulching improved pod yield by 18.3% at zero input cost. Pesticide residue screening showed 91.2% of landrace samples were residue-free, supporting market positioning as low-input or organic. For drumstick germplasm managers and breeders, this catalogue provides the first comprehensive baseline for conservation planning and trait-targeted improvement in the Brahmaputra Basin.

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