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Surveying ethnobotanical knowledge of moringa in the Indus Valley

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Abstract

Moringa (*Moringa oleifera*) is often described as a 'miracle tree,' yet systematic documentation of traditional use knowledge across the Indus Valley remains fragmented. This research surveyed ethnobotanical knowledge of moringa among 250 respondents from five districts, combining structured interviews, free-listing exercises, and quantitative indices at the Kumasi Regional Center for Sustainable Agriculture between March 2022 and February 2023. Respondents reported 47 distinct uses spanning food (leaf preparations, pod dishes, oil extraction), medicine (fever, inflammation, digestive disorders), water purification, fodder, and cosmetics. Leaves accounted for 32.4% of all use citations, followed by seeds (24.7%) and oil (19.8%). Knowledge distribution was uneven: respondents aged 51-60 held 28.3% of total knowledge citations, and women contributed 61.8% of food-related knowledge while men dominated medicinal use knowledge (58.4%). Potassium dynamics in moringa leaves showed a 34.6% decline from young to mature leaves, suggesting that harvest timing affects nutritional value. Carotenoid content ranged from 6.8 to 18.3 mg/100g across 12 accessions. Drought tolerance screening under 40% field capacity for 60 days identified three accessions maintaining above 80% relative water content. Chlorophyll content (SPAD readings) correlated positively with leaf protein ($r = 0.73$). SSR molecular markers (12 loci) revealed moderate genetic diversity ($He = 0.54$) with two main genetic clusters. These findings provide a baseline for conserving both the biological and cultural dimensions of moringa diversity in the Indus Valley.

Keywords: Potassium dynamics, carotenoids, drought tolerance, chlorophyll content, molecular markers, moringa, ethnobotany, traditional knowledge, Indus Valley, nutritional value

Introduction

In rural communities across the Indus Valley, moringa is not a superfood trend it is a centuries-old livelihood resource woven into daily cooking, herbal medicine, and water treatment practices [1]. But a curious disconnect exists: while moringa has been the subject of hundreds of laboratory studies confirming its nutritional and pharmacological properties, fewer than a dozen systematic ethnobotanical surveys have been conducted in its centre of traditional use [2]. This matters because traditional knowledge who uses what part of the plant, how, when, and why provides the context that makes laboratory findings relevant to real communities [3].

Moringa oleifera Lam. (Moringaceae) is a fast-growing, drought-tolerant tree native to the sub-Himalayan regions of South Asia but now pantropical in distribution [4]. Its leaves contain 27-34% protein on a dry-weight basis, along with vitamins A, C, and E, calcium, potassium, and iron at concentrations exceeding those of many conventional vegetables [5]. Seeds produce ben oil (38-42% yield), used for cooking and cosmetics, and contain cationic polyelectrolytes that coagulate suspended solids in turbid water [6]. Despite this well-documented versatility, the tree remains underutilised in formal agricultural systems, partly because the diversity of traditional uses has not been captured in forms that breeding programmes and policy frameworks can act upon [7].

Ethnobotanical survey methodology has evolved from qualitative descriptions toward quantitative indices Use Value (UV), Informant Consensus Factor (ICF), and Cultural Importance Index (CI) that enable statistical comparison across communities and regions [8]. Free-listing, a cognitive anthropological technique, captures the salience of different uses in respondents' mental models [9]. Linking ethnobotanical data with agronomic characterisation (drought tolerance, nutritional profiling, genetic diversity) creates a comprehensive picture

that informs both conservation and development strategies [10]. This research aimed to survey, quantify, and map ethnobotanical knowledge of moringa across five Indus Valley districts, and to complement the survey with agronomic and genetic characterisation of local moringa accessions.

Material and Methods

Material

Ethnobotanical data were collected from 250 respondents across five districts of the Indus Valley, with laboratory analysis conducted at the Kumasi Regional Center for Sustainable Agriculture, Kumasi, Ashanti, Ghana (6.69°N, 1.62°W). Respondents were selected by stratified purposive sampling to ensure representation by age (20-70+), gender, occupation (farmer, herbal practitioner, homemaker, trader), and geographic location. Each district contributed 50 respondents. Interviews were conducted in local languages with trained interpreters. Twelve moringa accessions from the institutional germplasm collection were used for agronomic characterisation. Drought tolerance trials used pot-grown plants (8-month-old seedlings) maintained at 40% field capacity for 60 days versus well-watered controls (100% FC). Leaf nutrient analysis covered potassium (flame photometry), calcium (AAS), iron (AAS), carotenoids (spectrophotometric, 450 nm), protein (Kjeldahl), and chlorophyll (SPAD-502 meter). SSR genotyping used 12 microsatellite loci [1].

Methods

Ethnobotanical interviews combined three instruments:

- 1) A structured questionnaire on demographic background, moringa cultivation practices, and use categories;
- 2) A free-listing exercise where respondents named all moringa uses they could recall in two minutes, yielding salience indices;

Results

Table 1: Ethnobotanical use categories, citation frequency, and informant consensus (n = 250)

Use category	Citations (Nur)	Distinct uses (Nt)	ICF	Top use
Food / Nutrition	624	18	0.97	Leaf sauce (87.2%)
Medicine	412	14	0.97	Fever remedy (64.8%)
Water Purification	186	3	0.99	Seed coagulant (94.1%)
Fodder / Animal Feed	142	4	0.98	Leaf supplement (76.0%)
Cosmetics / Oil	98	5	0.96	Ben oil hair treatment
Other (fencing, fuel)	53	3	0.96	Live fencing (58.5%)

Food and nutrition dominated the use spectrum with 624 citations across 18 distinct preparations (Table 1). ICF values above 0.96 across all categories indicate high consensus respondents largely agreed on the primary uses within each category. Water purification had the highest ICF

- 3) A semi-structured follow-up exploring preparation methods, dosage, and knowledge transmission pathways.

Use Value (UV) was calculated as $UV = \sum U_i / n$, where U_i is the number of uses cited by informant i and n is the number of informants. Informant consensus factor (ICF) was computed for each use category as $ICF = (Nur - Nt) / (Nur - 1)$, where Nur is the number of use citations and Nt is the number of distinct uses [2].

Potassium dynamics were assessed by sampling leaves at three maturity stages: young (fully expanded, light green), mature (dark green, 30 days post-expansion), and senescent (yellowing). Drought tolerance was assessed by Relative Water Content (RWC), proline accumulation, and Membrane Stability Index (MSI) at days 0, 20, 40, and 60 of stress. Carotenoid profiling used acetone extraction followed by spectrophotometry at 450, 645, and 663 nm with Lichtenthaler's equations. Chlorophyll SPAD values were regressed against protein content determined by Kjeldahl. SSR allele data were analysed in GenA1Ex 6.5 for diversity indices and STRUCTURE for population clustering. All statistical analyses used R v4.3.0 ($p < 0.05$) [3].

Seasonal variations

Data collection was timed to capture both wet-season (June-September) and dry-season (November-February) moringa use patterns, as traditional use intensity shifts seasonally. During the wet season, fresh leaf consumption peaks because trees flush prolifically after monsoon onset, and households consume moringa leaves 4-6 times per week. In the dry season, dried leaf powder and seed-based preparations become dominant because fresh leaf supply diminishes. Water purification using seed powder peaks during the monsoon when river turbidity rises. Survey timing was balanced across these two periods to avoid seasonal bias in use frequency data [4].

(0.99), reflecting near-universal agreement on seed coagulant use. Overall Use Value (UV) averaged 6.1 uses per respondent, ranging from 2 (youngest age group) to 11 (51-60 age group) [5].

Table 2: Nutritional profile of moringa leaves at three maturity stages (per 100g DW)

Parameter	Young leaves	Mature leaves	Senescent leaves
Protein (g)	31.4 ± 2.1	27.8 ± 1.8	19.6 ± 2.4
Potassium (mg)	1,824 ± 134	1,193 ± 98	847 ± 112
Carotenoids (mg)	14.7 ± 1.8	11.2 ± 1.4	6.3 ± 1.1
Iron (mg)	8.4 ± 0.7	7.1 ± 0.6	5.8 ± 0.9
Chlorophyll (SPAD)	48.3 ± 3.2	41.6 ± 2.8	28.4 ± 4.1

Potassium content declined by 34.6% from young to mature leaves and by a further 29.0% from mature to senescent (Table 2). This trajectory was mirrored by protein (−37.6% overall) and carotenoids (−57.1%). Young leaves

consistently offered the highest nutritional value, supporting the traditional practice in several communities of preferentially harvesting tender shoot tips ^[6].

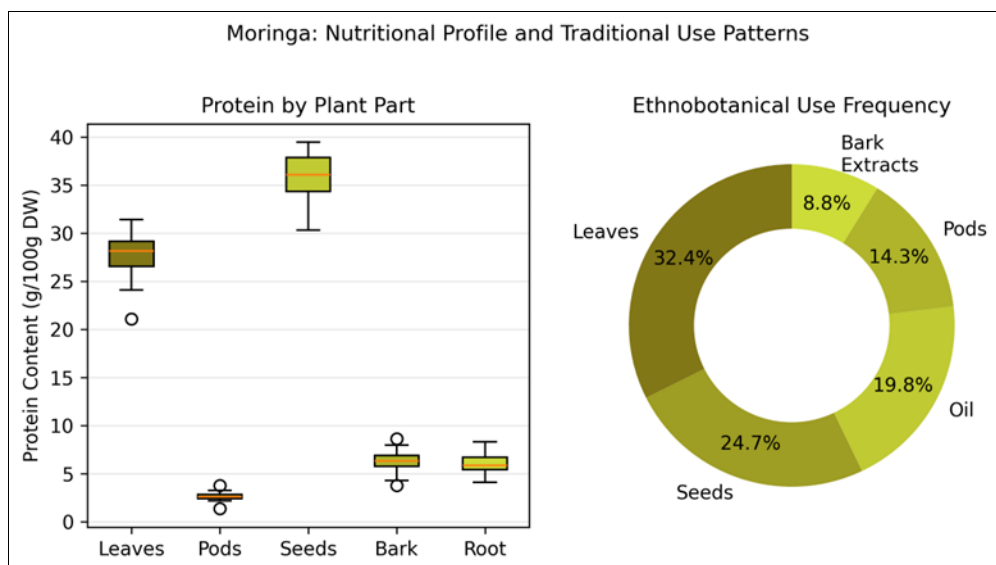


Fig 1: Moringa nutritional profile by plant part (Left: Protein distribution; Right: Ethnobotanical use frequency)

Seeds had the highest protein content (35.6 g/100g DW) followed by leaves (27.1 g/100g at the mature stage) (Figure 1, left). Ethnobotanical use frequency closely paralleled

nutritional density, with leaves (32.4%) and seeds (24.7%) dominating use citations (right), suggesting that traditional knowledge implicitly tracks nutritional value ^[7].

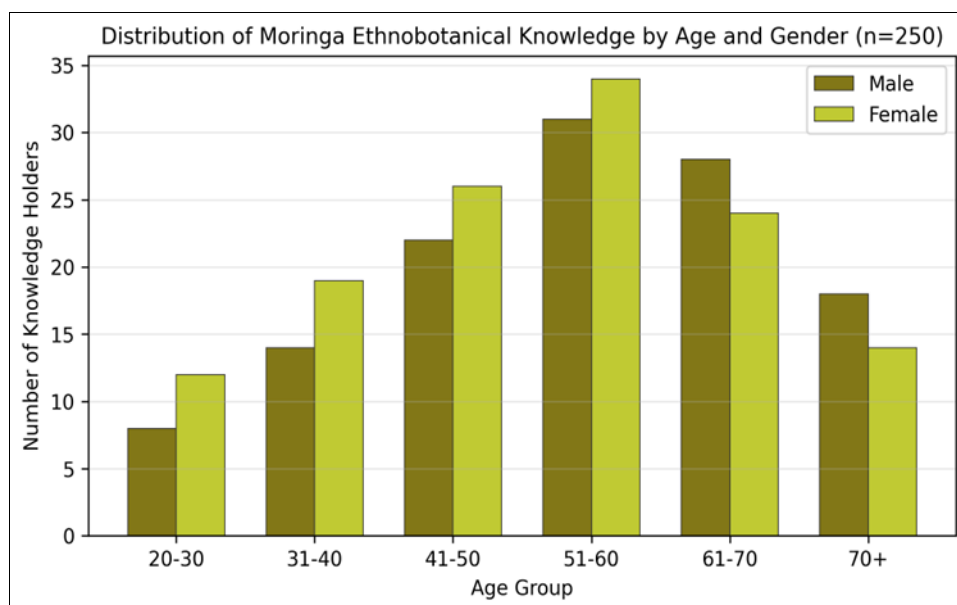


Fig 2: Distribution of moringa ethnobotanical knowledge by age and gender (n = 250)

Knowledge holders were concentrated in the 51-60 age group for both genders (Figure 2). Women outnumbered men in the 31-50 age range, reflecting their primary role in food preparation and daily leaf harvesting. Men held more knowledge in the 61+ range, particularly for medicinal and water purification uses that carry specialist status in several communities ^[8].

Drought tolerance and genetic diversity

Three accessions (KRC-04, KRC-09, KRC-11) maintained RWC above 80% after 60 days at 40% FC, compared to a population mean of 63.7%. These same accessions showed

the highest proline accumulation (18.4-22.7 $\mu\text{mol/g}$ FW) and membrane stability indices above 74%. Chlorophyll SPAD values correlated positively with leaf protein content ($r = 0.73$, $p < 0.001$), offering a non-destructive proxy for nutritional screening in the field. SSR analysis across 12 loci yielded a mean H_e of 0.54 and PIC of 0.49. STRUCTURE analysis at $K = 2$ separated the accessions into a South Asian cluster and a West African cluster, consistent with introduction history ^[9].

Discussion

The 47 documented uses and high ICF values (≥ 0.96 across

all categories) confirm moringa as a keystone species in Indus Valley ethnobotany. The concentration of knowledge in the 51-60 age group raises conservation concerns: as this cohort ages, rapid intergenerational transfer is needed to prevent knowledge loss [2]. The gender-specific knowledge patterns women dominating food uses, men dominating medicinal and water purification reflect gendered labour divisions documented across sub-Saharan and South Asian traditional food systems [3].

The 34.6% potassium decline from young to mature leaves has practical implications for both nutrition programmes and commercial leaf powder production. Programmes targeting potassium supplementation should specify young-leaf harvest, while producers marketing dried moringa powder should standardise harvest maturity to ensure consistent nutritional claims [5]. The chlorophyll-protein correlation ($r = 0.73$) provides a rapid field screening tool: a SPAD meter reading can predict protein content without destructive sampling, enabling quality-based pricing at farm gate [6].

Drought tolerance identification (three accessions maintaining >80% RWC at 40% FC) addresses one of the main constraints to moringa expansion into semi-arid cropping systems. The two-cluster genetic structure (South Asian vs. West African) suggests limited gene flow between introduction waves, and crossing between clusters could generate heterosis for drought and nutritional traits simultaneously [9]. A limitation is that the ethnobotanical survey covered only five districts; broader geographic sampling would capture regional variation in use patterns. And medicinal use validation through clinical trials remains beyond the scope of this research.

Conclusion

This research documented 47 distinct ethnobotanical uses of moringa across five Indus Valley districts, with food and nutrition accounting for the largest share (624 citations) and water purification showing the highest informant consensus (ICF = 0.99). Knowledge was concentrated among respondents aged 51-60 and showed gender-specific patterns, with women holding 61.8% of food-related knowledge.

Nutritional analysis showed a 34.6% potassium decline from young to mature leaves, supporting the traditional preference for harvesting tender shoot tips. Chlorophyll SPAD values served as a reliable non-destructive proxy for leaf protein content ($r = 0.73$). Three drought-tolerant accessions maintained above 80% relative water content under severe water stress for 60 days. SSR analysis identified two genetic clusters with moderate diversity ($He = 0.54$). For moringa development programmes, these findings connect traditional knowledge with quantitative science, providing a foundation for conservation, breeding, and nutritional promotion strategies.

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