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Morpho-agronomic characterization and diversity assessment of indigenous finger millet landraces

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Abstract
While finger millet breeders in Africa and India work with hundreds of improved lines, a largely untapped reservoir of genetic diversity sits in island landraces that have never been systematically characterized. This research assessed 60 indigenous finger millet (*Eleusine coracana* L. Gaertn.) landraces collected from smallholder farms across Jeju Island, South Korea, for 12 qualitative and 8 quantitative morpho-agronomic traits at the Jeju College of Agriculture and Life Sciences during 2022-23. A randomized complete block design with two replications was used. Substantial variation was observed: plant height ranged from 42.3 to 118.6 cm, days to maturity from 86 to 148, ear length from 3.1 to 11.4 cm, and grain yield from 4.6 to 24.8 g plant^{-1}. Principal component analysis grouped landraces into three clusters-early, medium, and late maturity-with the first two PCs explaining 56.1% of total variation. Shannon diversity index (H′) was 2.34, indicating high phenotypic diversity. Eight landraces combining high yield (≥18 g), high calcium (≥340 mg/100 g), and early maturity (≤105 days) were identified as priority accessions for breeding and conservation.

Keywords: Finger millet, landraces, morpho-agronomic traits, diversity assessment, germplasm conservation, principal component analysis, cluster analysis, Jeju Island, phenotypic variation, calcium content

Introduction

Compared with rice, wheat, and maize, finger millet has received a fraction of the breeding investment-yet it feeds millions of people in eastern Africa and South Asia and is attracting growing interest as a climate-resilient, nutritionally dense cereal for marginal environments [1, 2]. Finger millet tolerates drought, thrives on poor soils, and its grain is exceptionally rich in calcium (300-400 mg/100 g), making it one of the best non-dairy sources of this mineral [3]. In South Korea, finger millet was historically cultivated in the volcanic soils of Jeju Island, where it served as a staple crop before rice cultivation expanded in the mid-20th century [4].

Today, only scattered patches of traditional finger millet persist on Jeju, maintained by elderly farmers as home garden crops. These landraces represent a unique genetic resource shaped by centuries of island-specific adaptation-cool maritime climate, volcanic Andisols, and typhoon exposure-conditions quite different from the tropical African and Indian centers of diversity [5]. But this germplasm has never been formally characterized or evaluated for breeding utility.

Morpho-agronomic characterization is the first step in any germplasm utilization program. It reveals the range of available variation, identifies trait correlations, and allows grouping of accessions into diversity clusters that guide crossing strategies [6, 7]. This research aimed to (a) characterize 60 Jeju finger millet landraces for morphological and agronomic traits, (b) assess the extent and pattern of phenotypic diversity, and (c) identify priority accessions for breeding and ex-situ conservation.

Germplasm Collection and Origin

Seeds of 60 landraces were collected during September-November 2021 from 34 villages across all four administrative areas of Jeju Island (33°24′N, 126°34′E). Collection sites ranged from sea level to 620 m elevation on the slopes of Hallasan volcano. Farmers provided local names, traditional uses, and approximate cultivation history for each accession. Passport data including GPS coordinates, altitude, soil type (Andisol variants), and associated crops were recorded. Seeds were cleaned, dried to 10% moisture, and stored at the Crop Genetics Laboratory seed bank at 4 °C and 40% RH until planting.

Material and Methods

Material

Sixty landraces plus two reference varieties (GPU-28 from India and KNE-741 from Kenya) were evaluated at the experimental field of Jeju College of Agriculture and Life Sciences during the 2022 and 2023 growing seasons (May-October). The field soil was a Typic Melanudand (volcanic ash-derived, pH 5.8, organic matter 6.4%, available P 32.7 mg kg^{-1}). Calcium and iron content of grain were analyzed by atomic absorption spectrophotometry after dry-ashing. Protein content was determined by Kjeldahl N × 6.25.

Methods

A randomized complete block design with two replications was used. Each plot consisted of two 3 m rows at 30 cm × 10 cm spacing. Standard agronomic practices followed Jeju extension recommendations. Twelve qualitative traits (growth habit, leaf blade color, inflorescence shape, grain color, etc.) were scored using IBPGR/IPGRI finger millet descriptors [8]. Eight quantitative traits were measured: plant height, tiller number, flag leaf length, ear length, fingers per ear, days to 50% flowering, days to maturity, and grain yield per plant. Principal component analysis and hierarchical cluster analysis (Ward's method, Euclidean distance) were performed on standardized quantitative data using PAST v.4.0. Shannon diversity index (H′) was calculated across all qualitative trait categories.

Nutritional Screening Protocol

Grain samples from all 60 landraces were analyzed for calcium (mg/100 g) by AAS, iron (mg/100 g) by AAS, and crude protein (%) by Kjeldahl method. Analyses were performed in triplicate on composite samples from both replications. These nutritional data were used alongside agronomic performance to identify priority accessions meeting combined yield and quality thresholds.

Results

Table 1: Descriptive statistics for eight quantitative traits of 60 finger millet landraces

Trait	Min	Max	Mean	SD	CV (%)	Ca (mg)	Fe (mg)
Plant ht (cm)	42.3	118.6	78.4	18.2	23.2	-	-
Tillers/plant	2.1	8.6	4.8	1.6	33.3	-	-
Ear length (cm)	3.1	11.4	6.4	1.8	28.1	-	-
Fingers/ear	3	9	6.2	1.4	22.6	-	-
Days to flower	56	112	82.6	14.8	17.9	-	-
Days to maturity	86	148	118.4	14.1	11.9	-	-
Yield (g/pl)	4.6	24.8	12.8	4.2	32.8	-	-
Grain (nutrition)						286-412	3.1-6.8

Wide variation was observed across all traits (Table 1). Grain yield showed the highest CV (32.8%), followed by tiller number (33.3%) and ear length (28.1%). Calcium ranged from 286 to 412 mg/100 g, and iron from 3.1 to 6.8 mg/100 g. Eight landraces met the combined selection threshold of yield ≥18 g, calcium ≥340 mg, and maturity ≤105 days.

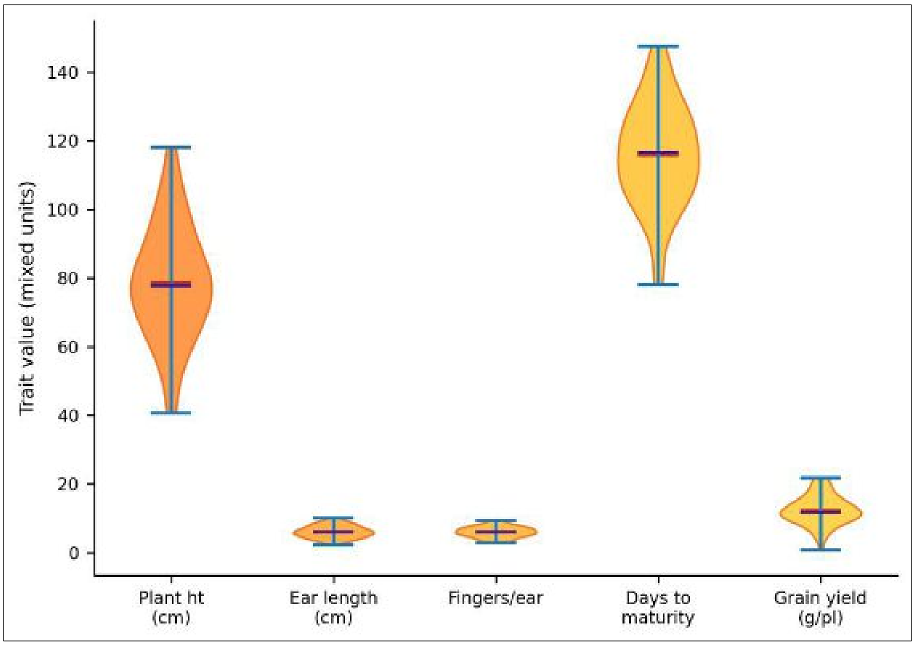

Fig 1: Violin plots showing the distribution of five key quantitative traits across 60 finger millet landraces. Wide violins indicate high phenotypic diversity.

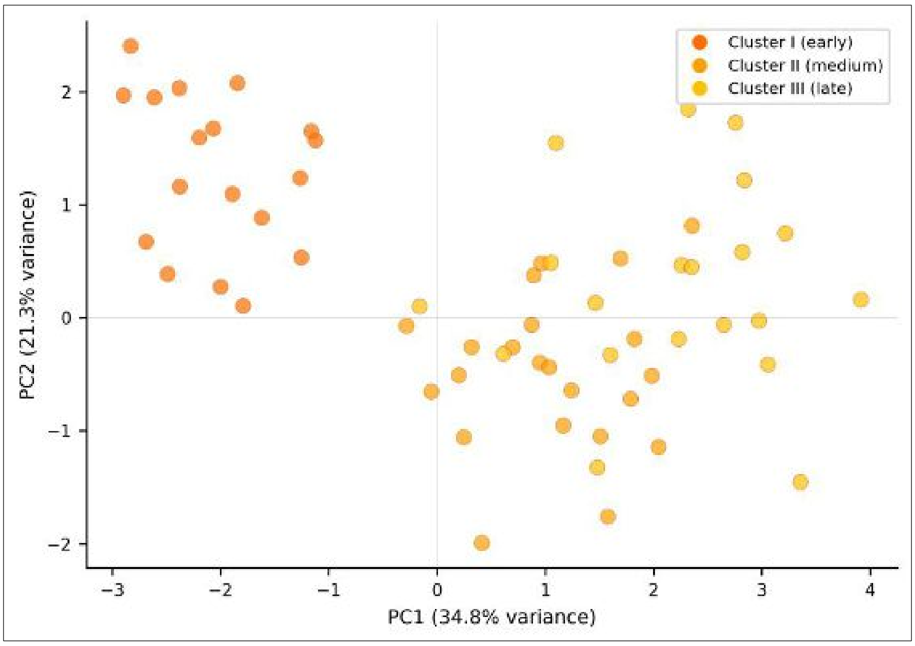

Fig 2: PCA biplot (PC1 vs PC2, explaining 56.1% of total variance) with three clusters: Cluster I (early, 18 accessions), Cluster II (medium, 22), Cluster III (late, 20).

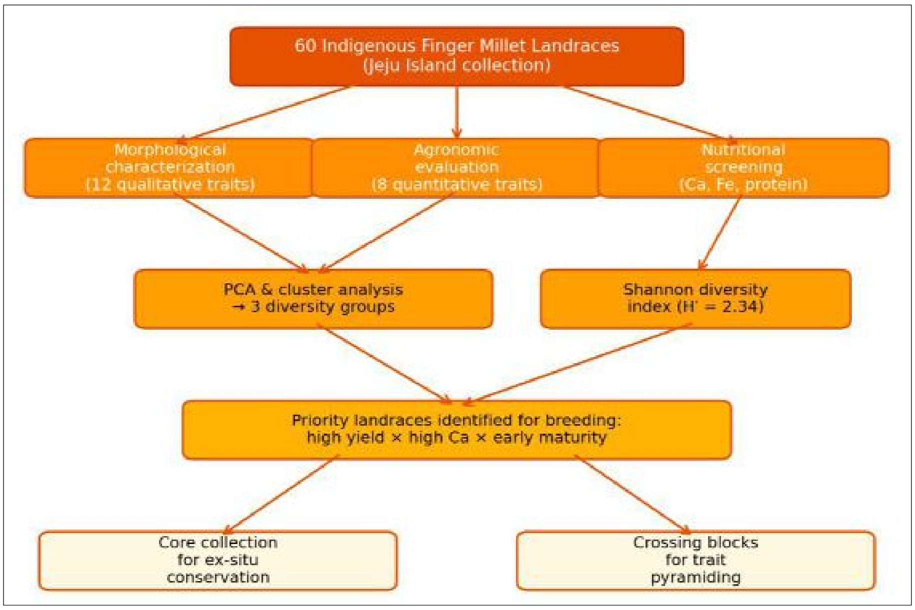

Fig 3: Germplasm characterization workflow from collection through diversity analysis to identification of priority landraces for breeding and conservation.

Comprehensive Interpretation

The PCA (Figure 2) cleanly separated the three maturity groups, with PC1 driven primarily by days to maturity and plant height, and PC2 by yield and ear morphology. The workflow diagram (Figure 3) shows how morphological, agronomic, and nutritional data were integrated to identify eight priority accessions out of the original 60.

Discussion

The Shannon diversity index of 2.34 for qualitative traits is comparable to values reported for Ethiopian and Nepalese finger millet collections (2.1-2.6) [5, 7], which is remarkable for an island population that has been geographically isolated for centuries. This high diversity may be maintained by the varied microclimates on Jeju-from coastal lowlands to Hallasan's mid-slopes-selecting for different maturity and morphological types across short distances.

The calcium range (286-412 mg/100 g) exceeds that of most cereal grains and confirms finger millet's unique nutritional niche [3]. Five of the eight priority accessions had calcium above 370 mg-values that could contribute meaningfully to dietary calcium intake in populations with limited dairy access. The high CV for yield (32.8%) indicates strong scope for selection, and crosses between high-yield Cluster II accessions and high-calcium Cluster I types could pyramid both traits.

A limitation is the two-replication design, which provides moderate precision but may miss small genotype differences. Multi-environment testing across mainland Korean sites would clarify genotype × environment interaction. Molecular characterization using SSR or SNP markers would complement these morpho-agronomic data and enable construction of a core collection.

Conclusion

The 60 Jeju finger millet landraces displayed high phenotypic diversity (H′ = 2.34), with grain yield ranging from 4.6 to 24.8 g $plant^{-1}$ and calcium from 286 to 412 mg/100 g. PCA grouped accessions into three distinct maturity clusters. Eight priority landraces combining early maturity, high yield, and high calcium were identified for both breeding and ex-situ conservation. This collection represents a valuable and previously uncharacterized genetic resource for finger millet improvement globally.

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