

Floristic Diversity, Habitat Preference, and Ecological Distribution of Zingiberaceae Species in Different Regions of West Bengal

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Abstract: *The Zingiberaceae, a family of aromatic, rhizomatous herbs with its principal centre of diversity in tropical and subtropical Asia, is well represented in the state of West Bengal, which spans an unusually steep environmental gradient from the humid Eastern Himalayan foothills to the saline Sundarbans delta within a comparatively small area. This study synthesises the floristic composition, habitat preferences, and ecological distribution of Zingiberaceae across four physiographic regions of the state: the Himalayan and sub-Himalayan region, the Terai–Dooars, the Gangetic plains and Rarh, and the coastal Sundarbans. Ten principal genera, including Curcuma, Zingiber, Hedychium, Alpinia, Kaempferia, Globba, and Amomum, are documented from the state, with habitat preference governed chiefly by canopy shade and substrate moisture at the family level and by elevation-linked temperature tolerance at the genus level. Family richness declines sharply from the Himalayan and Terai–Dooars regions, which support the great majority of wild diversity, through the Gangetic plains, where a substantial cultivated component supplements a reduced wild flora, to the Sundarbans, where the family is essentially absent as a wild element owing to salinity and tidal inundation. A structured field-survey and analysis framework is presented to generate the quantitative diversity and distribution data required to extend this synthesis, and narrow-range Himalayan and Terai–Dooars taxa are identified as priorities for formal conservation assessment.*

Keywords: Zingiberaceae; floristic diversity; habitat preference; ecological distribution; West Bengal; Eastern Himalaya; conservation

I. INTRODUCTION

The family Zingiberaceae (the ginger family), placed within the order Zingiberales, comprises about 50 genera and more than 1,300 species of aromatic, rhizomatous, perennial herbs distributed largely through the tropical and subtropical regions of Asia, Africa, and the Americas, with the greatest centre of diversity in tropical and subtropical Asia, particularly the Indo-Malesian and Indo-Burma regions. Members of the family are characterised by sympodially branched, often aromatic rhizomes, distichous leaves with a closed sheath and a ligule, and irregular, showy flowers borne in spikes, racemes, panicles, or on separate radical scapes, with a single fertile stamen and two staminodes fused into a petaloid labellum in most genera. The family is of considerable economic and cultural importance, providing spices (ginger, turmeric, cardamom), dyes, ornamentals, and a wide array of species used in traditional systems of medicine across South and Southeast Asia.

India is a major centre of Zingiberaceae diversity, with the Eastern Himalaya and the Indo-Burma biodiversity hotspot together accounting for a substantial share of Indian species richness in the family. West Bengal, situated at the meeting point of the Eastern Himalayan foothills, the Gangetic plains, and the deltaic coast of the Bay of Bengal, spans an unusually wide range of physiography, climate, and vegetation type within a relatively small area, from the humid subtropical forests of Darjeeling and Kalimpong in the north, through the moist deciduous forests of the Terai and



Dooars, the lateritic and alluvial tracts of the Rarh and Gangetic plains, to the brackish-water mangrove ecosystem of the Sundarbans in the south. This physiographic gradient makes the state an informative setting in which to examine how a taxonomically coherent, ecologically specialised plant family distributes itself across contrasting habitats. Zingiberaceae species are, in general, shade-tolerant to shade-loving understorey herbs of moist forest floors, streambanks, and forest margins, and most are sensitive to prolonged waterlogging, high salinity, and extended dry periods, traits that are expected to constrain their occurrence in some of the more physiologically extreme habitats found within West Bengal, such as the saline intertidal zone of the Sundarbans. At the same time, several genera, notably *Curcuma*, *Zingiber*, *Alpinia*, *Hedychium*, *Kaempferia*, *Globba*, and *Amomum*, are represented in the state both by wild, forest-associated species and by long-cultivated economic species, so that the realised distribution of the family across the state reflects both natural ecological preference and a long history of human cultivation and dispersal. Despite the ecological and economic importance of the family, and despite scattered taxonomic and ethnobotanical reports from particular districts, an integrated account of the floristic diversity, habitat preference, and ecological distribution of Zingiberaceae across the major physiographic regions of West Bengal has not been widely available in a single synthesis. This article addresses that need. It reviews and synthesises the taxonomic composition of the family in the state, examines the habitat associations reported for its constituent genera and species, and compares the ecological distribution of the family across four broad physiographic regions of West Bengal: the Himalayan and sub-Himalayan region, the Terai–Dooars, the Gangetic plains and Rarh, and the coastal Sundarbans.

1.1 Objectives

1. To document the floristic diversity of Zingiberaceae species reported from West Bengal, at the genus and species level.
2. To characterise the habitat preferences of the principal genera and species, in terms of light, moisture, soil, and associated vegetation type.
3. To compare the ecological distribution of Zingiberaceae across the major physiographic regions of West Bengal.
4. To relate observed distribution patterns to the ecological tolerances of the family and to identify regions and taxa of particular conservation concern.

II. STUDY AREA

West Bengal (roughly 21.5°N to 27.2°N and 85.8°E to 89.9°E) covers an area of approximately 88,752 km² and spans one of the steepest environmental gradients of any Indian state over a comparatively short latitudinal span. For the purposes of this study, the state is divided into four broad physiographic and floristic regions, following commonly used regional classifications.

2.1 Himalayan and Sub-Himalayan Region

This region comprises the hill districts of Darjeeling and Kalimpong, ranging in elevation from about 300 m to over 3,600 m, and supports subtropical broadleaved forest, temperate broadleaved and coniferous forest, and, at the highest elevations, subalpine and alpine vegetation. High rainfall (frequently exceeding 3,000 mm annually), persistent humidity, and a well-developed forest canopy make this region the most favourable in the state for shade-loving, moisture-demanding herbaceous genera, including many Zingiberaceae.

2.2 Terai–Dooars Region

Lying immediately south of the Himalayan foothills in the districts of Jalpaiguri, Alipurduar, and parts of Cooch Behar and Darjeeling, the Terai–Dooars is characterised by moist and wet deciduous forest, riverine grassland, and a dense network of rivers and streams draining the Himalaya. High soil moisture, alluvial soils, and a warm, humid climate support a rich understorey flora, including extensive natural populations of several Zingiberaceae genera.



2.3 Gangetic Plains and Rarh Region

This extensive central and western region, covering districts such as Murshidabad, Nadia, Bardhaman, Birbhum, Bankura, and Purulia, includes both fertile alluvial plains associated with the Ganga–Bhagirathi–Hooghly river system and the drier, lateritic Rarh tract to the west. Natural forest cover is more fragmented than in the north, and the Zingiberaceae flora of this region is a mixture of relict wild populations in remnant forest patches and sacred groves, and a substantial component of cultivated and naturalised economic species.

2.4 Coastal Sundarbans Region

The southernmost region, spanning parts of South and North 24 Parganas, forms part of the world's largest contiguous mangrove ecosystem, characterised by saline and brackish tidal creeks, halomorphic soils, and a specialised, salt-tolerant mangrove and mangrove-associate flora. Because most Zingiberaceae are physiologically intolerant of salinity and tidal inundation, this region is expected, and is generally reported, to support markedly lower diversity of the family than the other three regions, confined largely to the relatively less saline landward fringes and homestead plantings.

III. MATERIALS AND METHODS

3.1 Data Sources and Approach

This study combines a structured review of published floristic, taxonomic, and ethnobotanical literature on Zingiberaceae in West Bengal and the adjoining Eastern Himalayan and Indo-Burma region with a synthesis framework intended to support, and to be completed by, systematic field survey. Primary literature sources include regional floras and checklists covering the districts of Darjeeling, Jalpaiguri, and the Gangetic plains, taxonomic revisions of key genera (*Curcuma*, *Zingiber*, *Hedychium*, *Kaempferia*, *Alpinia*, *Globba*, *Amomum*), herbarium records, and published ethnobotanical surveys reporting the use of Zingiberaceae species by local and indigenous communities of the state. Nomenclature follows currently accepted taxonomic treatments, with synonymy checked against standard botanical databases.

3.2 Field Survey Protocol

The floristic and ecological framework presented here is designed to be populated through field survey using the protocol summarised below; results reported in tables marked accordingly (Section 4) are to be completed from primary field data collected under this protocol, since the present synthesis draws on secondary literature and has not yet incorporated a new field census.

1. **Site selection.** Sampling sites are to be selected within each of the four physiographic regions defined in Section 2, stratified to capture the principal forest and habitat types of each region (for example, subtropical and temperate forest at increasing elevation in the Himalayan region; riverine and moist deciduous forest in the Terai–Dooars; sacred groves, forest fragments, and cultivated tracts in the Gangetic plains and Rarh; and landward mangrove fringe and homestead plots in the Sundarbans).
2. **Transect and quadrat sampling.** Within each site, belt transects (10 m × 50 m) are laid along a representative environmental gradient (for example, streamside to upland, or forest edge to interior), with quadrats of 5 m × 5 m placed at regular intervals along each transect for the enumeration of Zingiberaceae individuals, following standard vegetation-sampling methodology.
3. **Specimen collection and identification.** Voucher specimens are collected in flower and, where possible, in fruit, following standard herbarium technique, and identified using relevant regional floras and monographic revisions, with identification confirmed against authentic herbarium material where available.
4. **Habitat and microsite recording.** For each population encountered, associated microhabitat variables are recorded, including canopy cover (visually estimated or measured with a spherical densiometer), soil moisture



class, substrate type, slope and aspect, proximity to water, and the dominant associated overstorey and understorey species.

5. **Geo-referencing.** The location of each population is recorded with a handheld GPS receiver (datum WGS 84), and distribution maps are prepared in a geographic information system (GIS) to display occurrence by region and habitat type.
6. **Phenological and ethnobotanical data.** Flowering and fruiting periods are recorded from field observation across repeat visits, and local names and reported traditional uses are recorded through semi-structured interviews with local communities, following appropriate prior informed consent procedures.
7. **Conservation status assessment.** Population size, extent of occurrence, and habitat threat status are recorded for each species and cross-checked against existing IUCN Red List assessments and any relevant state- or India-level conservation assessments, to flag species of particular conservation concern.

3.3 Data Analysis

Once field data are collected under the protocol above, floristic diversity within and across regions is to be summarised using standard diversity indices, including species richness, the Shannon–Wiener diversity index (H'), Simpson's dominance index, and Margalef's species richness index, computed for each region and habitat type. Similarity in species composition between regions is to be assessed using the Sørensen or Jaccard similarity index and displayed through cluster analysis or non-metric multidimensional scaling (NMDS) ordination. Association between species occurrence and recorded habitat variables (canopy cover, soil moisture, elevation) is to be examined using appropriate multivariate ordination (for example, canonical correspondence analysis) or simple correlation and chi-square association tests, depending on the structure of the resulting dataset. Frequency, density, and abundance of each species within sampled quadrats are to be used to compute an importance value index (IVI) for community-level comparison.

Table 3.1: Summary of the survey and analysis framework

Component	Method	Output
Site selection	Stratified selection across four physiographic regions	Representative site list
Vegetation sampling	Belt transects with regular quadrats	Species occurrence, frequency, density
Specimen identification	Herbarium technique; regional floras and revisions	Confirmed species list with vouchers
Habitat recording	Canopy cover, soil moisture, substrate, slope, aspect	Habitat association per population
Geo-referencing	Handheld GPS; GIS mapping	Distribution maps by region and habitat
Diversity analysis	Shannon–Wiener, Simpson, Margalef indices	Regional diversity comparison
Compositional comparison	Sørensen/Jaccard similarity; NMDS/cluster analysis	Inter-regional similarity
Conservation assessment	IUCN criteria cross-check; local threat assessment	Species of conservation concern

IV. RESULTS

4.1 Floristic Composition

Based on the literature reviewed, West Bengal supports a substantial representation of the family Zingiberaceae, drawn principally from the genera *Curcuma*, *Zingiber*, *Alpinia*, *Hedychium*, *Kaempferia*, *Glozza*, *Amomum*, *Elettaria*, *Boesenbergia*, and *Roscoea*, together with a number of species of horticultural and economic origin that are widely cultivated or occasionally naturalised. The genus *Curcuma* (turmeric and its wild relatives) and the genus *Hedychium* (ginger lilies) are represented by the greatest number of species in the state, reflecting the broader pattern of these genera as major centres of diversity across the Eastern Himalaya and northeastern India. Table 4.1 lists the principal genera reported from the state together with representative species and their general status (wild, cultivated, or both);



the exact number of species and populations recorded per genus is to be finalised from the field survey described in Section 3 and is presented here with placeholders pending that census.

Table 4.1: Principal Zingiberaceae genera reported from West Bengal

Genus	Representative species	Status	No. of species recorded (survey)
Curcuma	C. longa, C. angustifolia, C. aromatica, C. caesia, C. zedoaria	Wild and cultivated	—
Zingiber	Z. officinale, Z. zerumbet, Z. montanum	Wild and cultivated	—
Hedychium	H. coronarium, H. spicatum, H. coccineum, H. ellipticum	Predominantly wild	—
Alpinia	A. galanga, A. nigra, A. malaccensis	Wild and cultivated	—
Kaempferia	K. galanga, K. rotunda	Cultivated and naturalised	—
Globba	G. bulbifera, G. racemosa	Wild (forest understorey)	—
Amomum	A. subulatum, A. aromaticum	Wild and cultivated (large cardamom)	—
Elettaria	E. cardamomum	Cultivated (introduced)	—
Boesenbergia	B. rotunda	Cultivated and occasionally naturalised	—
Roscoea	R. purpurea, R. alpina	Wild (high-elevation)	—

Note: species counts and population numbers are to be completed from field survey data (see Section 3.2); the genus and representative-species list reflects the composition reported in the regional floristic and taxonomic literature reviewed for this study.

4.2 Habitat Preference

The habitat associations reported in the literature for the principal genera are broadly consistent with the general ecological character of the family as shade-tolerant to shade-loving understorey herbs of moist substrates, though with recognisable differences among genera that correspond to elevation, light, and moisture gradients.

- **Curcuma** species are generally associated with semi-shaded to moderately open situations in moist deciduous and subtropical forest, often on well-drained loamy soils; several species, including *C. longa*, are additionally cultivated in open agricultural fields, reflecting a broader ecological tolerance than most other genera in the family.
- **Zingiber** species favour moist, humus-rich soils in partially shaded forest understorey and forest-edge situations, frequently along streambanks and in seasonally moist depressions; *Z. officinale* is additionally cultivated under partial artificial shade.
- **Hedychium** species are characteristic of moist to wet forest understorey and forest margins at mid to high elevation in the Himalayan and sub-Himalayan region, often forming dense colonies along streams, in forest gaps, and on moist rocky slopes; several species tolerate cooler temperate conditions at higher elevation than most other genera recorded from the state.
- **Alpinia** species typically occupy shaded to semi-shaded, moisture-retentive sites in evergreen and moist deciduous forest of the Terai–Dooars and lower Himalayan foothills, often along stream margins and in forest interior.



- **Kaempferia** species are generally low-growing herbs of semi-shaded, well-drained sites, frequently associated with disturbed or cultivated ground as well as open forest floor, consistent with their common cultivation in homestead gardens across the plains districts.
- **Globba** species are shade-demanding understorey herbs restricted to relatively humid, undisturbed forest floor, particularly in the Himalayan and Terai–Dooars regions, and are generally regarded as more sensitive to canopy disturbance than the preceding genera.
- **Amomum** species, notably large cardamom (*A. subulatum*), are associated with cool, humid, shaded conditions under a forest canopy at mid to high elevation in the Darjeeling and Kalimpong hills, where the crop is traditionally cultivated as an understorey plant beneath retained native tree cover (a system locally termed "alder-cardamom" agroforestry).
- **Roscoea** species are restricted to relatively high-elevation, open to lightly shaded temperate and subalpine grassland and forest-margin habitats in the Darjeeling Himalaya, reflecting the greatest cold tolerance recorded within the family in the state.

Across genera, the literature consistently reports an association between Zingiberaceae occurrence and (i) a well-developed, moisture-retentive litter or humus layer, (ii) partial to substantial canopy shade, and (iii) freedom from prolonged waterlogging or salinity, with the principal axis of ecological differentiation among genera and species being elevation and associated temperature regime rather than moisture availability per se, since nearly all recorded taxa require consistently moist, well-drained substrates.

4.3 Ecological Distribution Across Regions

Table 4.2 summarises the expected and reported pattern of regional representation of the principal genera across the four physiographic regions defined in Section 2, drawn from the distribution ranges given in the taxonomic and floristic literature reviewed. This table is presented as a qualitative synthesis; the quantitative frequency and density of occurrence by region, needed for a full comparative diversity analysis, are to be generated from the field survey outlined in Section 3.

Table 4.2: Reported regional representation of principal Zingiberaceae genera in West Bengal

Genus	Himalayan/sub-Himalayan	Terai–Dooars	Gangetic plains/Rarh	Sundarbans
Curcuma	Present	Present	Present (cultivated)	Rare (homestead only)
Zingiber	Present	Present	Present (cultivated)	Rare (homestead only)
Hedychium	Abundant	Present	Sparse(cultivated ornamentals)	Absent
Alpinia	Present	Abundant	Sparse	Very rare
Kaempferia	Present	Present	Present (cultivated)	Rare (homestead only)
Globba	Present	Present	Very rare	Absent
Amomum	Abundant(mid–high elevation)	Sparse	Absent (wild)	Absent
Elettaria	Cultivated only	Absent	Absent	Absent



Genus	Himalayan/sub-Himalayan	Terai–Dooars	Gangetic plains/Rarh	Sundarbans
Roscoea	Present (high elevation only)	Absent	Absent	Absent

The overall pattern that emerges is one of clear regional gradation in family and generic richness, with the Himalayan and sub-Himalayan region and the Terai–Dooars together expected to account for the great majority of wild Zingiberaceae diversity recorded in the state, the Gangetic plains and Rarh region supporting a smaller wild component supplemented substantially by cultivated species, and the Sundarbans supporting only a very limited representation of the family, confined to homestead cultivation of economically important species such as turmeric and ginger on the relatively less saline landward fringe, consistent with the physiological salt- and inundation-intolerance general to the family.

4.4 Phenology and Economic and Ethnobotanical Significance

Flowering in most Zingiberaceae genera recorded from West Bengal is concentrated in the pre-monsoon and monsoon months (broadly April to September), coinciding with peak soil moisture availability, although some Himalayan genera such as *Roscoea* flower somewhat later in the season and some *Curcuma* species show a distinct dry-season dormant rhizome phase. Many species recorded from the state carry established economic and ethnobotanical importance: *Curcuma longa* (turmeric) and *Zingiber officinale* (ginger) as major spice and traditional-medicine crops of the plains; *Amomum subulatum* (large cardamom) as a significant hill-agriculture export crop of Darjeeling and Kalimpong; and numerous wild species of *Curcuma*, *Zingiber*, *Hedychium*, and *Kaempferia* reported in ethnobotanical surveys as sources of traditional remedies for digestive, respiratory, and dermatological conditions among indigenous and rural communities across the state. Several *Hedychium* and *Alpinia* species are additionally valued as ornamentals for their showy, often fragrant inflorescences.

4.5 Conservation Observations

Preliminary conservation concern, based on the literature reviewed, attaches particularly to wild, forest-restricted species with narrow elevational or habitat range in the Himalayan and Terai–Dooars regions, including several *Hedychium*, *Globba*, and *Roscoea* species, whose populations are potentially vulnerable to ongoing forest fragmentation, canopy disturbance associated with tea and cardamom cultivation expansion, and unregulated collection for the ornamental and traditional-medicine trade. A formal conservation status assessment for each recorded species, following IUCN criteria and incorporating population size and extent-of-occurrence data, is identified as a priority output of the field survey component of this study (Section 3.2).

V. DISCUSSION

The pattern synthesised in this study, of declining Zingiberaceae richness from the humid Himalayan foothills through the Terai–Dooars and Gangetic plains to the saline Sundarbans, is consistent with the well-established ecological character of the family as a group of shade-tolerant, moisture-demanding, salt-sensitive understorey herbs. This pattern mirrors similar regional gradients reported for the family elsewhere in the Eastern Himalayan foothill-to-plain transition, and reinforces the general principle that family-level ecological traits, in this case a shared requirement for humus-rich, well-drained, consistently moist substrate under at least partial canopy shade, can predict broad-scale distributional pattern even where individual genera and species differ considerably in their specific elevational and microhabitat preferences.

Within this general pattern, elevation emerges as the principal axis differentiating genera within the wetter, forested regions of the state. Genera such as *Amomum* and *Roscoea*, associated with cooler, mid- to high-elevation habitats of the Darjeeling Himalaya, are effectively excluded from the warmer lowland regions regardless of moisture availability,



whereas genera such as *Alpinia* and *Globba*, associated with warm, humid lowland and submontane forest, are correspondingly poorly represented at high elevation. *Curcuma*, *Zingiber*, and *Kaempferia*, by contrast, show the broadest apparent ecological amplitude across the state, a pattern plausibly related to the long history of cultivation and human-mediated dispersal of the economically important species within these genera, which may have extended their realised distribution well beyond that of their presumed wild progenitors.

The near-absence of the family from the Sundarbans is a particularly clear illustration of a physiological constraint operating at the ecosystem scale: even genera with otherwise wide ecological amplitude in the state, such as *Curcuma* and *Zingiber*, are confined in this region to homestead cultivation on the least saline landward margin, rather than occurring as naturalised or wild populations within the mangrove matrix itself. This observation is consistent with the general absence of the family from tidal, halomorphic habitats reported elsewhere in its global range, and underscores that the ecological distribution of *Zingiberaceae* in West Bengal is governed more by edaphic and hydrological constraints than by simple latitudinal or climatic zonation.

The comparatively higher richness attributed to the Gangetic plains and *Rarh* region relative to the Sundarbans, despite lower rainfall and more fragmented forest cover than the northern regions, appears attributable in large part to the substantial cultivated and homestead-garden component of the regional flora, particularly of *Curcuma*, *Zingiber*, and *Kaempferia*. This highlights a broader methodological point for floristic studies of economically important plant families: a regional species or occurrence count that does not distinguish wild, naturalised, and cultivated status risks conflating genuine ecological distribution with the distribution of agricultural and horticultural practice, a distinction this study has attempted to preserve by recording status alongside occurrence (Table 4.1) and one that should be rigorously maintained in the field survey component that follows.

The conservation observations arising from this synthesis, namely that narrow-range, forest-restricted wild species in the Himalayan and Terai–Dooars regions are the taxa of greatest concern, align with broader regional patterns of threat to Eastern Himalayan understorey flora from forest fragmentation, land-use conversion associated with tea and cardamom cultivation, and unregulated wild collection. Because several economically valuable genera in the family, notably *Amomum*, are themselves cultivated as forest-understorey crops, there is a plausible opportunity, that this study's field component is well placed to investigate further, for agroforestry systems that retain native canopy cover to also support the persistence of associated wild *Zingiberaceae* diversity, an outcome that would align conservation and livelihood objectives in the hill districts of the state.

VI. CONCLUSION

This synthesis indicates that West Bengal, by virtue of its unusually compressed environmental gradient from Himalayan foothill to deltaic coast, supports a floristically rich and ecologically well-differentiated assemblage of *Zingiberaceae*, concentrated overwhelmingly in the humid, forested Himalayan and sub-Himalayan and Terai–Dooars regions, present in reduced and substantially cultivation-influenced form across the Gangetic plains and *Rarh*, and virtually absent as a wild element from the saline Sundarbans. Habitat preference within the family is governed principally by canopy shade and substrate moisture at the family level, and by elevation-linked temperature tolerance at the genus level, with cultivated economic species such as turmeric, ginger, and large cardamom showing the broadest realised ecological amplitude owing to their long history of human cultivation.

The genus- and habitat-level synthesis presented here, and the survey and analysis framework set out in Section 3, are intended to provide both an interim reference account and a structured basis for the systematic field survey needed to generate the quantitative diversity, density, and distribution data that this synthesis has, at several points, identified as still required. Completion of that field survey, and the resulting formal conservation status assessment of narrow-range Himalayan and Terai–Dooars taxa, are recommended as the priority next steps arising from this study, together with continued documentation of the ethnobotanical knowledge associated with the family across the diverse communities of West Bengal.



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