A taxonomic review of the genus *Ocimum* L. (Ocimeae, Lamiaceae)

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**Abstract**

The plants of the genus *Ocimum* L. are rejuvenating herbs due to their aesthetic and magnanimous healing nature. *Ocimum* L. is a pivot of modern research such as phytochemistry, molecular and medicinal biology. However, there needs to be more taxonomic interpretation and identification of the genus, summing up the need for our study. The morphological discrepancies and nomenclature of *Ocimum* L. are jumbled up, the same species has been named multiple times by multiple authors. It culminates in erroneous evaluation for taxonomy-based research. Our indignation highlights the taxonomic alterations and modifications that *Ocimum* L. has undergone since primeval period. The genus's classical to the modern taxonomic transition has not been studied hitherto. The aim is to provide precise information on the antecedent and contemporary stature of *Ocimum* L. The present study attempts to provide taxonomic clarity for a highly economic genus in order to enhance the commercial perspective and efficiency of selective breeding practices. The present study emphasizes identifying samples with their type, protologue, and herbarium specimen and extricate between ecotype, morphotype, and chemotypes. Molecular taxonomy can provide better insights and transparency. But for a better exposition, such studies must revolve around correctly identified species. The selection of representatives from different populations of the same species can help understand the consistency of vegetative and reproductive characteristics. In this review, few corrections have been provided for misidentified or mistaken species. The species with incorrect nomenclature has been identified and corrections have been suggested. For a better understanding, habit photographs of Indian *Ocimum* L. have been furnished and morphological features (vegetative and reproductive) for proper diagnosis and correlation has been provided. Specimen examination either through physical or digital herbaria is an obligatory criterion for an error-free taxonomic inquest. Our findings will help to achieve accuracy while interpreting the genus and its species. The retrospection will aid in floristic, biodiversity, taxonomic, phylogenetic, biochemistry and molecular systematic related works. The observations will apprehend the existing gap concerning the taxonomy of *Ocimum* L.

**Keywords**

*Ocimum*; identification; morphology; molecular; taxonomy

**Introduction**

The 'Empress of all herbs' Basil is known as Tulsi or Tulasi in Hindi, an incarnation of Hindu goddess Lakshmi. The term 'Basil' descended from the Greek word 'Basileus/Basilikos,' which means princely or Royal. The plants...
can be given in Kings Hand or Royal House because of its astounding fragrance (1). Basil is a term that manifests all the aromatic members of Ocimum L. The genus 'Ocimum' signifies fragrant-lipped, a term procured from 'okimon' and 'ozein,' which purports the herbs having smell or odor. 'Ocimum' is a Latinized term derived from the ancient Greek word 'Οκἰμον' (Okimon) owing to an ending 'um,' which implies neuter genera. The earliest reference to 'Οκĩμον' was put forward by Theophrastus (2). The genus erstwhile named Basil (2), Okiminn / Okimon / Akinos / Okimoides / Okimone / Ocimane / Ocimae / Ocimum (3), Ocymun (1,4,7), Ocicum (4,5,6), Ozymum (7), Ocyms / Oyco (1,8), Basilic (9,10), Ocimon / Okimon (11), Ozymun / Ozimum (12).

Ocimum L. is native to warm tropical and temperate regions. The primary centre of origin is Africa (most species are confined to this continent), Tropical Asia, Central and South America, while the secondary origin is India (13). Ocimum L. is chiefly an East Indian genus (6). It is an indigenous genus of India, and its species are dispersed throughout the country. Ocimum L. belongs to the tribe Ocimeae Dumort., subfamily Nepetoideae (Dumortier) Luersson, the largest group of the mint family Lamiaceae Martinov. The tribe Ocimeae Dumort. is the most speciose group incorporating nine genera distributed in the tropics and subtropics. Ocimum L. is the type genus of Ocimaeae, specified with concave compressed corolla lip, declimate stamens, synaceous anthers, and explosively releasing pollen (14). Dumortier first traced Ocymaeae (=Ocimeae); subsequently, Bentham described it as Ocimideaee (Ocyimeoideae). As the name doesn’t accord with ICBN, it was rectified into Ocimeae. Briquet carved Ocimeae (Ocimoideae) into three subtribes Hyptidinae, Moschosminae (=Ociminae), and Plectranthinae (15). Ocimeae Dumort. was split into sub-tribe Hyptidinae, Hanceolinae, and Ociminae (including Basilicum, Orthosiphon, Ocimum, and Platostoma) (16). The sub-tribe Ociminae (Dumont). Schmidt was first introduced by Ryding while studying the pericarp structure of Ocimeae Dumort. where sub-tribe Ociminae split up into three informal groups. The Ocimum group holds Ocimum L. with Becium Lindl., Erythrochlamys Gürke, Hemizygia (Benth.) Briq. and Syncolostemon E. Mey. ex Benth. (17).

Numerous nomenclature and classification disputes have muddled up the genus. Furthermore, we have perceived the same while examining the pieces of literature. The complexity and confusion are due to polyploidy and intra and inter-specific hybridization. It resulted in plants with vast morphological variations, leading the way for many subspecies, varieties, and form. Such forms have created uncertainty, accentuating the need to revise the taxonomy (18). Due to immense morphological variability, the genus is convoluted regarding phylogenetic relationships. The tribe Ocimeae, the largest group in Lamiaceae in South East (S.E) Asia, consists of nine genera and the tribe badly needs revision (16). The taxonomic complexity has been studied by Paton (19), Khosla (20), and Grayer et al. (21). The Indian literature furnishing the taxonomy of Ocimum L. based on cytology and phytochemistry is somewhat complicated (20). A taxonomy and phylogeny study reported seven species of Ocimum L. in India (22). Their description as a taxonomic revision of Ocimum L. must be more supportive. A revision needs rigorous and extensive analysis of a taxon, herbarium specimen analysis, interpretations, corrections, historical account, and developments. Few exemplary taxonomic works have been put through, a synopsis (19) and a revision of Ocimaeeae in S.E Asia (16). In India, no such taxonomic study has been accomplished for Ocimum L.

Ocimum L. constitutes annual herbaceous, fragrant members and a few perennial shrubs. The species of Ocimum L. are widely cultivated and naturalized in open or disturbed areas, roadside, and forest areas. Few species are cultivated commercially and kept as pot herbs in homes and gardens. The Basil is characterized by the presence of the upper lope of the calyx, which is large and decurrent. The plants in the genus are sweet-scented herbs or shrubs. Stem – quadrangular; Leaves – spreading, green or purplish green; Inflorescence – dense or lax; Bracts – ovate or obovate, sessile or sub sessile; Flowers – verticillate spiked, terminal or axillary; Pedicel – slender, pubescent, same or longer than calyx; Calyx – two lipped, upper one wider, rounded and lower lip four toothed; Corolla – tube short, two-lipped, superior lip equally four fids, inferior lip longer; Corolla–cinnamon, pinkish white or white, purple white, lobes pubescent on back, posterior lip with two obvate oblong median lobes slightly longer or equal than two oblong lateral lobes, anterior lip obovate oblong; Stamens – four, filaments declimate, out of which two are shorter; stamens posterior pair may have a small tuft of hairs at base; Gynoecium – style with two sub equal lobes; nutlets oblong, smooth or rough, may or may not be mucilaginous when wet. (Fig. 1).

The taxonomic study of Ocimum L. needs to be explored more. The present study is an attempt to surmount the drawback. The work enumerates the correct taxonomic knowledge and identification of the Ocimum L. species. Accurate identification will help in applied research to get more authenticated results while implementing Ocimum L. analysis. The notes obtained from the literature were framed for reviewing the taxonomic status of the genus with a more conclusive and precise outcome. Our work is an effort to streamline the taxonomical ramifications of Ocimum L.

Materials and Methods

The review has been done using web sources of BHL, Google Books, Internet Archive, JSTOR, NCBI, PubMed, Science Direct, Scopus, Smithsonian Library, Springer, Web of Science, etc. We have also gathered information from relevant literature (Floras, Journals, Records, Revisions) available at BSI, Shillong. The classical pieces of literature incorporated in the citation of homotypic and heterotypic synonyms of Ocimum L. were examined. The research articles primarily searched for review, taxonomy, revision, and florras executing Ocimum L. The inputs were retrieved using search terms/keywords such as Basil, Basil in India, Basil and its uses, diversity of tulsi, Ocimum species,
Fig. 1. Representative of Ocimum L. (O. tenuiflorum L.) (A) habit (B) adaxial view of leaf (C) abaxial view of leaf (D) inflorescence (E) inflorescence tip (ia-inflorescence axis; fb-flower bract) (F) closure view of inflorescence showing floral arrangement (G) complete flower along with fruiting calyx (fc) and flower pedicel (fp) (H) bract I calyx (J) corolla showing epipetalous stamen (K) gynoecium exhibiting gynobasic style (gs), bifid stigma (bs) and ovary (o) (L) ovary T.S revealing ovules (ov), ovary locule (ol) and placenta (op) (M) nutlets. ©Mamita Kalita.

Ocimum research articles, marker-based study in Ocimum,
molecular taxonomy of basil, taxonomic revision, morphology and taxonomy of *Ocimum*, etc. Only the significant, definitive, and peer-reviewed research articles on *Ocimum* L. were included in our analysis. The poor research findings and contradictory records were excluded, along with data obtained from dubious and predatory journals. All the relevant facts and particulars of *Ocimum* L. were acquired, analyzed, and reviewed under five sections: The initial system of classification includes the early position of the genus between the 16th to 19th centuries; the second section describes the classification of the phylogenetic system followed by the ongoing status of the genera. The fourth and fifth sections included the documentation on Indian *Ocimum* L. and current taxonomic inquests, respectively.

The photographs of six *Ocimum* L. species were captured using a digital camera (Fig. 2). The habit, vegetative and floral characteristics were studied by alluring a representative of the genus (*O. tenuiflorum* L.), collected during the flowering and fruiting phase (Fig. 1). The micro-morphological features were investigated using a Labomed CZM4 stereo zoom binocular microscope, and photo plates were prepared using Adobe Photoshop 7.0. The *Ocimum* L. representatives were analyzed with their type specimens, consulting regional and national herbaria, such as ARUN, ASSAM, CAL (acronyms given by the Botanical Survey of India) and GUBH. The microfilms of herbarium specimens from online databases BSI-IHV, JSTOR, KEW, G, MNHN, MO, and NY were also consulted for correct interpretations and conclusions.

**Results**

**The initial system of classification**

In the artificial (arbitrary) system of classification, Theophrastus tells of Basil (*O. basilicum*) as herbaceous plants with woody roots, flowering for a long duration (2). According to Pliny, the Elder *Ocimum* must be avoided as it is detrimental to human health, similar to the belief of Chrysippus. He mentioned around 35 remedies of *Ocimum* used by people in succeeding ages (23). Dioscorides sketched out *Ocimum* (Basil) in aromatics (*Okiminon*), living creatures (*Okimon*), roots (*Akinos*), and other herbs and roots in *Okimoides* (*Ocimoideae*). Four species exist in *Okiminon* and *Okimone*; one in *Akinos*; two in *Okimoides*. The *Akinos* and *Okimoides* are also familiar as *Ocimastrum* (a name given by Romans) (3). Casper Bauhin cited *Ocimum* as *Okimon Dioscoridi*, a more than hundred-year-old odoriferous genera with 11 species. The species differ in leaf size, aroma, and corolla color. The 11 species and their synonyms were named as per the binomial system of nomenclature (24). Andrea Caesalpino kept *Ocymum* inside *Ocimoideae*, which, in turn, contained herbs and suffruticose (perennial herbs having a woody base) (4). John Ray tells of *Ocimum/Ocymum* (*De Ocymo–Basil*) as plants with
spiked spiral flower arrangements (Verticillatis). While describing the transformation of species into plants, he brought up Ocimum into Serpillum. He has also, mentioned five species, Ocimum, O. vulgatissum, O. minimum, O. indicum, O. minus angustifolium folis serratis (polynomial name) in Floricereae of Herbcea (Herbaceous plants) (1). Tournefort availed only corolla features, construe Ocimum (Basilic) as single petal flower (labiate) with upper corolla erect and lower curly. He set the genus in 4th class De herbis & sufricribus, flore monopetalio, labiato (single petal, lipped flower, herbs and suffruticose in habit) of group Simplices Monopetaloi, Petaloids within Herbceae (9). In his Bibliotheca Botanica, Linnaeus appraises Dioscoridaes and Theophrastus as exceptional Phytoplogists. In 1742, Linnaeus classified Ocymum in the 14th class Didynamia (four stamens in pairs of unequal length), order Gymnospermia (5), besides other Labiatae Juss. genera. (=Lamiaceae, I.CN 2017, Article 18.5). Later, he placed the genus Ocymum in Verticillatae. He considered the basal tooth region of upper stamina (stamens) as an essential and universal characteristic of Ocymum L. He depicted five species (O. frutescens, O. basilicum, O. minimum, O. tenuiflorum, O. menthoodues) (25). Rumphius described three Ocimum (=Ozimum) species as Basilicum agreste, B. indicum, and Ozimum citratum (12). A Commentary by Linnaeus (8), comprehends B. agreste as Ocymum gratissimum, B. indicum as Ocymum, Ozimum citratum as O. tenuiflorum, and Majana rubra as O. frutescens. Majana rubra was erroneously reduced by Linnaeus to O. frutescens. While recognizing the error, Linnaeus made Rumphian description and figure as a fundamental basis of Ocimum l. the base of Coleus scutellarioides Lenth. He further described Ocimum as a genus having two-lipped calyx, i.e., Calyces bilabiata (26). B. agreste Rumph. (as incarnated in Herbarium Amboinense) reduced as Ocimum tenuiflorum, supplementing three additional species as O. gratissimum, O. americanus, and O. scutellarioides (27). In light of the natural system of classification (based on natural affinities), Michael Adanson emphasized floral characteristics, raising Ocimum Tourn. (vertical spike flower, calyx five-toothed) as Ocimum Lat., Okimon Ippork, Bas- silic Gall. (Lat-Latin; Ippork-Hippokrate and his work; Gall-Barrelier and his work) (11). A.L De Jussieu placed Ocimum L. (Basilic) in the fourth category of 6th order Labiatae, characterized by bilabiate calyx, bilobed corolla, and four fertile stamens. Labiatae, in turn, placed in the 8th class (Corolla hypogyna) of Monopetalae amongst Dictolydodeae (28). A.P. de Candolle allocates Labiatae in Irregulararies (unequal or dissimilar lobes) of Gamopetalae with lobes arranged in valves or lips (29). Lamarck epitomizes 21 species of Ocymum as BASILIC (10) and, together with Candolle, gave an account of BASILIC (30). They put forth three species, Ocymum basilicum as Basilic commum, O. bulla- tum as B. crepu, and O. minimum as B. nain. Ocimum L. was placed in the subtribe Eucoimeae of the tribe Ocimodaeae (31,32). Ocimum L., held in tribe Ocimodaeae (having declinate stamens) under 150th order Labiatae, was quartered into four sections based on filament features, Ocimodon Benth. (19 species), Hemizygia Benth. (15 species), Hieroci- mum Benth. (11 species), and Gymnocium Benth. (08 species) along with 43 species placed in Species exclusae, a list of species excluded from Ocimum L. and identified as different species (33). Stephan Endlicher located Ocimum L. in sub-tribe Moschosmeae (corolla subequal, lowest one declinate, narrower and flat), tribe Oscomoideae Benth. (declinate stamens, lobes of two or four upper planes are subequal) in order Labiatae, cohort Gamopetalae of fourth section Acrampiphrya (peripheral terminal vegetation) (34). Bentham and Hooker placed deflexed fruiting calyx Ocimum L. in the subtribe Eucoimeae (four sub-equal corolla lobes, calyx lobe or posterior tooth is wider than rest) of tribe Oscimoideae (four perfect declinate stamens, rarely two). The tribe was set in Labiatae of series Bicarpellatae (hypogynous, stamens as many as corolla lobes), sub-class Gamopetalae (united petals), class Dictolydones (two cotleyledons, pentamorous or tetramerous flowers) of Phan- erogams (31). Bentham’s first remarkable botanical contribution relates to 11 species in Labiatae genera in the Ocymum section. He considered the dercurtum margins of the calyx’s upper tooth and the corolla’s flat lower lip as distinguishing characteristics of the genus. Moreover, he recognized nine O. basilicum L. varieties for the first time. Bentham suggested considering them as varieties originating in gardens, which might have arisen from two wild species, O. basilicum var. pilosum and O. basilicum var. glabratum (6). Later, he segregated the tribe Oscimoideae into three sections, Ocymodon Benth., Hierocymum Benth., and Gym- nocyum Benth. The tribe Oscimoideae was first published in the article Labiatae and later carved into the sub-section Eucoimeae and Lavanduleae (31). Ocimum L. was erroneously considered Becium Lindl., Erythrochlamys Gürke., Hyperaspi Briq., and Naucotilus Bremek. Becium Lindl. set out by Lindley (35) contains 35 species. He appraises the dissimilarity of Becium Lindl. from other Oscimodeae genera. Engler brought Erythrochlamys Gürke as a new genus (36). Hyperaspi gen. nov. was first encountered by Briquet together with one species (37). He suggested that Hyperaspi Briq, differ from all other members of Oscimodeae, occupying the group of Oscimodeae-Moschosminae, a special place with marked affinities for Erythrochlamys Gürke and Ocimum L. Ocimum L. in light of the phylogenetic system of classification A.W. Eichler developed the first evolutionary or phyloge- netic system. He cited O. basilicum (kitchen and oil perfumery usage) in series Labiatiflorae (didynamous stamens), situated in Sympetaleae (fused petals), class Dicoty- ldae (dicots), division Angiospermae of sub kingdom Phanerogamae (seed plants). His classification scheme (38) became the foundation for the Engler system. Engler and Prantl relate Ocimum L. including Becium (einsch. Bectum Lindl.) in Oscimodeae-Moschosminae, sub-class Metachlamydae (Sympetaleae) segregating from genus Hemizygia Briq. and Erythrochlamys Gürke. They cleave Ocimum L. into three sections Ocimodon Benth. (rear stamens with an appendage at base), Hierocymum Benth.
(tufts of hair present and without appendage at the bottom), and *Gymnocicum* Bentham. (bare without appendage). They further split Sect. *Ocimodon* Bentham into *Basilica* Briq., *Gratisisma* Bentham. and *Hiantia* Bentham. based on calyx features (39).

Bessey's classification (40) was modern, revised, and developed on Benthamian classification. Lamiiales were held in super-order Strobiloideae-Sympetalae-Polycarpellatae (carpels many, petals united, actinomorphic), class Oppositifolia (Dicotyledoneae) of phylum Anthophyta (flowering plants). He stated the origin of Oppositifolia from Cycadean (gymnosperm), which orderly evolved into progressive groups. The former has sequentially evolved into syncarps to polycarpellate to Dicarpellate, having Gentianales, Polemoniales, Scorpiulariales, and Lamiiales (characterized by strobiloid flower). The strobiloid attribute was also recognized by Hans Hallier. His classification of phylogeny was parallel to the Besseyan system, both adhering to the monophyletic origin of phyla (41). Hutchinson arranged families of flowering plants based on probable phylogeny placing *Ocimum* L. (odoriferous, herbaceous, and rarely woody) in the last family Labiatae of division Herbacea (annual, biennial, perennial herb or shrubs derived from herbs), sub-phylum Dicotyledons and phylum Angiospermae (42). Takhtajan carves *Ocimum* L. including *Becium* Lindl., *Erythrochlamys* Gürke. and *Naoutchilus* Brenek. in subtribe Ocinæae, tribe Nepetoideae, super-order Lamianae (also called Lamiflorae), sub-class Lamiidae together with Lamiæ and Lamiaceae kept in Magnoliopsida (dicot flowering plants) (43). Arthur Cronquist propounds a similar scheme of the Takhtajan classification. He advocated parallel evolution in the gymnoceium of Lamiæ, an order allied to Solanales and Gentianæae. Lamiæ was retained in the sub-class Asteridae, which he communes as the most advance and recently evolved. Most of the Sympetalæ members of the Engler system belong to the Asteridae. The evolution corresponds with the evolutions of pollinating agents such as insects. Lamiaceae of Asteridae is an advanced family arranged along with three other families (Boraginaeae, Lennoaceae, and Verbenaeae) (44).

The genus is monophyletic in origin (45) if the restrained genera *Becium* Lindl. and *Erythrochlamys* Gürke are included within it. Ocinæae Dumort. is monophyletic, which embraces monophyletic subtribes *Lavandulanae*, *Hyptidinae*, *Ocininae*, and *Plectranthinae* (46). Takhtajan, Cronquist, and Hutchinson had complementary opinions regarding the monophyletic theory of evolution. However, Engler & Prantl's classification system trusted in polyphyletic origin, and Thorne's perception is paraphyletic. In the contemporary world, a more appropriate, stable, and advanced (molecular-based) phylogenetic classification exists, i.e., APG (Angiosperm phylogeny Group) classification, which supports the monophyletic origin of Angiosperms. In APG, *Ocimium* L. is positioned in sub tribe Ocinæae Dumortier along with eight other genera. The order Lamiæ (inclusive of sub-family Nepetoideae, family Lamiaæae) was also treated as monophyletic and placed in Euasterids I of clade Asterids (47). Given APG III, Lamiæ was allocated in the clade Lamiales (synonym of Euasterids) of Asterids. Also, it was accustomed to the Takhtajan classification having more admissibility as he favored small and natural groups where characteristics could be easily held up (48). In recent APG IV, Asterids placed in Superasterids with newly introduced and related orders of Lamiales (Icacinæae, Metteniæae, Vahliaæae) (14).

**Current status of Ocimum L.**

ICN rules have frequently not been applied in naming the species of the genus; the same species has been named numerous times (45). A few taxonomic statements were appended (49) while describing six species of *Ocimum* L., so the genus is represented as *Ocimum* L. emend. (ICN Article 47.1). The nomenclature entanglement of the genus is such that 463 names are subjugated in *Ocimum* L., which includes 291 synonyms, 144 accepted, 18 unchecked, and 10 ambiguous (50). Following the records, there are 118 species of *Ocimum* L., including 97 accepted and 21 doubtful names (51). Over 2022, the same database counted 117 species of *Ocimum* L. inclusive of 105 accepted and 12 doubtful. Globally, *Ocimum* L. is represented by 150 species (52) and 64 species (45). There are 65 truly accepted species, 8 sub species, and 9 varieties of *Ocimum* L. distributed pantropically (53). The only vulnerable species is *O. fischeri* Gürke, and the endangered ones are *O. urundense* Robyns & Lebrun, according to IUCN red list 2011 and 2016, respectively (54). Considering the tree definition given by IUCN's Global Tree Specialist Group (GTSG), *O. ellenbeckii* Gürke and *O. grandiflorum* Lam. are the two tree species of *Ocimum* L. (55). *Ocimum × africanum* Loure. is a nothospecies (ICN Article 3.2) resulting from a cross between *O. americanum* L. (hoary Basil) and *O. basilicum* L. (sweet Basil). There are three autonyms (ICN Article 26.1) in *Ocimum* L., *O. gratissimum* subssp. *gratissimum* var. *basilicum*, *O. gratissimum* var. *basilicum*. The *Ocimum* section *Hierocylum* endure *O. tenuiflorum* L., and the *Ocimum* section *Ocimum* comprises *O. americanum* L., *O. basilicum* L., *O. forskoelei* Bentham., and *O. kilimandscharicum* Gürke. The former section has been referred to as the Sanctum group (56) and the latter as the Basilicum group (20). Such infrageneric classification delineating *Ocimum* L. into Basilicum and Sanctum groups is frequently used in economic and industrial literature (52,57). Such a classificatory system should not be used as a standard as the classification does not comply with ICN (45).

The type specimen of *Ocimum* L. is Lectotype (LT): *Ocimum basilicum* L., designated by N. L. Britton et Millspaugh, Bahama Fl. 380. 26. 1920. The Indian subcontinent is epitomized by seven species, two sub-species, and four varieties. The species are: *Ocimum africanum* Lour. (specific epithet *africanum* refers to its wide distribution in the continent of Tropical Africa), *O. americanum* L. (American signifies the nativity or origin being America), *O. basilicum* L. (basilicum and basilicos term commend as royal), *O. filamentosum* Forssk. (filament is marked and osum–fully developed) *O. gratissimum* L. (gratissimum explains an exaggerated expression of pleasantness due to the aroma), *O. kilimandscharicum* Gürke (‘kil’ suggests the species origin from the Kilimanjaro hills of Kenya, and

**Contemporary documentation**

The Indian origin, O. tenuiflorum L. (holy Basil), is recognized as African cultivated species (16). The species is incorrectly known as O. sanctum L. (currently synonym) which emulates the vernacular name holy Basil (20). It is considered an environmental weed invasive to India. The Sanskrit authors have distinguished two varieties of holy Basil based on the differences in leaf color. However, they are a cultivar of O. tenuiflorum L. (cv. Radha and cv. Krishna), originating through selective breeding. National Medicinal Plants Board (NMPB 2019) prioritized O. tenuiflorum L. among 32 medicinal plants that need conservation. A similar species in appearance, growth, and habitat is O. kilimandscharicum Gürke (camphor basil). The species is alien to Indian flora. The exotic camphor-yielding plant is found in both wild and cultivated states. The species was imported from India in 1953 and cultivated in Thailand (16). During the physical herbarium visit at CAL, we found a few write-ups in herbarium sheets and by correlating all of them we can conclude that Camphor basil seeds were acquired by BSI, Shillong from Forest Research Institute, Dehradun in 1949 and successfully grown in Batasipur, Rangapahar, Umsaw experimental garden of the North East province. We found that O. kilimandscharicum Gürke herbarium specimens present in ASSAM were prepared either from Nursery or Dehradun during 1949-50. Dr. Janaki Ammal (Director, BSA, during 1952) might have procured the nursery specimen (BSA 4993) from ASSAM. This might be why several documentations has stated its distribution in N.E. India. We have discerned no herbarium specimens from CAL and ARUN. The species is not being reported from N.E. India in wild circumstances, as validated by POWO (Plants of the World Online). Another specimen was received by ASSAM herbarium from CDRL (CSIR-Drug Research Laboratory) Jammu & Kashmir on 07-07-1959 (exotic from Kenya); however, it is the deficit of accession number.

O. filamentosum Forsk. (long-stamen basil) was earlier known as O. adscendens Willd. On examining, O. adscendens Willd. at KEW, Harley found resemblances with Becium Lindl. He documented Becium Lindl. as a new distributional record to India because of Becium filamentosum Forsk. Chiov. and concluded O. adscendens Willd. as a synonym (67). However, the former species is a basionym and homotypic synonym of O. filamentosum Forsk. Another physical scrutiny of a herbarium specimen is the type specimen present in CAL herbarium. Ocimum exsul Collett et Hemsl. (CAL0000020414/415) is a member of Becium Lindl. and a synonym of Ocimum filamentosum Forsk. which in turn, is a basionym of Becium filamentosum (Forsk.) Chiov. Becium Lindl. (type: Becium bicolor Lindl.) was subjugated as separate genera of Labiatae (68). However, Becium Lindl., Hyperaspis Briq., Erythrochlamys Gürke, and Naoutochilus Bremek. now remain as synonyms.
of Ocimum L. The Neotype (LINN-749.2) of O. gratissimum L. (clove basil) is a cultivated species of Uppsala, originally from India (19). Suddee et al. recognized two varieties of O. gratissimum L. subsp. gratissimum (var. gratissimum and var. macrophyllum) and their distribution from India. Var. macrophyllum is distinct from var. gratissimum in having lax inflorescence and sparse indumentum. This incarcera
tion is held up by referencing Indian material, where the
discontinuity between the two varieties is also supported.
Also, var. macrophyllum was introduced from or to India
and later disseminated through African cultivation (16).

O. americanum sensu A.J. Paton is a north Indian
native species, more minor than O. basilicum L., some-
times called O. canum Sims. (69). The correct nomenclu-
ture for the former is O. americanum L. The type specimens
were regarded as different (13), although they were con-
cluded as the same based on the observations of Paton
and Putievsky (69). They suggested the voucher specimen of
O. canum Sims in the rise of such ambiguity. (13) re-
ferred to as interpretative Epytype for both O. americanum
L. and O. canum Sims. (69). Paton considers two varieties
of O. americanum sensu A.J. Paton., var. americanum and
var. pilosum (Willd.) based on stem indumentum. He con-
Sizer O. basilicum var. pilosum as the type specimen of
O. americanum var. pilosum (Willd) Paton (19), now recog-
ized as a synonym of O. africanum Lour. (lemon basil).
Although O. americanum var. americanum is incognito and var.
pilosum (Willd.) is a species called O. africanum Lour.
(=Ocimum × citriodorum Vis.). The O. americanum L. (hoary
Basil) and O. basilicum L. (sweet Basil) cross resulted in O. ×
citriodorum Vis. (13), a correct name for O. americanum
sensu Push pangadan & Sobti non L. (69). The epithet citri-
odorum has been frequently used as a basionym for treat-
ing the entity at the infraspecific rank of O. basilicum L.
(57). The Bush basil O. minimum L. was considered as a
variety of O. basilicum L. (13, 57) but is often mentioned as
a separate species (19,69). However, it is a varietal syno-
nym for O. basilicum var. minimum (L) Alef. (53).

Current status on the taxonomic research
In Ocimum L., inter and intra-specific hybridization results
in cultivars, chemotypes, and plants with vast morphologi-
cal variation. According to Paton, morphological traits
alone are unreliable to substantiate results when the char-
acters overlap. Molecular taxonomic and morphological
studies provide authenticity regarding identification, char-
acterization, phylogeny, and classification based on
shared traits. RAPD (Random amplification of polymorphic
DNA) studies have shown that O. africanum Lour. And O.
basilicum L. are different species, and both are related to
O. americanum L. (70). At CAL herbaria, we have come ac-
ross the specimen of T. Chowdury (O. citriodorum,
DDTC-317, 22-10-2015, no accession number), we conclude
it correct with rectification in nomenclature as O. african-
um Lour.

In view of Kumar et al. (71), the phylogeny and tax-
onomy of Ocimum L. are doubtful. They performed ISSR
(Intersimple sequence repeats) and psbA-trnH (non-
coding fragment between psbA and trnH of chloroplast
gene) markers genotyping for Ocimum L. They found
the former more effective. Based on phylogeny, the spe-
cies were bunched into three groups, Basilicum, Gratissi-
mum, and Sanctum. The genotyping revealed the close-
ness of Basilicum-Sanctum and Gratissimum-Basilicum
groups predominated through ISSR and psbA-trnH, re-
spectively (Fig. 3). The interpretation seems correct and ana-
logous to the groupings of Engler and Prantl (39) and Paton
(19). Based on morphological interpretations, the present
study suggests both Basilicum (O. basilicum L., O. afric-
orum Lour. O. americanum L., O kilimandscharicum Gürke)
and Sanctum (O. tenuiflorum L., O. filamentosum Forssk.)
as concomitant. O kilimandscharicum Gürke might act as a
knot (link) between the two groups. They further claim O.
viride Willd. and O. gratissimum L. as different species and
used them in their phylogenetic analysis. On close exa-
nination of the images provided in their study (71) we found
it as either chemotypes or ecotypes of O. gratissimum L.
O. viride Willd. is incognito and exists only as a synonym for
O. gratissimum L. Also, O. adscendens Willd. is an ordinal
synonym of O. filamentosum Forssk. nevertheless, the
image of the species is correctly identified.

Six Ocimum L. species and six varieties of O. basili-
cum L. were investigated through nuclear DNA content and
chromosome number (72). The results suggested the prev-
ance of infra-generic groups within Ocimum L. They sug-
gested O. basilicum clade (varieties, cultivars of O. basili-
cum and O. minimum) are tetraploids and O. americanum
clade (O. basilicum var. purpurascens, O. africanum, O. afric-
num) as hexaploids. Our observation suggests that
both clades, in a true sense, form the Basilicum sub-
section of Ocimum L. However, the differences in ploidy
might be due to the use of cultivars and varieties (not true
species) for their study and O. minimum L. var. purpu-
rascens is no more valid, O. minimum L. (=O. basilicum var.
minimum (L) Alef.) is a variety, and var. purpurascens
doesn’t exists.

Four clusters of Ocimum L. supported by high boot-
strap values of AFLP (Amplified fragment length polymor-
phism) are O. africanum/O. americanum, O. basilicum, O.
gratissimum, and O. tenuiflorum. In the Neighbor-joining
(NJ) analysis, six accessions of O. basilicum ‘Erevanskii’
came within O. basilicum (cluster) and hinge on O. afric-
umum/O. africanum (cluster) due to parsimony analysis. O.
kilimandscharicum Gürke was away from both the clusters;
however, it has more affinity with O. africanum/O. ameri-
cum and O. tenuiflorum but has a low bootstrap percent-
age (73). ISSR and RAPD interpretation shows species-
specific DNA fragments in O. sanctum L. and O. basilicum L.
The amplicons, which are unique and don’t show intra-
specific polymorphism, were regarded as species-specific
markers. No such amplicons were recovered in O. americi-
um L. and O. polystachyon L. (74). They found shuffling of
O. polystachyon L. amidst O. basilicum L. genotypes; the
reason might be the non-existence of the former. It can be
a form of O. basilicum L. (presently a synonym).

The species of Ocimum L. were validated using three
barcodes rbcL (ribulose-1,5-bisphosphate carboxylase/
oxidogenase large subunit), matK (Maturase K), and psbA-
trnH of the chloroplast genome. The psbA-trnH spacer was more useful as a discrimination tool since it gives more variation at the inter-species level (75). They pointed to the morphological similarity between *O. tenuiflorum* L. and *O. filamentosum* Forssk. The image of the latter has been mis-identified since it is devoid of peculiar characteristics (serrated, ovate-oblong leaves, 3-5 cm raceme with few distant verticils) of *O. filamentosum* Forssk. Another molecular scrutiny related to ScoT (Start Codon Targeted) polymorphism of *Ocimum* L. has shown more polymorphic

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**Fig. 3.** Phylogram/dendrogram showing *Ocimum* L. species in three cluster Basilicum, Sanctum and Gratissimum using NJ (neighbour joining) method among seven species of *Ocimum* L. The phylogenetic trees are resulted from A ISSR, showing more efficiency in clustering than B psbA-trnH dataset; the groups are illustrated through floral representative, (a) *Ocimum basilicum* L. (b) *Ocimum tenuiflorum* L. (c) *Ocimum gratissimum* L.

**Source:** (A and B) reproduced with permission from Kumar et al. (2016); (a-c) ©Mamita Kalita
percentage than ISSR. The dendrogram obtained from ScoT analysis is well-founded, justifiable, and informative compared to ISSR. Two species (O. viride and O. sanctum) have been out-grouped (76), possibly due to poor diagnosis during species identification. O. viride Willd. is currently regarded as a synonym of O. gratissimum L. subsp. gratissimum.

Plastid markers rbcl, matK, trn L-F, trnH-psbA are suitable in the formation of the exclusive monophyletic clade of O. tenuiflorum L. and another clade having O. africanaum Lour., O. americanum L., O. basilicum L., and O. kilimandscharicum Gürke. Such differences in clade formation are due to high divergence showing a long history of evolution in comparison to low divergence that leads to clustering (77). The species O. tenuiflorum Vana 8258 is mis-identified, the correction is given as O. americanum L. Also, rectifying image O. tenuiflorum 5751 as O. campechianum Mill. and O. campechianum 7564 as O. tenuiflorum L. The genus Ocimum L. is diversified with heterogeneity in forms, cultivars, varieties, hybrids, and ecotypes. The inter and intra-crossing tendency results in morphotypes and chemotypes. The genotype controls the chemotype; however, developmental and environment-related patterns regulate their expression. In keeping with Jurges et al. (2018), photon quality modulates the development and responses of oil glands (essential oil in Ocimum L.). Again, the magnitude of secondary metabolites revolves around the plant’s age, light concentration, and other abiotic factors. So, the plants of Ocimum L. have morphological diverseness together with varied bioactive compounds profile.

Conclusion

The present study has primarily focused on Ocimum L. (taxonomic background) and its species distributed in India. We have tracked down much antiquity literature for better understanding and inference. In our study, we have analyzed the taxonomic position of Ocimum L. in artificial, natural, and phylogenetic classification systems, demarcating the features and criteria used for the hierarchical arrangement. Also, photographic representation of the habit, micro-morphological features have given a clear understanding in anticipating Ocimum L. Further, we had extricated the documentation based on Indian Ocimum L. to know the taxonomic development route of the genus. The molecular taxonomy specifics of Ocimum L. were evaluated to correlate with classical taxonomy (morphology based). The phylogenetic clades obtained from marker genotyping were close to phenetic dendrograms. For molecular and biochemistry based research, we encourage proper validation and identification of specimens before experimentation. It has helped us in reaching clarity and a conclusion. The hybridization tendencies of specific and infra-specific taxa are high, and with 65 species, we can expect a magnificent divergence. The frequent misinterpretations occur between O. africanaum Lour./ O. basilicum L. and O. americanum L.; confusion among the cultivars or morphotypes of O. basilicum L. and O. gratissimum L. The usage of synonyms such as O. sanctum (for O. tenuiflorum L.) and O. citriodrum Vos. (for O. africanum Lour.) should be avoided. Similarly, O. viride Willd. and O. suave Willd. are chemotypes of O. gratissimum L., and their stature as distinct species is not justifiable. The sweet Basil (O. basilicum L.) has a sufficient number of cultivars, ecotypes, and chemotypes. Using varietal names except for var. basilicum and var. minimum is discouraged. The ongoing records were examined interchangeably with past ones for suitable repercussions. We have provided a few corrections for research articles of utmost importance in the present scenario. Substantial analysis of nomenclature disputes, taxonomy, and classification has been attained. Meticulous observation and interpretations will help us to overcome the problems pertaining to Ocimum L.

Abbreviations

L./LINN—Linnaeus; ICBN—International code of Botanical Nomenclature; BHL—Biodiversity Heritage Library; JSTOR—Journal Storage; NCBI—National Center for Biotechnology Information; BSI—Botanical Survey of India; ARUN—Arunachal Pradesh Regional Centre, Itanagar, Arunachal Pradesh; ASSAM—Eastern Regional Centre, Shillong, Meghalaya; CAL—Central National Herbarium, Howrah, West Bengal; GUBH—Gauhati University Botanical Herbarium; IVH—Indian Virtual Herbarium; KEW—Royal Botanic Garden, Kew; G—Conservatoire et Jardin botaniques de la Ville de Genève; MNHN—Muséum national d’Histoire naturelle; MO—Missouri Botanical Garden’s Herbarium; NY—New York Botanical Garden Herbarium; ICN—International Code of Nomenclature for Algae, Fungi, and Plants; IUCN—International Union for Conservation of Nature; BSA—Central Regional Centre, Allahabad, Uttar Pradesh; DNA—Deoxyribonucleic acid.

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Authors contributions

ND has conceived the topic for review work. MK has carried out the literature study and presented the information. MK drafted the manuscript; ND scrutinized the review data and provided rectifications. ND and MK have finalized the manuscript for correspondence. Both authors have read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

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