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RESEARCH ARTICLE

Ocimum kilimandscharicum Guerke (Lamiaceae): A New Distributional Record for Peninsular India with Focus on its Economic Potential

R. C. Misra[1] · G. Das[2]

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Abstract *Ocimum kilimandscharicum* Guerke (Lamiaceae), alien to the Indian flora, was discovered in the natural habitat from two locations of different agro-ecological zones of Odisha. After critical review of published literature on distribution, it was earlier known only from Uttarakhand. However, its natural occurrence in Odisha was found to be a new record for peninsular India. A detailed diagnostic description, photographs, ecology and potentiality of the species was provided for easy identification and further economic utilization.

Keywords *Ocimum kilimandscharicum* · New record · Economic potential · Peninsular India

Introduction

Over the last few decades, a number of developing countries have become potential zones and recipients of alien species to and from other countries due to fast economic globalization and associated activities in trade and transport. The expanding economy of India has triggered vast infrastructural developmental projects that has led to loss of natural habitats and further opened up the disturbance corridors for providing niche to the establishment and spread of alien species [1]. These alien plants have either escaped from cultivation, spread after unintentional introduction, are casuals or naturalized to adapt with the changing environment. Majority of alien flora in India has its native range in South America, Asia, Africa, Europe and Australia. The peninsular India, particularly the state of Odisha in the eastern flank, is a shelter of many aliens and the rich biodiversity is under several threats due to over-exploitation, recurrent floods and cyclone followed by land degradation and soil erosion. The state harbours an estimated number of 3000 species of vascular plants representing about one-fifth of the total flora of India. The great extent of the state coupled with wide variation in edaphic, topographic and climatic factors contributes to the enormous genetic variation of crops, landraces, aliens, wild/weedy relatives and particularly in wild indigenous economic species holding great promise for the future. Many wild plants/wild relatives used by the primitive tribes have the potential for use by the others as food, medicine and other necessities. The discovery of *Ocimum kilimandscharicum*, a multipurpose economic crop, from the natural habitats of the central table land and the east-coastal zones forms the first record of the flora of Odisha as well as for the peninsular India.

Ocimum Linn. belonging to the tribe Ocimeae of family Lamiaceae is a large and diversified genus of economically useful, medicinal and aromatic importance, associated with various Indian cultural traditions. It is highly valued for its therapeutic properties in traditional as well as modern pharmacological system. The main center of diversity of *Ocimum* appears to be Africa [2] with a secondary center in South America (Brazil) and Asia (India) [3]. The taxonomy and nomenclature of *Ocimum* species/varieties are in a state of confusion. Various workers have reported the estimate of species not in exact numbers but approximately

✉ R. C. Misra
rcmisranbpgr@gmail.com

[1] ICAR-National Bureau of Plant Genetic Resources, Exploration Base Centre, C. R. R. I. Campus, Cuttack 753006, Odisha, India

[2] All India Coordinated Research Project on Medicinal & Aromatic Plants and Betelvine, Orissa University of Agriculture and Technology, Bhubaneswar 751003, Odisha, India

varying from 30 to 160 [2, 4]. However, out of 333 scientific plant names of species rank, *Ocimum* has 68 accepted species names and the rest are placed as synonyms, unplaced and unassessed [5]. India is represented by nine species of *Ocimum* (including three exotics) mainly confined to tropical and peninsular region [6]. *O. kilimandscharicum* Guerke, commonly known as camphor basil (Kapur Tulsi), is a native of Kilimanjaro, Kenya (East Africa) and then spread widely in the tropical and subtropical regions such as Rwanda, Athens, Nigeria, Ghana, Thailand and India. However, this species has a very restricted distributional area in India and was recorded earlier from wild habitats of Uttarakhand and not reported elsewhere as natural born. The wild occurrence of *O. kilimandscharicum* Guerke in the core zone of Kapilash sanctuary and other natural habitats of Odisha form a new plant record for the flora of Odisha as well as peninsular India.

Material and Methods

During the exploration mission in 2012–2013 for germplasm collection of medicinal and aromatic plants in parts of Odisha, the first author observed the natural occurrence of one *Ocimum* species at two different locations in Khurdha and Dhenkanal districts belonging to different phyto-geographical zones of the state (Figs. 1, 2, 3). The seed germplasm bearing accession number IC-599299 and IC-599345 were collected from the field and conserved in the National Gene Bank, NBPGR, New Delhi for long term storage. Further, the seeds were multiplied and live plants were maintained and further characterized in experimental plots of NBPGR Base Center, Cutttack (Fig. 4). The plant specimens bearing both vegetative and flowering parts were deposited in the herbarium of NBPGR base centre, Cuttack, Odisha (Fig. 5) along with one set at the National Herbarium of Cultivated Plants (NHCP), NBPGR, New Delhi. The herbarium specimens were critically studied and cross-checked with the references cited in the Indian literature and abroad and the morphological features of the plant were examined using the trinocular lens and dissection microscope and the distinctive characters were described. The collected specimens were also compared with the images of the authentic herbarium type specimens found at the Royal Botanic Gardens, Kew to confirm the identity of the plant. The photographs of the vegetative, flowering/fruiting and the seeds along with the associated species in the natural habitat were taken for reference and future use.

Fig. 2 Natural occurrence of *Ocimum kilimandscharicum* in Khurda district, Odisha (close view)

Fig. 1 Natural occurrence of *Ocimum kilimandscharicum* in Khurda district, Odisha (distance view)

Fig. 3 *Ocimum kilimandscharicum* in the wild habitat at Kapilash wildlife sanctuary, Dhenkanal district, Odisha

Fig. 4 *O. kilimandscharicum* maintained in experimental plot, NBPGR Base Centre, Cuttack

Results and Discussion

After thorough examination of the vegetative and floral characters of live plants grown at the experimental plots of the centre coupled with study on herbarium specimens and perusal of literature [6–8], the species was identified as *O. kilimandscharicum* Guerke, a species reported in wild state so far only from Uttarakhand [9, 10]. It was observed that the plant was found growing luxuriantly in wild habitats and its occurrence has been recorded at only two locations, one from the core areas of Kapilash wildlife sanctuary of Dhenkanal district and other from a scrub forest near Begunia of Khurda district, Odisha. Apart from these localities, there is no authentic record on the wild distribution of this species in India except for references cited in north India. However, some records were available in which it was reported to be cultivated in small scale in parts of India across different states such as Uttar Pradesh, West Bengal, Assam, Tamilnadu, Karnataka, Maharashtra, Uttarakhand, Kerala, Jammu and Kashmir without mentioning the specific locality of occurrence in some cases (Fig. 6) [6–8, 11, 12]. On verification of major published Indian literature regarding distribution [13–23], including its collection from Karnataka state of the Western Ghats [24, 25], it was found that it has not been reported till date in wild state from peninsular region of India including Odisha. Therefore, the present collection counts an addition of species to the flora of Odisha and forms a new distributional record for peninsular India. A detailed taxonomic description on morphology of different parts of the plant species along with field photographs (Figs. 7, 8, 9, 10, 11), ecology, and economic uses are provided for easy identification and sustainable utilization.

Fig. 5 Herbarium specimen preserved at NBPGR, Cuttack

Taxonomic Description

Ocimum kilimandscharicum Guerke in H. G. A. Engler, Pflanzenw. Ost-Afrikas, C: 349.1895. *Ocimum johnstonii* Baker in D. Oliver and auct.suc (eds.). Fl. Trop. Afr. 5:345.1900. *Ocimum tortuosum* Baker in D. Oliver and auct.suc (eds.). Fl. Trop. Afr. 5:339.1900 [26–28].

Perennial aromatic under-shrub up to 100 cm height, stem and branchlets erect, 4-angled, woody at base, pubescent; young shoot hoary tomentose with retrorse hair at the apical node; indumentums of long spreading hair, becoming denser on inflorescence axis. Leaves simple, opposite-decussate, elliptic- ovate to oblong, 3.5–6.0 × 1.5–3 cm; petiole hirsute, 10–28 mm; leaf base cuneate, unequal; margin serrate, apex acute, pubescent with white hair on both sides, much denser and longer on veins beneath; veins grooved dorsally and raised ventrally; strongly camphor scented. Flowers small, dense, verticillate, six in a whorl; in terminal hairy spikes/racemes; verticels 3–15 mm apart, distance reduces towards apex; bracts sessile, ovate to lanceolate, hirsute, 2–3 mm; 10–22 flower whorls/spike, spike 14–30 cm, pedicel 2–3 mm. Calyx 2-lipped, campanulate, hirsute with white long hair, 4–5 mm long in anthesis and 5–6 mm in fruit; posterior lip reflexed, large, broad, rounded, decurrent on tube, apex

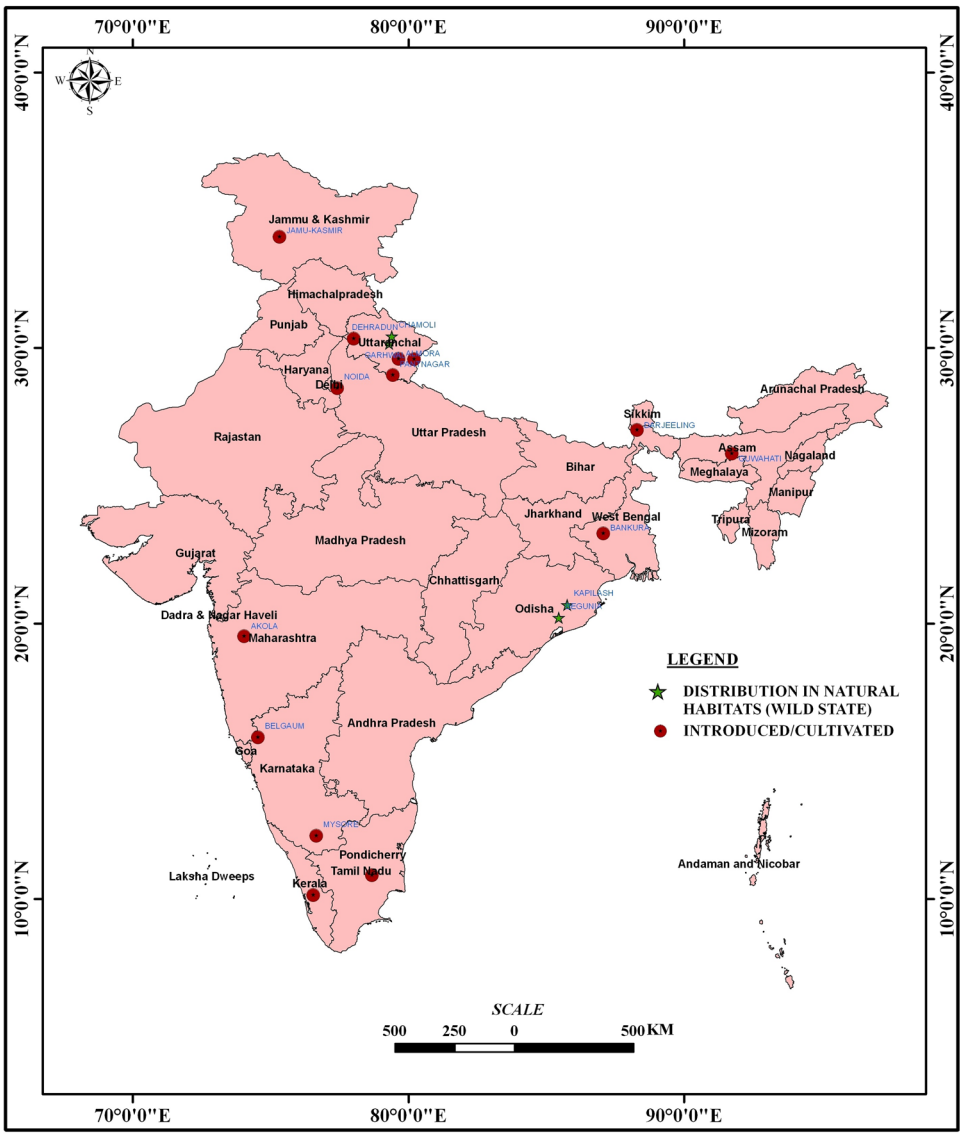

Fig. 6 Localities of occurrence of *O. kilimandscharicum* in India

Fig. 7 Vegetative twig of *O. kilimandscharicum*

Fig. 8 Flowering twig of *O. kilimandscharicum*

Fig. 9 Inflorescence of *O. kilimandscharicum*

Fig. 10 Flowers of *O. kilimandscharicum*

mucronate; anterior lip 4-toothed, with 2-median lanceolate teeth slightly move upwards, slightly longer than 2-lateral teeth, more or less equal to posterior lip; throat open, tube pubescent with ring of hair at throat base. Corolla campanulate, purplish white, 2-lipped, 7–9.5 mm long including corolla tube, lobes pubescent dorsally; upper lip truncate, 4-fid, with 2 ovate-oblong smaller median lobes apparently joined together and slightly longer than 2-lateral broader lobes; lower lip elliptic-oblong, comparatively white. Stamens 4, declinate, in 2-pairs, exserted, posterior pair with a fascicle of hair near the base, anther cells confluent, filaments free. Style thinly 2-fid. Nutlets ovoid-oblong, smooth, black; produce mucilage when wet. Essential oil light yellow colour, with strong odour of camphor.

Fig. 11 Seeds of *O. kilimandscharicum*

Ecology

The plant species was found to be naturally growing in wild habitats among other species interspersed with herbs, shrubs and climbers in two different landscapes, a reserved forest and a partly disturbed forest land. One accession from a population of few plants was collected from an open hill slope in a degraded forest land inside Kapilash wildlife sanctuary of Dhenkanal district and another was collected from an open scrub forest in Khurdha district, in two different agro-ecological zones of Odisha such as central table land and east-coastal plains respectively.

The plant prefers tropical climate with open sunny areas and well drained soils in the dry habitat with annual rainfall more than 1200 mm. It was observed that the species has good compatibility with moist and dry deciduous elements like *Ficus hispida*, *Tetrastigma lanceolaria*, *Cayratia trifolia, Luffa aegyptiaca*, *Coccinia grandis, Passiflora foetida, Micania micrantha, Chromolaena odorata, Corchorus aestuans, Cassia tora, Sida acuta, Acalypha indica, Phyllanthus fraternus, Tridax procumbens, Commelina diffusa, Aerva lanata* and grasses like *Eragrostis ciliaris, Perotis indica, Chloris barbata* and *Cynodon dactylon.* It was experimented that the plants are readily propagated from seeds and sufficient seedlings were raised and further transplanted in experimental plots. The plants can be grown in plains under irrigated and non-irrigated conditions. Once the plant is established, it thrives as a perennial and can be coppiced for 2–3 years.

Type Specimens Examined and Germplasm Collected and Conserved

(i) Site 1: India, Odisha state, Dhenkanal district, Gondia block, village: Kolhapur–Majhisahi inside Kapilash wildlife sanctuary, elevation: 522 m from mean sea level, R.C.

Misra HS no 954 and 955 (Herbarium of NBPGR Base Centre, Cuttack), dated 19.03.2013; seed germplasm accession no. IC-599345 (collection no.RCM/GD/132), source: natural, partly disturbed wild. (ii) Site 2: India, Odisha state, Khurda district, Begunia block, village: Badasahi-Talasahi, elevation: 114 m from mean sea level, R.C. Misra HS No 918 and 919 dated 13.03.2013, seed germplasm accession no. IC-599299 (collection no.RCM/GD/84), source: natural, disturbed wild. (iii) Images of herbarium type specimens of *O. kilimandscharicum* bearing barcode nos. K000347060 to K000347062 of Royal Botanic Gardens, Kew.

Etymology

The genus name *Ocimum* is a Latinized version of the Greek plant name *Okimon*, by which basil is referred to in the work of Dioskurides. It is derived from the word '*ozein*' i.e. smell (cf. ozone "the smelling one" directly refers to the Greek present participle ozon and English odour). The name of the species *kilimandscharicum* is derived as per the origin of plant from Kilimanjaro hills in Kenya and scar/scaur means broken cliffs on the side of a mountain or bare place on a hill-face.

Economic Potential

Ocimum kilimandscharicum is an economically important perennial herb used for various purposes in medicinal, agriculture, industrial and ornamental sectors. The information on various economic potentialities including its indigenous uses in Odisha state is provided below for sustainable use of the germplasm at the species level.

The local people of Saura and Kolha tribes of Kapilash sanctuary, Odisha take the juice of fresh leaves along with the black pepper for curing flu, fever and bronchial asthma. They use the dry leaves or leaf powder for storage of rice grains, pulses and other food stuff not only against the attack of pests but also to provide aromatic flavor to remove the pungent smell of storage particularly during rainy season. The burnt leaf-smoke is also diffused in their huts to ward off insects and mosquitoes. They also reported that 8–10 leaves are immersed in boiled water for 10–15 min and then used for bath for the treatment of scabies/ringworm, body ulcers/wounds and for removing the foul body smell.

In traditional medicine, this plant is widely used for the treatment of various ailments including cold, cough, malaria, abdominal pains and diarrhea [7]. The leaves of *O. kilimandscaricum* are acrid, spasmolytic, thermogenic, aromatic, insecticidal, antibacterial, antiviral, appetizing, antioxidant, ophthalmic and deodorant. It is useful in cough, bronchitis, catarrh, foul ulcers and wounds, anorexia and vitiated conditions of vata [8, 11]. Besides, the dichloromethane extract of leaves and twigs has been reported to be more active on chloroquine sensitive than resistant *Plasmodium falciparum* strains exhibiting promising antiplasmodial activity proving the claims of Luo and Kurio ethnic groups of Kenya [29]. Aqueous extract of leaves exhibited wound healing activity such as increase in granuloma breaking strength, wound contraction and decrease in epithelization period in different wound models in rats such as excision, incision and dead space wounds [30]. Aqueous leaf extract also showed antidiarrheal activity such as delay in onset of defecation, reduced intestinal fluid accumulation and reduced cumulative faecal weight in rats [31]. The hydro-methanolic leaf extract significantly lowered the tumour volume and increased survival rate of mice showing antimelanoma potential and partial protection to bone marrow [32]. In Kenya, the infusion of leaves is taken to cure measles and also mixed with *Lippia ukamensis* to treat flue and stomachache. The vapors of boiling leaves are inhaled to treat congested chest, cold and cough [33]. The decoction of leaves is also used in eye diseases [34]. The essential oil extracted from the leaves is widely used in local applications on sprains and in various dental and oral preparations of drugs [6, 35] and is suitable for the liver comparative to muscle during oxidative stress conditions [9]. The oil also exhibited mosquito larvicidal activity against *Culex quinquefasciatus* larvae and highest anticandida property for combating candidiasis, a common infection in HIV/AIDS patients [36]. The antimicrobial efficacy of essential oil of this plant was evaluated against a few bacterial (*Escherichia coli, Staphylococcus aureus, Streptococcus mutans,* and *Salmonella typhimurium*) and fungal (*Candida albicans, Aspergillus niger* and *A. fumigatus*) strains and highest degree of inhibition was found against tested microbial strains [37, 38]. Extracts of whole plant are also used in traditional medicine and have been shown to contain biologically active constituents that are insecticidal, fungistatic and antimicrobial [10, 39]. The leaves of *O. kilimandscharicum* have therapeutic potential as an anticancer agent due to the presence of ursolic acid (9.82 %) in crude extract [40]. 'Naturub', a new brand of multiuse medicine derived from this plant, manufactured by local communities of Kakamega forest, Kenya has been used for the treatment of cold, flu, cough, chest congestion, muscular pains and as a mosquito repellant [41]. Besides, an herbal formulation containing volatile oil and camphor separated from volatile oil of *O. kilimandscharicum* as a component, with other plant extracts was patented by the Director General, Defence Research Development Organisation, Government of India to treat toothache and related disorders [42].

Ethno-botanical database showed that the plant has various central nervous system activities like neurotoxic,

anti-neuralgic, CNS stimulant, tranquilizer, anti-alzheimerican and sedative effects [7]. The whole plant is used by the Kikuyus for the treatment of malaria in the central province of Kenya [43]. Ethno-botanical studies in Burundi, Africa report the traditional use of this camphor containing basil as a veterinary medicine as well [44].

Besides the medicinal uses, the plant is a source of essential oils and aromatic compounds containing biologically active constituents that act as insect repellants and may be used as a solvent for DDT and also against mosquitoes and storage pests [6, 45, 46], which is further supported by the indigenous uses of tribes in Odisha documented in this report. The exposure of three insect species such as *Rhyzopertha dominica, Sitophilus zeamais* and *Sitotroga cerealella* of maize and sorghum grains to leaf powders, essential oil and crude extracts induced 100 % mortality after 48 h. It shows highest repellent action to *S. zeamais* [47].The essential oil also inhibited the development of eggs, larvae and pupae, oviposition and subsequent progeny production of stored-product beetles [48]. The use of plant extracts as repellants against malaria vectors has been advocated in different studies in Kenya and Tanzania [49, 50]. The crude extracts and the smoke from burnt plant material including seeds of *O. kilimandscharicum* in experimental huts caused an increase in exophily behavior, blood feeding inhibition during human biting and high deterrence against indoor resting of mosquitoes and shows significant repellency against *Anopheles gambiae, A. funestus, A. arabiensis* and *C. quinquefasciatus* [51–53]. Besides these, significant anti-oxidant activity of leaf extract was observed for the presence of high phenolic content and can be used as an effective preservative in food industry [54]. The oil extracted from the leaves and seeds contain camphor as most active component used in perfumes and preparation of drugs, suitable for cosmetics and pharmaceutical industries. The plant is used in the Mediterranean area as a culinary herb in interesting forms and also for decorative purposes as a landscape shrub and an attractive fragrant ornamental [55].

Conclusion

Ocimum kilimandscharicum offers a wealth of opportunities to develop as a multipurpose crop by finding its use in agriculture, pharmaceutical, ornamental and industrial sectors. Despite its various economic utilities, it is meagerly used as a medicinal and aromatic crop on a very limited scale in India and still remains as one of the neglected basils as compared to other *Ocimum* species. Its economic potentiality in various agri-horticultural practice along with the pharmaceutical and industrial uses should come to limelight and be promoted for cultivation in larger scale. The researchers at the International Centre of Insect Physiology and Ecology (ICIPE) and University of Nairobi, Kenya together with the members of Muliru Farmers Conservation Group developed a commercially branded range of medicine products known as Naturub$^{(R)}$. This includes balm and ointment prepared from the purified extracts of leaves of *O. kilimandscharicum* using combination of traditional knowledge and modern science and technology. The commercialization of this medicinal plant has heightened and received wide acceptance in the market and are competitive with major international brands. This on-farm cultivation has created nearly 900 jobs for small holder farmers with sale of Naturub$^{(R)}$ and generated revenue of US $75,000 in a short span (2005–2010) and won the Equator Prize in 2010 during United Nations General Assembly, New York. This registered medicinal product has a great market demand and sharp competitive edge as compared with other balm and ointment products and is available in national store chains and outlets of Kenya and the share of revenue has increased three times a year and enhanced the income by an average of 300 % [56, 57].

The pesticide/insecticide activity of its leaves will be much useful in crop protection system for storage of grains, pulses and other food stuff. Majority of tribal population of India is prone to malaria disease, therefore, the domestication and widespread use of this species by local inhabitants should be of utmost priority in India, as the whole plants are used as repellants against malaria vectors in Kenya and Tanzania. The awareness for community based initiative be increased among the local people about the importance of this plant and need for conservation. Besides, this species will play a vital role in widening the genetic base of *Ocimum*, a widely accepted medicinal and aromatic genus. Further, the economic and breeding potential along with its specific traits pertinent to essential oil composition showing different physico-chemical properties be investigated in details for crop improvement studies. Moreover, it can also be used in hybridization experiments with other members of *Ocimum* which will definitely throw some light on its crossability and be useful in elucidating the interrelationships of species/varieties within the genus.

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