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ORIGINAL ARTICLE

Indian spinach: an underutilized perennial leafy vegetable for nutritional security in developing world

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Abstract Exploration and sustainable utilization of wild crops are essential for the dietary diversification and also for ensuring the nutritional requirements of growing human population. In this background, the present study was undertaken to evaluate the occurrence, distribution and habitat characterization of two underutilized perennial leafy vegetables of Basellaceae, i.e., *Basella alba* and *Basella rubra*, commonly called as Indian spinach or Malabar spinach. For this, extensive field surveys and habitat analysis have been conducted in selected districts of North and West India and national and global distribution maps were prepared based on the available literature. The habitat analysis clearly indicates that Basella species can luxuriously grow in diverse soil conditions (i.e., from acid to alkaline conditions and also in degraded and nutrient poor soils). However, the fresh leaves and stems of both Basella species are rich in protein, vitamin A, vitamin C, Ca, Fe, Mg, P, K, Na, Zn, Cu, Mn and Se and also having essential amino acids and flavones. It can be directly used in salads or can be used as a standalone vegetable for making soups, stews, steamed and oil fried items. In India, it is also being used to make snacks (pakoda). Though it was widely cultivated in Southeast Asia and China since ancient times, it is being gradually neglected and replaced by other greens. Owing to its adaptability to grow luxuriously in hot and humid tropical climate, it can be exploited as a promising leafy vegetable for the warming climatic conditions. However, suitable agronomic practices and crop improvement programs are necessary for improving the adaptability and nutritional quality of Basella species.

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Keywords Indian spinach · Underutilized crop · Nutritional security · Developing world

1 Introduction

Sustainable food production is utmost important for meeting the UN-Sustainable Development Goals such as (1) no poverty, (2) zero hunger and (3) good health and well-being all over the world and especially for feeding an exponentially growing human population in developing countries (Godfray et al. 2010; Abhilash et al. 2016; Dubey et al. 2016). While agrobiotechnological interventions coupled with other technological improvements could be able to enhance the global food production up to a certain extent, there is growing body of evidences indicating that food production under changing climatic condition is a challenging task as climate change adversely affects the growth as well as the yield and nutritional quality of agricultural crops (Godfray et al. 2010). Furthermore, the global warming and associated climate change have already negatively impacted the availability of critical natural resources and thereby negatively affected the agricultural productions in many ways (Godfray et al. 2010; Dubey et al. 2016). Therefore, adaptive and climate resilient practices as well as the use of climate smart crops are essential for the current and futuristic climatic conditions.

In this context, the utilization of neglected and underutilized crops offers huge promise in fulfilling the food and nutritional requirement of the resource-poor peoples in developing world (Singh and Abhilash 2018) as the traditional or local varieties have better climate

tolerance and adaption potential than the modern crop varieties. Moreover, they are rich in essential nutrients and can be considered as promising crops for dietary diversification. Importantly, as envisioned by the Food and Agricultural Organization of the United Nations (www.fao.org), the food production relied on locally and seasonally available crops can reduce the production, storage and transport cost, thereby reducing the ecological footprint considerably.

Basella spp., commonly called as Indian spinach or Malabar spinach, is an underutilized perennial leafy vegetable of Basellaceae having a remarkable nutrient profile (Khare 2004; Ernst 2017). The fresh leaves and stems of this climber are edible and reported to have protein, vitamins, essential minerals, amino acids and flavones. The crop is an ideal species for home garden and can be cultivated anywhere (in field or in pot culture). Importantly, Basella species are hardy and can grow in almost all kind of tropical soils and need relatively minimal attention and agronomic practices. Despite these attributes, the crop is a neglected and underutilized and not yet yearned a proper place in the mainstream market of leafy vegetables. While spinach and other leafy vegetables are seasonal (i.e., winter), the cultivation of couple of vines of Indian spinach in any home garden can supplement the dietary requirements of a family throughout the year. Considering the enormous significance of leafy vegetables for averting the hidden hunger especially due to the micronutrients deficiencies (Yadav and Sehgal 1995), the present research is aimed to study the ecology and global distribution of Indian spinach, developing suitable strategies for the large-scale cultivation and exploitation, and also to signify the importance of its cultivation for supplementing the food and nutritional requirements of rapidly growing human population in resource-poor developing countries.

2 Materials and methods

Extensive field surveys have been conducted in selected districts of Uttar Pradesh (Azamgarh, Barabanki, Chitrakoot, Ghazipur, Gorakhpur, Jaunpur, Mau, Mirzapur, Sonbhadra and Varanasi) and Nadia district of West Bengal to analyze the habitat, distribution and ecology of *Basella* species. Quadrate method was employed to assess the occurrence and abundance of Basella species, and the stem cuttings of both *B. alba* and *B. rubra* were collected for field demonstration and also for standardizing

Fig. 1 Habit and habitat of *Basella rubra*. **a** Habitat; **b** flowering twig; **c** stem cuttings; **d**, **e** different stages of leaf; **f** a tender vine; and **g** fruits

Fig. 2 Habit and habitat of *Basella alba*. **a** Habitat; **b** inflorescences; **c** different stages of leaf; **d** a tender vine; **e** fruits and **f** mature seeds

agronomic practices. The habitat, growth stage, length of the whole plant and the number of primary and secondary vines were noted. Similarly, soil samples were collected from above locations and physicochemical and biological characterizations were done according to the standard procedural protocols published elsewhere: soil pH and EC were measured by using a pH meter (CyberScan-500) and water holding capacity (Estefan et al. 2013), bulk density (Estefan et al. 2013), available nitrogen (Subbiah And Asija 1956), available phosphorus (Olsen 1954), available potassium (Toth and Prince 1949), microbial biomass carbon (Vance et al. 1987), microbial biomass nitrogen (Vance et al. 1987) and soil organic carbon (Walkley and Black 1934) were measured accordingly. The global and regional distribution of Basella species was prepared using QGIS software (QGIS 3.1 GIRONA), and the nutrient profile was obtained from United States Department of Agriculture (www.usda.org).

3 Results and discussion

3.1 Ecology of Indian spinach

Basella species are well grown in tropical lowlands of Asia and Africa. They are also found in subtropical regions and popularly known as Ceylon spinach, Indian spinach or Malabar nightshade (Kumar et al. 2015a, b). There are two common species: *Basella rubra* (Fig. 1) and *Basella alba* (Fig. 2). *B. rubra* is commonly found as a backyard/ornamental plant, whereas *B. alba* is usually cultivated in India. Both species are well adapted to diverse kind of soils. *B. alba* L. is having green stems and leaves, whereas *B. rubra* is having spectacular red stems and leaves (Khare 2004; Kumar et al. 2015a, b). Both are twining herbaceous vines, perennial, succulent, branched, smooth and annual growing to about 6–9 m in length. *B. alba* have thick, fleshy, broad, oval to heart-shaped leaves, whereas *B. rubra* have pink or red-violet stems and pink color veins running in the leaves. The tender stem secretes gelatinous or mucilaginous substances (Palada and Crossman 1999), and the red-violet color of *B. rubra* is attributed by the presence of betalains

Table 1 Distribution of Basella species in selected districts of Uttar Pradesh and West Bengal

S. no.	Location	Abundance[a]		Habitat	Remarks[b]
		B. alba	*B. rubra*		
1	Pachevaran, Chunar, Mirzapur, Uttar Pradesh	++	+++	Kitchen garden	*B. alba* (7.3 mL; 8 Mb; 13 Sb), *B. rubra* (13.6 mL; 10 Mb; 16 Sb)
2	Naugarahan, Chunar, Mirzapur, Uttar Pradesh	+	−	Roadside	*B. alba* (8.5 mL; 15 Mb; 13 Sb)
3	Vishunpuran, Chunar, Mirzapur, Uttar Pradesh	++	+++	Garden	*B. alba* (6.9 mL; 13 Mb; 14 Sb), *B. rubra* (8.3 mL; 10 Mb; 17 Sb)
4	Rajgarh, Mirzapur, Uttar Pradesh	+	++	Backyard garden	*B. alba* (7.5 mL; 10 Mb; 11 Sb), *B. rubra* (7.8 mL; 16 Mb; 12 Sb)
5	Bhava, Rajgarh, Mirzapur, Uttar Pradesh	+++	−	Lawn	*B. alba* (7.3 mL; 16 Mb; 19 Sb)
6	Sarso, Rajgarh, Mirzapur, Uttar Pradesh	−	+++	Boundary wall	*B. rubra* (5.8 mL; 13 Mb; 15 Sb)
7	Bharkatwa, Rajgarh, Mirzapur, Uttar Pradesh	+++	−	Kitchen garden	*B. alba* (7.8 mL; 16 Mb; 12 Sb)
8	Sakteshgarh, Mirzapur, Uttar Pradesh	++	−	Garden	*B. alba* (6.5 mL; 14 Mb; 16 Sb)
9	Sirsi, Rajgarh, Mirzapur, Uttar Pradesh	+	−	Backyard garden	*B. alba* (8.5 mL; 15 Mb; 17 Sb)
10	Patihar, Rajgarh, Mirzapur, Uttar Pradesh	+	−	Roadside boundary	*B. alba* (4.9 mL; 12 Mb; 9 Sb)
11	Chaukhada, Rajgarh, Mirzapur, Uttar Pradesh	+++	+++	Roadside field	*B. alba* (3.3 mL; 9 Mb; 6 Sb), *B. rubra* (3.6 mL; 5 Mb; 6 Sb)
12	Bhagauda, Rajgarh, Mirzapur, Uttar Pradesh	++	+++	Kitchen garden	*B. alba* (4.1 mL; 11 Mb; 8 Sb), *B. rubra* (6.5 mL; 12 Mb; 14 Sb)
13	Pachokhadan, Rajgarh, Mirzapur, Uttar Pradesh	+	−	Kitchen garden	*B. alba* (8.0 mL; 10 Mb; 9 Sb)
14	Pusauli, Robertsganj, Sonebhadra, Uttar Pradesh	+	−	Roadside	*B. alba* (2.9 mL; 4 Mb; 5 Sb)
15	Renukoot, Sonebhadra, Uttar Pradesh	+++	+	Home garden	*B. alba* (9.1 mL; 12 Mb; 15 Sb), *B. rubra* (3.0 mL; 4 Mb; 2 Sb)
16	Pipari, Sonebhadra, Uttar Pradesh	−	++	Roadside	*B. rubra* (5 mL; 6 Mb; 3 Sb)
17	Dala, Sonebhadra, Uttar Pradesh	+++	−	Kitchen garden	*B. alba* (4.9 mL; 8 Mb; 5 Sb)
18	Susuvahi, Varanasi, Uttar Pradesh	+++	−	Kitchen garden	*B. alba* (5.6 mL; 12 Mb; 10 Sb)
19	Babatpur, Varanasi, Uttar Pradesh	+++	−	Backyard garden	*B. alba* (7.1 mL; 10 Mb; 9 Sb)
20	Sarai dangari, Varanasi, Uttar Pradesh	+++	−	Roadside	*B. alba* (6 mL; 8 Mb; 5 Sb)
21	BHU Agricultural farm, Varanasi, Uttar Pradesh	+++	++	Agriculture farm	*B. alba* (5.3 mL; 11 Mb; 7 Sb), *B. rubra* (4.2 mL; 4 Mb; 5 Sb)
22	Mohamadabad, Ghazipur, Uttar Pradesh	+	−	Roadside	*B. alba* (3.5 mL; 4 Mb; 6 Sb)
23	Kasimabad, Ghazipur, Uttar Pradesh	++	+	Kitchen garden	*B. alba* (6.3 mL; 8 Mb; 6 Sb), *B. rubra* (2.9 mL; 6 Mb; 7 Sb)
24	Mardeh, Ghazipur, Uttar Pradesh	+	+++	Kitchen garden	*B. alba* (4 mL; 5 Mb; 4 Sb), *B. rubra* (3.1 mL; 5 Mb; 4 Sb)
25	Mojrapur, Azamgarh, Uttar Pradesh	++	−	Backyard garden	*B. alba* (1.9 mL; 4 Mb; 4 Sb)
26	Haraiya, Azamgarh, Uttar Pradesh	+++	−	Roadside	*B. alba* (7.1 mL; 6 Mb; 8 Sb)
27	Adampur, Azamgarh, Uttar Pradesh	+++	−	Backyard garden	*B. alba* (4.3 mL; 8 Mb; 4 Sb)
28	Bandhanpur, Mau, Uttar Pradesh	−	++	Roadside	*B. rubra* (1.8 mL; 4 Mb; 3 Sb)
29	Ranipur, Mau, Uttar Pradesh	+	−	Backyard garden	*B. alba* (2.5 mL; 7 Mb; 5 Sb)
30	Khorhat, Mau, Uttar Pradesh	+++	+	Roadside	*B. alba* (2.9 mL; 7 Mb; 8 Sb), *B. rubra* (1.5 mL; 5 Mb; 4 Sb)
31	Basila, Chitrakoot, Uttar Pradesh	+++	−	Kitchen garden	*B. alba* (8.2 mL; 6 Mb; 5 Sb)
32	Devora, Chitrakoot, Uttar Pradesh	++	−	Backyard garden	*B. alba* (4.3 mL; 8 Mb; 4 Sb)
33	Dilona, Barabanki, Uttar Pradesh	+++	+++	Garden	*B. alba* (7.2 mL; 5 Mb; 7 Sb), *B. rubra* (5.1 mL; 5 Mb; 4 Sb)
34	Kandhipur, Barabanki, Uttar Pradesh	++	−	Kitchen garden	*B. alba* (5.1 mL; 10 Mb; 6 Sb)

Table 1 continued

S. no.	Location	Abundance[a]		Habitat	Remarks[b]
		B. alba	*B. rubra*		
35	Gunauli, Barabanki, Uttar Pradesh	+	–	Kitchen garden	*B. alba* (3.6 mL; 5 Mb; 6 Sb)
36	Kalyani, West Bengal	+++	++	Home garden	*B. alba* (2.5 mL; 7 Mb; 5 Sb), *B. rubra* (3.2 mL; 4 Mb; 3 Sb)
37	Mohanpur, West Bengal	+++	+	Field boundary	*B. alba* (4.2 mL; 5 Mb; 6 Sb), *B. rubra* (1.6 mL; 5 Mb; 6 Sb)

[a]Abundance: +++ (higher), ++ (medium), + (low) and – (nil)

[b]*m* meter, *L* length, *Mb* main branch, *Sb* secondary branch

(Winters 1963; Haskell et al. 2004). Flowers are bisexual, red or white in auxiliary or terminal spikes, and the fruits are red or black in color, round and soft with red or purplish juice. The seeds are round and black.

In the present study, both *B. alba* and *B rubra* were reported from Azamgarh, Barabanki, Chitrakoot, Ghazipur, Gorakhpur, Jaunpur, Mau, Mirzapur, Sonbhadra and Varanasi districts of Uttar Pradesh and also from Nadia district of West Bengal. The occurrence, abundance and growth characteristics (i.e., average length of the vine as well as the number of main and secondary branches) are presented in Table 1. The field survey revealed that Basella species are luxuriously growing in diverse kind of habitat such as gardens, kitchen garden, lawns, home garden, cultivated lands and even along the roadsides. Importantly, the species can grow well in a wide range of soil conditions. For instances, the physical qualities of soil such as pH, electrical conductivity (EC), water holding capacity (WHC) and bulk density (BD) were ranged from 6.12 to 8.23, 95.6 to 286 ms m^{-1}, 36–48% and 1.29–1.623 g cm^{-3}, respectively, whereas the microbial biomass carbon (MBC) and microbial biomass nitrogen (MBN) were ranged from 26.4 to 92.8 and 8.0 to 98 μg g^{-1}, respectively. Similarly, available NPK values were ranged from 16.20 to 53.19; 33.56 to 59.76 and 11.80 to 111.66 ppm, respectively. The habitat quality analysis clearly demonstrates that Indian spinach can grow in a diverse kind of soil conditions (Table 2).

3.2 Regional and geographical distributions

The geographical distribution of Basella species is presented in Fig. 3a. They are considered to be native of India and are commonly found in tropical Asia (Bangladesh, Bhutan, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Nepal, Pakistan, Philippines, Sri Lanka, Thailand and Vietnam), tropical Africa (Algeria, Egypt, Libya, Morocco, Mauritania and Tunisia), Brazil, Belize, Colombia, West Indies (Cuba, Haiti, Jamaica and Dominican Republic) and Fiji (Khare 2004; Ernst 2017). The distribution of Basella species in India is presented in Fig. 3b. Both species are reported from almost all Indian states such as Kerala, Karnataka, Tamil Nadu, Andhra Pradesh, Telangana, Maharashtra, Gujarat, Madhya Pradesh, UP, Bihar, Rajasthan, Haryana, Goa.

3.3 Medicinal and nutritional significance

Basella species are widely used in traditional medicine and especially in ancient Indian pharmacopeia to treat against constipation and inflammation (Kumar et al. 2015a, b). It is also used as a diuretic and as a toxicide (Toshiyuki et al. 2001; Kumar et al. 2015a, b). The detailed nutrient

Table 2 Distribution of Basella species in various states of India

Species	Location/districts/state	References
B. alba	Jamnagar (Gujarat)	Sushila et al. (2010)
B. alba	Tamil Nadu, Pondicherry, Maharashtra, Orissa, West Bengal, Bihar, Madhya Pradesh, Uttar Pradesh, Rajasthan and Gujarat	Reddy et al. (2015)
B. alba	Karnataka	Nandini et al. (2015), Shylesha (2013)
B. alba	Kolkata, West Bengal; Calicut, Kerala	Pal (2015), Haneefa et al. (2012)
B. alba, B. rubra	Sonebhadra, Uttar Pradesh	Singh and Dubey (2012)
B. alba	Kannauj District, Uttar Pradesh	Kumar (2013)
B. rubra	Coimbatore, Tamil Nadu	Thavamani and Subburaj (2017)
B. rubra	Hoshangabad District, Madhya Pradesh, India	Quamar and Bera (2014)
B. rubra	Chandrapur District, Maharashtra	Reddy (2012)
B. rubra, B. alba	Zaheerabad, Medak District, Andhra Pradesh	Salomeyesudas and Satheesh (2009), Chadha (2008)
B. alba	Umiam, Meghalaya	Saha et al. (2013)
B. alba	Tripura	Pareek et al. (2010)
B. alba	Tamil Nadu and Karnataka	Shylesha (2013)
B. alba	Jharkhand	Ravishankar et al. (2014), Pan and Bhatt (2018)
B. alba	Arunachal Pradesh	Singh et al. (2015)
B. rubra	Mysore	Kumar et al. (2015a, b)
B. rubra	Chhattisgarh	Chauhan et al. (2014), Khelker et al. (2012)
B. alba	Kerala	Sumesh et al. (2016)
B. alba	Orissa	Sinha and Lakra (2005)
B. alba	Karnataka	Sheela et al. (2004)
B. rubra	Punjab	Kaur and Sidhu (2014)
B. alba	Maharashtra	Deshmukh and Gaikwad (2013)
B. rubra	Bihar	Fatma and Pan (2013)
B. alba	Haryana	Kaur et al. (2016)
B. rubra	Darjeeling hills, West Bengal	Sharma (2012)

profiling of *B. alba* is provided in Table 3. According to USDA (www.ndb.nal.usda.gov), *B. alba* is a highly nutritious and having all essential minerals such as calcium (Ca), iron (Fe), magnesium (Mg), phosphorus (P), potassium (K), sodium (Na), zinc (Zn), copper (Cu), manganese (Mn) and selenium (Se); important vitamins including vitamins C, A, Bi6, folate, niacin, panthotheinc acid; antioxidants like apigenin and all essential amino acids (Kumar et al. 2015a, b; Das et al. 2017). Therefore, large-scale utilization of Basella can be beneficial for attaining the food and nutritional security at regional and local level and also for giving an opportunity to conserve agro-biodiversity for sustainable development. Moreover, Basella species are also endowed with various industrially important chemicals such as acacetin, anthraquinone, Basella saponins A, B, C and D, betacyanin, ferulic acid (Table 3).

3.4 Cultivation practices

Basella species can be propagated through seeds or stem cuttings in well-drained soils mixed with decomposed leaf litter and cow dung. Cuttings of 10–15 cm can be placed in rows spaced 15 cm apart. Periodic irrigation will ensure the growth and yield and also prevent the flower formation, which may cause leaf bitterness (Ernst 2017). It is also requires trellis for growth so that trellising will also facilitate the periodic harvest (Ernst 2017). Apart from the field

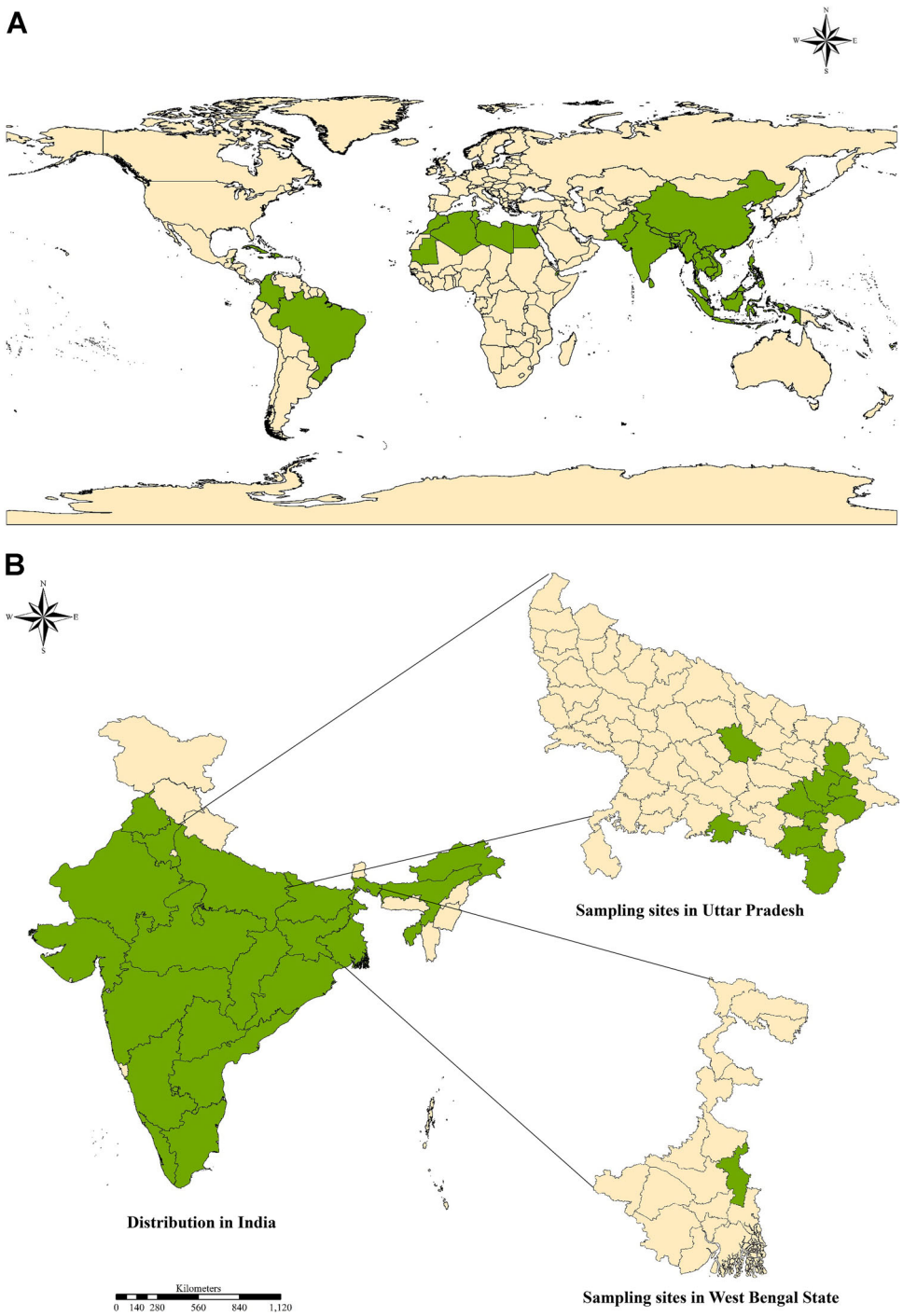

Fig. 3 **a** Global distribution of *Basella* species. **b** Distribution of Basella species in India

cultivation, the Malabar spinach can be cultivated in terrace (terrace gardening) and also the boundaries of the garden. Though the plants are hardy and resistance to pest and diseases, it is also susceptible to some potential pests such as leaf miners, plant bugs and nematodes (Saha et al. 2013; Ernst 2017). Young stems and leaves can be hand harvested periodically (Table 4).

Table 3 Nutrient profile of *B. alba* (100 g fresh weight). *Source*: United State Department of Agriculture: www.ndb.nal.usda.gov

(a) Proximate analysis	
Variables	Quantity
Water	93.15
Energy	19 kcal
Protein	1.8 g
Total lipid (fat)	0.3 g
Ash	1.4 g
Carbohydrate	3.4 g
(b) Minerals	
Minerals	Quantity
Calcium (Ca)	109 mg
Iron (Fe)	1.2 mg
Magnesium (Mg)	65 mg
Phosphorus (P)	52 mg
Potassium (K)	510 mg
Sodium (Na)	24 mg
Zinc (Zn)	0.43 mg
Copper (Cu)	0.107 mg
Manganese (Mn)	0.735 mg
Selenium (Se)	0.8 µg
(c) Amino acids	
Amino acids	Quantity
Tryptophan	0.028 g
Threonine	0.055 g
Isoleucine	0.053 g
Leucine	0.101 g
Lysine	0.086 g
Methionine	0.019 g
Cystine	0.027 g
Phenylalanine	0.085 g
Tyrosine	0.048 g
Valine	0.065 g
Arginine	0.07 g
Histidine	0.039 g
Alanine	0.075 g
Aspartic acid	0.108 g
Glutamic acid	0.283 g
Glycine	0.067 g
Proline	0.07 g
Serine	0.057 g
(d) Vitamins	
Vitamins	Quantity
Vitamin C	102 mg
Thiamin	0.05 mg
Riboflavin	0.155 mg
Niacin	0.5 mg
Pantothenic acid	0.053 mg
Vitamin B-6	0.24 mg

Table 3 continued

(d) Vitamins	
Vitamins	Quantity
Folate, total	140 µg
Folate, food	140 µg
Folate, DFE	140 µg
Vitamin A, RAE	400 µg
Vitamin A, IU	8000 IU
(e) Lipids	
Lipids	Quantity
Fatty acids, total trans	0 g
Cholesterol	0 mg
(f) Flavones	
Flavone	Quantity
Apigenin	62.2 mg

Carbohydrate factor: 3.57; fat factor: 8.37; protein factor: 2.44; nitrogen-to-protein conversion factor: 6.25

4 Concluding remarks and future prospects

The present study concludes that Basella species are highly nutritious and can be easily cultivated in tropical, subtropical and temperate regions of the world. In India, both *B. alba* and *B. rubra* are luxuriously growing in various states and found in almost all agroecological zones of the country. The field survey and habitat analysis clearly indicate that both Basella species can be well adapted to diverse soil conditions. Owing to its high nutritional and medicinal significance, Basella species can be commercially cultivated throughout the tropical and temperate regions for fulfilling the nutritional requirements of the growing human population. Since the plant is hardy and does not require much agronomic practices, it can be easily cultivated than any other leafy vegetable and will be an ideal substitute for resource-poor farmers in developing region. Moreover, the cultivation of such locally available species will create a sense of sustainability and agro-biodiversity feeling in local farmers and will pave an example for conserving other neglected and lesser-utilized crops in various agro-climatic regions of the world. However, extensive field surveys in various agro-climatological regions of the world are essential for analyzing the genetic diversity of the species and also for developing suitable agronomic and breeding programs for improving the nutritional quality and environmental adaptability.

Table 4 Chemcial constituents in Basella species. *Source*: Kumar (2013), Oyewole and Kalejaiye (2012), Toshiyuki et al. (2001), Paul and Singha (2010), Werner and Thomas (2006), Nishimato and Hirose (1991), Murakami et al. (1999), Khare (2007), Glassgen et al. (1993), Lin et al. (2010), Killur et al. (1983), Saleem et al. (2001), Iwamoto et al. (1985), Grubben and Denton (2004), Pareek et al. (2010), Anusuya et al. (2012), Venkatalakshmi and Senthamaraiselvi (2012)

Chemicals	Plant parts				
	Leaf	Leaf mucilage	Stem	Fruits	Seeds
Acacetin	✔		–	–	–
Anthraquinone	–	–	✔	–	–
Basella saponins A	✔	✔	✔	✔	✔
Basella saponins B	✔	✔	✔	✔	✔
Basella saponins C	✔	✔	✔	✔	✔
Basella saponins D	✔	✔	✔	✔	✔
Beta sitosterol	✔	–	–	–	–
Beta-carotene	✔	–	–	–	–
Betacyanin	–	–	–	✔	–
Betavulgaroside I	✔	✔	✔	✔	✔
Ferulic acid	✔	–	–	–	–
Gomphrenin I	–	–	–	✔	–
Gomphrenin II	–	–	–	✔	–
Gomphrenin III	–	–	–	✔	–
Kaempferol	✔	–	–	–	–
Linoleic acid	–	–	–	–	✔
Lupeol	–	–	–	✔	–
Momordin II B	✔	–	–	–	–
Momordin II C	✔	–	–	–	–
Stigmasterol glucoside	✔	–	–	–	–
Syringic acid	✔	–	–	–	–
Uronic acid	–	✔	–	–	–
Vanilla	✔	–	–	–	–

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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