An updated review on Malabar spinach (Basella alba and Basella rubra) and their importance

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Abstract
Recent studies have shown fruits from less-known and unexplored plants as an excellent source of nutrients and biologically active compounds for food and non-food applications (Khan et al. 2011, 2015). Basella plant is extremely heat tolerant and fast-growing perennial vine which is wildly cultivated as a cool-season vegetable. Basella alba is also known as Malabar spinach, Indian spinach, Ceylon spinach, climber spinach and vine spinach. In India, it is commonly known as “Poi”. Red-violet colour of leaves, stalks, petioles and fruits are due to the presence of betalains (Palada et al. 1999). This crop is suitable for both home and market garden in the lowland tropics. This plant is full of nutrition like normal spinach. Also, the oil obtained from its seeds can become the source of safe vegetable oil. This plant is good for health due to the presence of mineral, protein, oil, carbohydrate, fibre, carotenoid, organic acid, vitamins.

In the winter season, Malabar spinach can be used in place of normal spinach as it has similar Nutritional and medicinal value. Basella plant species contain betacyanin, carotenoids, bioflavonoids, β-sitosterol and lupeol which are reported to have antioxidant, antiproliferative, antimicrobial, anti-inflammatory activities etc. and help in curing various diseases, namely anticancer, antiviral, antioxidant, anti-inflammatory, anti-cholesterol, anti-ulcer, antimicrobial, anti-hypoglycemic, wound healing, androgenic from the ancient times. Leaf juice is used in to treat catarrh and it is also an as safe laxative for children, pregnant women and in a urinary diseased patient. In Ayurveda Malabar spinach is called as “Upodika”, “Potaki”, “Malvaa”, “Amritvallari”, and in Siddha/Tamil as “Vaslakkirai” (Khare, 2004). It used as a vegetable in many countries like Philippines, Thailand China, Mongolia, India, Sri Lanka and many African countries. In India, In Andhra Pradesh curry of Basella and Yam is made popularly known as Kanda Bachali Kooru, in Odisha, it is used to make Curries and Saiga.

Keywords: Malabar Spinach, Basella, Poi, Gomphrenin-I, Upodika

Introduction
Origin of Basella alba is India and Indonesia and it naturally has grown in tropical Asia and tropical Africa (Saroj et al 2012). Malabar spinach is extremely heat tolerant and fast-growing perennial vine which is wildly cultivated as a cool-season vegetable. Fruits are fleshy, stalkless, spherical and purple in colour. In India, it is commonly known as “Poi” found all over the country, except hills. The plant is a succulent, branched, smooth, twining and herbaceous vine reaching a length of several meters. The stems are green or purplish. The leaves are heart- shaped (cordate leaves), 5 to 12 cm in length, stalked with a pointed tip (Harold, 1963).

Two species of Basella (Basella rubra L. and Basella alba L) identified by Carl Linnaeus. Both two species Basella rubra L and Basella alba L are differentiated by their leaf characteristics and stem colours. Malabar spinach belongs to the Basellaceae family (Deshmukh, 2014). The stem of Basella alba is green in colour with bigger stem than the red-stemmed Basella rubra.

Malabar spinach has been used to cure various diseases, namely anticancer, antiviral, antioxidant, anti-inflammatory, anti-cholesterol, anti-ulcer, antimicrobial, anti-hypoglycemic, wound healing, androgenic from the ancient times (Shade et al. 2017). This plant is used for the cure of many skin problems, diarrhoea, dysentery and also used as a laxative. Basella plant show antioxidant, antiproliferative, antimicrobial, anti-inflammatory activities due to the presence of betacyanin, carotenoids, bioflavonoids, β-sitosterol and lupeol (Moutusi et al. 2019). Juice of leaves and stem are used as laxatives for children and pregnant women. In Ayurveda Malabar spinach is called as “Upodika”, “Potaki”, “Malvaa”, “Amritvallari”, and in Siddha/Tamil as “Vaslakkirai” (Khare, 2004).

Malabar spinach is also rich in vitamins A, and C, Iron and Calcium (Haskell 2004). The leaves contain carotenoids, organic acids, water-soluble polysaccharides, bioflavonoid, betacyanin, and vitamin K. Fruit extract of Basella alba plant were used as an acid-base.
indicator, to detect the endpoint of acid-base titrations (Mitra et al. 2016) [69]. Many Indian states consumption of Basella alba as the vegetable is quite common. Consumption in Nigeria, India (Tongco et al. 2015) [73], Bangladesh (Haskell et al. 2004) [27] and so many other countries like China, Philippines, Thailand indicates that Basella alba does not possess any toxicity.

**Taxonomy**

Term “Basella” derived from Malayalam word, given by Linnaeus. Linnaeus first described two species of Basella L. i.e. Basella rubra and Basella alba in his book “Species Plantarum” in 1753 (Khare 2007) [32] based on their leaf character and stem colour. Roxburgh (1832) was the first person who called all three name Basella alba, Basella rubra and Basella lucida are synonyms and adapt Basella alba as a correct name (Sidwell 1999) [69]. According to Echo plant information sheet, two colour forms of Basella are not separate species and the first species having a green stem and green leaf are identified as Basella alba L. while the second species having a red stem and red leaves are found are identified as Basella alba L var. cordifolia (Lamk.) Almeida (Almeida 2003) [6]. Basella alba is also known as Malabar spinach, Indian spinach, Ceylon spinach, climber spinach and vine spinach (Roy et al 2010, Sen et al 2010) [63, 67]. Name of Basella alba in a different language of the world is “Malabar spinach” in English, “Lu luo kui” in Chinese, “Pazu” in Turkish, “Mong toi” in Vietnamese (Eland, S., 2008) [18], “Espinaca blanca de Malabar” in Spanish, “Basella” in French, “Spinacio della cina” in Italian “indischer spinat” in German (Eland, 2008 and Deshmukh et al 2014) [18, 19], “Alugbati” in Filipino, Philippines (Tongco et al 2015) [73] and “Amunututu” in the Yoruba language of Nigeria (Alakinde et al. 2014) [9].

**Morphology**

Malabar spinach is a perennial vine with fibrous roots. The stem of Malabar spinach is fleshy, succulent, thin, smooth, bright and leaves are distributed spirally. Side branching also observed in the stem. Stem length is about 8 to 10 m. The leaf stalk is short and leaf is oblong as its length is longer than its width. Flowers of Basella alba are white, red or pink depending on the variety. Fruits colour is red or black. The surface of the seed is bright and rough with black and brown in colour. Thick testa is present around the seed. Seeds can remain viable for four years under optimum conditions. (Almeida, 2003, Mahr, 2014) [6, 41].

Cytological, pollen morphological and protein profile studies of both red and green stemmed Basella plant confirmed that both plant are generated from same Basella alba L. species (Roy et al 2010) [63]. According to Echo plant information sheet, The plant with green stem and green petiole is Basella alba L. while the red stem and red petiole is Basella alba L var. cordifolia (Lamk.) Almeida (Almeida 2003) [6].

**Pigments of Basella spp.**

Leaves and fruits contain Betacyanin and Flavonoid pigments. Major red pigments present in dye extract of Basella alba is gomphenin-I, which is the compound of betalain family. Red-violet colour of leaves (Cyunel 1989) [13], stalks, petioles and fruits are due to the presence of betalains (Palada et al. 1999) [57]. Natural colour pigment anthocyanin is also present in stem, leaves and flowers (Glassgen et al 1993) [21]. Betalains are the red or yellow coloured tyrosine derived pigments present in many plants such as Beetroot, bougainvillaeas, amaranthus and opuntia. Betalains content in leaves and fruits of Basella plant is less than the tubers of beet (Kumar et al. 2016) [36]. Betalains, extracted from B. vulgaris and the prickly pear Opuntia ficus-indica are used in food (Delgado-Vargas et al 2002) [14]. Betalains extracted from fruits of Basella plant are also used in food formulations (Kumar et al. 2015) [37]. It is considered as an alternative of synthetic colourants because of its positive effects on health (Lin et al. 2010, Khan et al. 2012) [19, 30] and also uses in the pharmaceutical and cosmetic industry (Khan et al. 2015) [28]. Due to the presence of pigments, fruit extract of Basella alba can be used as a natural colourant on fabrics (Mitra et al. 2015) [48].

**Cultivation of Malabar spinach**

*Malabar spinach* is a leafy vegetable, suitable for both home and market garden in the lowland tropics (Siemonsma et al. 1994) [70]. This perennial plant is native to countries of tropical Asia like India, Sri Lanka and Indonesia, and it can be easily grown as an annual crop during the summer and as ornamental foliage vine in gardens or park (Mahr, 2014) [41].

**Cultivated lines: according to Malabar spinach – World Vegetable Center**

(a) VI047671-A1: Vigorous growth, high yielding, thick green leaves with pink veins, Purple stems with short internode length, and late flowering line.

(b) VI047914: Vigorous growth, high yielding, thick dark green leaves, Green stems with short internode length and late-flowering line.

(c) VI049472: Vigorous growth, Narrow, thin, light green leaves, Light green, thin stems with long internode length and early flowering line.

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**Table 1:** Characteristics of Basella alba l. and Basella alba l.var. cordifolia (lambk.) Almeida (Almeida, 2003) [6]

| S. No. | Character                  | Basella alba l. | Basella alba l.var. cordifolia (lambk.) Almeida |
|--------|---------------------------|-----------------|-------------------------------------------------|
| 1.     | Stem                      | Fleshy, stout at the base with slender upper branches. | Very long, slender, succulent, glabrous and much-branched. |
| 2.     | Leaves                    | Auxiliary dark green, broadly ovate in shape and acute. | Broadly ovate, acute or acuminate, thick, apiculate with a cordate base. |
| 3.     | Flower                    | White, pink or red in colour and sub sessile. | White or red in colour, sessile in few lax pedunculate spikes. |
| 4.     | Bracts                    | Scaly and small. | Small and apiculate. |
| 5.     | Bracteoles                | Acute. | Longer. |
| 6.     | Fruit                     | Black or dark purple in colour and enclosed within the persistent fleshy calyx. | Small and red or black in colour. |
| 7.     | Seed                      | Black, globose. | Black |

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(d.) **VI051016:** Vigorous growth, Narrow, thin, dark green leaves with pink veins, dark purple stems with long internode length and medium to the late flowering line.

**Climatic requirement:** Hot, sun-drenched climate is suitable for cultivation of Malabar spinach. 70 to 75 % relative humidity is needed for the cultivation and also humidity is essential to inhibit flowering that causes bitterness in the leaves. The plant growth is highest at the optimum temperature 32°C and as temperature drops to 26 °C the growth of plant slows down. Optimum 18-23 °C temperature is needed for seed germination. Direct sunlight and windproof areas are ideal for the cultivation (Mahr, 2014) [41].

**Soil:** Malabar spinach can be grown easily under proper soil and climate conditions (Palada et al 1999) [56]. Soil with high organic matter content, moisture and suitable drainage system is needed for cultivation. Optimum pH 6.5-6.8 is required for root development (Mahr, 2014) [41].

**Fertilizer requirement:** Before planting application of 100 t/ha organic manure complement with 250 kg/ha 10:10:20 nitrogen, phosphorus, and potassium. Straw mulching is useful particularly in the initial stages of development and during dry periods to preserve water. (Acikgoz et al. 2018) [2]. For good quality leaf application of 10 to 20 t/ha well-decomposed cow manure (Palada et al 1999) [56].

**Sowing and Spacing:** Cultivation of Malabar spinach done by both seed and seedling. A seed rate of 10-15 Kg requires for the one-hectare area. Recommended spacing for transplanted seedling is 100 cm between rows and 50 cm between plants (Palada et al 1999) [57]. Natural (straw, sawdust, herbage and other materials) and synthetic (polythene in different colours) both materials are used for mulching. These are well known for modifying the energy and water balance at the surface of soils mulches creating favourable conditions for plant growth by modifying soil temperature (Farias-Larios et al., 1997) [19], decreasing the moisture loss from the soil, suppress weed growth (Borosic, et al., 1998) [9], control of soil-borne pathogens, and reduce insect/pest populations (Farias-Larios et al. 1997) [19]. The yield of a mulched plant is higher than the unmulched plant. Silver plastic mulch gives the highest yield (Gonzaga et al 2014) [22].

**Diseases:** A total of 26 and 19 endophytic cultivable fungi were isolated from *B. alba* and *B. rubra* respectively. Majority of the endophytes belongs to the genus *Alternaria* and several genera in class Dothideomycetes. *Alternaria* is predominant in both the plants (Moutusi et al. 2019) [51]. Endophytic fungi can either complete or part of their life cycle inside the host tissue and colonize either in intercellular or intracellular spaces of leaves, stem, flowers, fruits, seeds and roots. The host plants show higher nutrient uptake, get immense resistance to herbivores, abiotic stresses (Mishra et al. 2014) [47].

Leaf Blight of *Basella alba* Caused by *Alternaria alternata* (Fr.) Keissler in India. In PDA media white to brown in coloured fungal colonies are formed. The fungus produces brown, short, simple, or sometimes branched conidiophores. Conidia are obclavate, obpyriform or ellipsoidal with a short conical beak with pale brown in colour. Conidia had three to eight transverse septa with one to two longitudinal septa (Sankar et al 2011) [64]. Leaf spot is elliptical to irregular oval, yellow-brown to dark brown, and concentrically zonate with diffuse margins frequently surrounded by light-coloured haloes. Initially, the infection started from the leaf tips and reached to leaf base at a later stage. In severe infections, spots coalesce to cause necrosis, wilting, and ultimately death of leaves (Sankar et al. 2011) [64].

In Malabar spinach, Leaf spot disease is caused by *Colletotrichum.* This disease is more severe in *B. rubra* than *B. alba.* *Cercospora Basellae-albae* produces necrotic spot on leaves of *Basella alba*. This pathogen was first described from *Basella alba* in India (Srivastava et al. 1994) [73] and was reported recently in Thailand (Meeboon et al. 2007) [65], Philippines (Begum et al. 2010) [7]. Necrotic spots appear on both sides of young and mature leaves. Initially, spots are circular to subcircular, 1-10mm wide with reddish-brown in colour. In a later stage, spots turn into black to brown in colour with grey centres and reddish-purple borders. Conidiophores are visible as minute black dots on the leaf spots. Conidiophores are unbranched, pale olivaceous brown, uniform in colour, straight or mildly genulate with thickened conidial scars and sparingly septate. Conidia are hyaline, straight to slightly curved, indistinctly multisepitate, acuate at the apex, truncate at the base with a thickened hilum. Crous and Braun (2003) [12] stated that *Colletotrichum Basellae-albae* was similar to *Colletotrichum apii s. lat.* but conidial size of *C. apii s. lat.* is longer than *Basellae-albae* while conidiophores of *C. apii s. lat.* has narrower than *C. Basellae-albae.*

**Yield:** 1.5-2 kg fresh leaves are obtained per plant (Acikgoz et al. 2018) [2]. For seed production, dry fruits are selected. Total 1000-2000 kg/ha dry seed is obtained (Grubben et al. 2004) [23].

**Importance**

**Use as an indicator:** Fruit extract of *Basella alba* is used as a natural indicator in acid-base titration to detect endpoint because of the sharp colour of occurring with the change in pH value. The original colour of the dye is violet and their pH value is 4.9 (Mitra et al. 2015) [48]. Normally Synthetic colourants used for acid-base titration are hazardous to human beings and environment while natural indicators are economical, simple, easily available and eco-friendly. (Mitra et al. 2016) [49].

**Medicinal uses:** Natural foods have several health benefits (Schmidt 1974) [66]. The risk of cardiovascular diseases, stroke, and cancer can be reduced by adding fruit and vegetable in the daily diet (Rice-Evans et al 2003) [62]. *Basella* plant species contain betacyanin, carotenoids, bioflavonoids, ß-sitosterol and lupelol which are reported to have antioxidant, antiproliferative, antimicrobial, anti-inflammatory activities etc. and help in curing various diseases, namely anticancer, antiviral, antioxidant, anti-inflammatory, anti-cholesterol, anti-ulcer, antimicrobial, anti-hypoglycemic, wound healing, androgenic from the ancient times (Shade et al. 2017) [68]. In Ayurveda Malabar spinach is called as “Upodika”, “Potaki”, “Malvaa”, “Amritvallari”, and in Siddha/Tamil as “Vaslakkirai” (Khare, 2004) [31]. Several different types of medicinal elements are found in the *Basella* plant which helps in fighting many diseases such as:

a) Saponins phytochemicals have anti-inflammatory, anti-microbial, vasodilatory actions, and antioxidant effects (Garcia et al. 2005) [20] and have the ability to fight against cancer and cardiovascular diseases (Kumar et al. 2013) [34].
b) Kaempferol, the flavonoid is protective against cardiovascular diseases and cancer (Yang et al. 2008) [79].

c) Red stemmed Basella rubra plant have wound-healing effect (Haneefa et al 2012) [24], antibacterial activity (Oyewole et al 2012) [55] and antiviral activity (Dong et al. 2012) [56], anti-inflammatory effect (Kumar et al. 2011) [58] and antilucre effect (Venkatalakshmi et al 2012) [53].

d) Leaf juice is used in to treat catarath (Nandkarni et al. 1908) [25].

e) Leaf juice also used as safe laxatives for children, pregnant women and in the urinary diseased patient (Mishra et al. 2006) [46].

f) Flowers are locally used as Antidote for poisons.

g) Plant extract caused an increase in the WBC count which help in the management of anaemia and immunity-dependent disorders (Sonkar et al. 2012) [71].

h) Plant leaves show amylase activity which helps in the diagnosis of acute pancreatitis. (Sonkar et al. 2012) [71].

i) Boiled Basella alba is used to treat retained placenta in the cow (Adekilekun et al. 2012) [41] because it develops severe diarrhoea that causes the placenta to come out.

j) Leaves are also used as anthelmintic, demulcent, anti-inflammatory, anti-malarial and analgesic (Yanadaiah et al. 2011) [78].

Table 2: The nutritional content of Malabar spinach (Yang et al 2008 and USDA, 2018) [79]

| S. No. | Nutrients | Quantity (per 100 g) |
|-------|-----------|---------------------|
| 1.    | Water     | 93 g                |
| 2.    | Energy    | 19 kcal             |
| 3.    | Protein   | 1.8 g               |
| 4.    | Fat       | 0.3 g               |
| 5.    | Calcium   | 109 mg              |
| 6.    | Phosphorus| 52 mg               |
| 7.    | Iron      | 1.2 g               |
| 8.    | Magnesium | 65 mg               |
| 9.    | Potassium | 510 mg              |
| 10.   | Sodium    | 24 mg               |
| 11.   | Zinc      | 0.43 mg             |
| 12.   | Vitamin A | 8000 IU             |
| 13.   | Vitamin B1| 0.05 mg             |
| 14.   | Vitamin B2| 0.16 mg             |
| 15.   | Vitamin B3| 0.50 mg             |
| 16.   | Vitamin C | 102 mg              |

Nutritional importance: Basella rubra is a good source of calcium, iron, and vitamins A and C. Seed contain fatty oils such as palmitic, oleic and linolenic acid (Anonymous, 2004). Carotenoids also found in the leaves of Basella rubra with major beta-carotene, small amounts of alpha-carotene and traces of other carotenoids (Panteado et al. 1987) [58]. This plant is good for health due to the presence of mineral, protein, oil, carbohydrate, fibre, carotenoid, organic acid, vitamins. According to Lyimo et al. 2003 [40], Malabar spinach contains 98.7 mg./100g vitamin C, 5% protein, 1.5% fiber, 0.7% fat, 250.0 mg./100g Ca, 4.0 mg./100g Fe. It also contains 15.9 g./100g ash, 27.7 g./100g protein, 3.1 g./100g fat, 42.1 g./100g carbohydrate, 306.7 kcal./100g energy, 400.0 mg./100g Vitamin C, 48.7 mg./100g Ca, 21.5 mg./100g Fe and g./100g fiber (Maisyuthusakul et al. 2008) [42].

Use in pest management: Basella rubra seeds contain two types of antifungal peptides α and β basrubsrins which are effective against some important fungi like Botrytis cinerea, Mycosphaerella arachidicola and Fusarium oxysporum (Wang et al. 2001) [76]. Antiviral glycoprotein effective against potato virus has been also found in Basella leaves. Methanolic extract of leaves of B. alba contains two glycosides flavenoids vitexin, and vitexin-2′-O-arabinofuranoside which inhibit the growth of Spodoptera littua. These flavonoid glycosides act as deterrents to S. littura larvae (Aboshi et al. 2018) [31], green peach aphid, Myzus persicae (Dreyer et al 1981) [17], 50% population of aphid Myzus persicae is inhibited by 0.1% concentration of vitexin (Dreyer et al. 1981) [17]. The concentration of vitexin and vitexin-2-O-arabinofuranoside glycosides flavenoid is higher in younger leaves than mature leaves (Rhoades 1979) [61]. Basella plant also acts as a trap crop against whitely. Intercropping of celery and B. alba with cucumber reduced whitely on cucumber due to presence of Geranylnitritre which reduces whitely colonization (Zhao et al. 2014) [81].

Oil content in Malabar spinach: Malabar spinach oil can work as very good vegetable oil (Abedotun 2004). Saturated fatty acids like lauric acid, arachidic acid, behenic acid, lignocenaric acid, palmitic acid, stearic acid and myristic acid while unsaturated fatty acids like oleic acid, eicosenoic acid, palmatoleic acid, erucic acid, docosahexaenoic acid, arachidonic acid, linoleic acid and alpha-linolenic acid are present in the oil of both red and green species of Malabar spinach. In the oil of red Malabar spinach total amount of saturated and unsaturated fatty acid is about 22.19% and 50.7% respectively while in oil of green Malabar spinach oil total amount of saturated and unsaturated fatty acid is about 21.41% and 52.36% respectively (Abedotun 2017) [3]. That’s why Malabar spinach oil can be used as a vegetable oil in homes.

Use as a vegetable: Malabar spinach is used to make many types of dishes in many countries like Philippines, Thailand China, Mongolia, India, Sri Lanka and many African countries. In the Philippines, a vegetable dish called utan which is cooked with sardines, onions, garlic, and parsley. In Mangalorean Tuluva cuisine, a coconut-based gravy called gassi is pair with the Basella plant, making a delicacy called Basale gassi to be eaten with rice dumplings called Pundi soaked overnight in the gravy, or with red rice. Soup is called “poi na bhajia”.

Table 3: Malabar spinach dishes made in India (Wikipedia)

| S. No. | State          | Dishes                                  |
|-------|----------------|-----------------------------------------|
| 1.    | West Bengal    | In the vegetable dish, cooked with red pumpkin, and in non-vegetarian dishes, cooked with the bones of the fish |
| 2.    | Karnataka      | Basalede kunhi Pindi                    |
| 3.    | Andhra Pradesh | curry of Basella and Yam were popularly known as Kanda Bachali Koora and snack item bachali koora bajji |
| 4.    | Odisha         | Curries and Saaga                       |
| 5.    | Maharashtra    | Dunto or valchi bhaji                   |
| 6.    | Gujarat        | Pakodas, popularly called "poi na bhajia" |
Conflicts of Interest
The authors have no conflict of interest to declare.

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