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NOTES ON NEGLECTED AND UNDERUTILIZED CROPS

'Drumstick tree' (*Moringa oleifera* Lam.): a multipurpose potential species in India

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Abstract *Moringa oleifera* Lam., a medium sized tree species has gained importance due to its multipurpose usage and well adaptability to dry and hot climates of north-western plains, central India and dry regions of peninsular India. This species is reported in this paper for distribution of diversity and genetic resources value in different parts of the country. Information on diversification in use viz. regional importance has been included to broaden the scope for value addition, identification of potential value and use in plant genetic resource programmes.

Keywords Collection · Conservation · Drumstick tree · Edible value · Horse radish tree · *Moringa oleifera* · Multipurpose species · Potential value · India

Introduction

The genus *Moringa* Adans. (family Moringaceae) has more than 13 species (Verdcourt 1985), of which two species viz. *M. oleifera* Lam. (syn. *M. pterygosperma* Gaertn.) and *M. concanensis* Nimmo occur in India. *M. oleifera* (the drumstick tree, horse radish tree, West Indian Ben) is a fast-growing, medium sized and drought-resistant tree distributed in the sub-Himalayan tracts of northern India (Singh et al. 2000; Hsu et al. 2006) and in the tarai tract of Uttarakhand, foothills of Himachal Pradesh, Sikkim and part of northern Uttar Pradesh (Bareilly, Pilibhith, Shahjahanpur, Bahraich, Gorakhpur and adjoining region) in India. The tree is widely cultivated and naturalized worldwide in the tropics and sub-tropical regions of the world. The other species *M. concanensis*, a small tree that resembles *M. oleifera* grows wild in India (Rajasthan, Madhya Pradesh, Gujarat, Maharashtra, Goa, Andhra Pradesh and Tamil Nadu). This little known species differs from the former in bipinnately compound longer leaves and yellow flowers streaked with pink or red. It is locally used for edible fruits and medicinal purpose (Wealth of India 1962; Singh et al. 2000).

M. oleifera (locally called shobhanjana, murungai, soanjna, shajna, sainjna) is considered to be the best-known and widely distributed tree species among the genus (Morton 1991; Fuglie 1999). This is the only species in this genus which has been accorded some research and development at the world level. A species considered to be a potential crop has been neglected in the past. Owing to rich nutritional content in fruit, leaf and other plant parts it deserves attention particularly for improvement, commercial cultivation and utilization in India especially in the northern part. This paper highlights the information on assessment of diversity distribution in India *vis.-à-vis.* plant genetic resources, utilization in India and scope for marketability.

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Botanical description

Botanical description ($2n = 28$) (of wild and cultivated): a deciduous perennial tree (up to 12 m) characterized by slender stem with drooping branches; stem brittle with corky whitish-grey bark; leaves feathery above and glabrous beneath, pale green, tripinnate, 30–60 cm long, lateral ones somewhat elliptic, terminal one obovate and slightly larger than the lateral ones, oblique sided at base; flowers honey scented, 2.5 cm in diameter, borne in profuse axillary drooping panicles; calyx tube hairy, lobes petaloid, linear-lanceolate; petals white or rarely pink, dotted with yellow streaks at the base, anterior erect; stamens five, yellow, alternating with five staminodes; ovary oblong, style cylindrical; fruit is beaked (pointed at apex and tapering at base) capsule, drooping, brown, 20–120 × 1.0–2.8 cm, nine-ribbed, three-valved, three angled or nearly cylindrical on maturity, splitting lengthwise into three parts when dry, about 15–24 seeds embedded in pith, parietal placentation; seeds ivory white-brown, with three papery deciduous wings.

Cultivation

This species grows best in the average maximum temperature range of 25–35°C, although it can survive the summer temperature up to 48°C for a limited period and can tolerate frost in winter (Price 2000). In India this species is generally propagated through cuttings (1–2 m long), during the months of June–July. Under commercial cultivation it is pruned up to 3 m to facilitate easy harvest of pods and leaves.

M. oleifera shows the seasonal behaviour in different parts of India. In the north and eastern parts of the country, leaves are shed in December–January and new ones appear in March–May along with flowers followed by fruiting in April–June (Fig. 1). However, in the southern states flowers and fruits are produced throughout the year, July–September and March–April being two peak periods for crop (Wealth of India 1962).

Seeds do not have any dormancy period and can be sown after separating from the mature pods (Prabhakar et al. 2003). They are orthodox and remain viable for about 3–4 months under ambient conditions. This species is resistant to most pests but hairy caterpillars causing root rot and defoliation can cause serious threat especially to fresh leaves and the planted stumps. Flower drop due to infestation of caterpillar pests *Eupterote mollifera* Walker and *Noorda blitealis* Walker, and seasonal incidence of fruit fly by *Gitona* sp. are other commonly reported problems (Murthy and Regupathy 1992). The large trunks (1–2 m) of old trees ooze gum that harbour swarms of hairy caterpillars causing itching on human body.

Status of production

Perennial types are beset with many production constraints, such as a relatively longer pre-fruit bearing

Fig. 1 Fruiting in *Moringa oleifera*: wild tree with heavy fruit bunch (*left*); cultivated tree with flowering and fruiting simultaneously (*right*)

period, requirement of a greater number of rainy days in regions where water is scarce, and vulnerability to pests and diseases. Under commercial cultivation *M. oleifera* is grown both as annual and perennial. Annual types developed at Tamil Nadu Agricultural University (TNAU), revolutionised the moringa cultivation in South India. Due to fast adaptability to varied agro-climatic conditions annual types have replaced more than two third of the perennial types in southern states (Rajangam et al. 2001).

The plant starts bearing fruits at the age of 6–8 months if raised from the cuttings. Fruit yield is low in the initial two years but from third year onwards, a single tree yields approximately 600–1,600 fruits per year (Ramachandran et al. 1980; Morton 1991) with an average of 200–250 fruits/plant per year. Studies conducted at Indian Institute of Horticultural Research (IIHR) have shown that the higher yields were mainly due to higher number of pods produced per tree rather than fruit size (Prabhakar and Hebbar 2008).

India is the largest producer of moringa with an annual production of 1.1–1.3 million tonnes of tender fruits from an area of 38,000 ha. Among the main states of moringa cultivation, Andhra Pradesh leads in both area and production (156.65 km^2) followed by Karnataka (102.80 km^2) and Tamil Nadu (74.08 km^2). In other states, it occupies an area of 46.13 km^2. In these states, more than 52,000 farmers are engaged in small scale commercial cultivation with annual net income of about $1,500/hectare (Rajangam et al. 2001; Patel et al. 2010).

Diversity distribution and genetic resources in India

Considerable genetic variability is available in the tarai tracts of Uttarakhand and Uttar Pradesh, India (Ramachandran et al. 1980; Grubben and Denton 2004). In the areas of natural distribution it occurs as a component of the mixed broad leaved/conifer forest along forest of sub-Himalayan tracts, often associated with sal and khair forest or nearby crop fields and river side (Gaur 1999; Singh et al. 2000; Fig. 2). In Bhabar area of Kumaon, Uttarakhand Himalaya rare types with beautiful pink-white flowers were recorded (1,000–2,000 m) (Strachey 1918; 1974). In neighbouring regions in the Nepal Himalaya it occurs as a

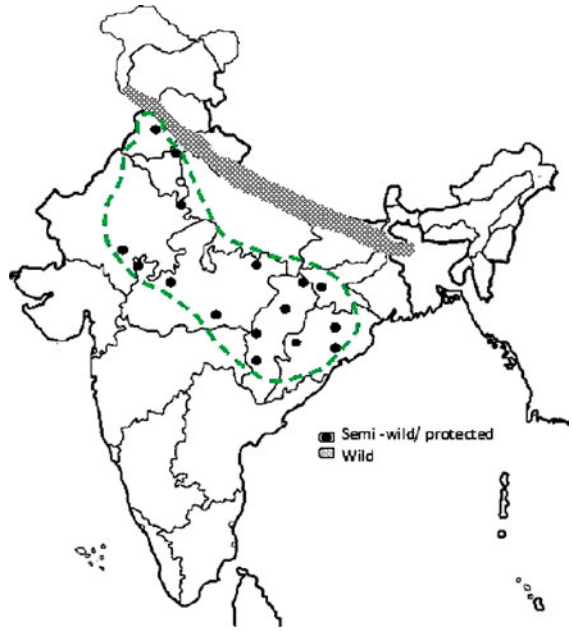

Fig. 2 Distribution of diversity in *Moringa oleifera* (map prepared by Sh. Shashi Kant Sharma, NBPGR) (*shaded areas* for wild types; *dotted areas* for protected/semi-domesticated populations)

common forest species (Bhattarai and Baral 2006). The second author while on way to exploration enroute from Srinagar-Rudraprayag-Karnaprayag road, Garhwal Himalaya, Uttarakhand observed sparse but prolific flowering population with predominantly pink flowers (the pink flowers are common in wild forms). He also found pink flowered population in Panchkula district of the foothills of Himachal Pradesh in the western Himalaya. This species occurs under protected habitats in the tribal dominated tracts of central India (parts of Bihar, Chhattisgarh and Simlipal region of Orissa) evidently exhibiting trends of protection/semi-domestication (Duthie 1960; Wood 1977; Haines 1978; Dr. DR Pani, pers. comm.). This species is commonly cultivated as perennial in home gardens in South India (a probable area of domestication). In several areas it is also seen to run wild near areas of cultivation in states of Kerala, Rajasthan, etc. (Shetty and Singh 1987; Murthy and Venu 2005). Due to high value of fruits (commonly called pods) and seed production, this species has rapidly spread to many tropical countries of the world in over last century.

Promising cultivars with variability in fruits have been identified from the Indian Gene Centre. Tamil Nadu is the pioneering state having good variability

in genotypes represented from diversified geographical areas including introductions from Sri Lanka. The cylindrical-round fruits are commonly available as compared to three-angled types. Fruits of cultivar *Bombay* are curly and of best quality. Cultivar *Jaffna* (probably introduced from Sri Lanka) with soft pulp, thin and long fruits (60–90 cm), commonly long and tasty fruited cultivar *Chavakacheri murungai* (90–120 cm long fruit) and its selection *Chanakacheri muruga* are cultivated in south India. In Tamil Nadu, less popular varieties with thick, shorter fruits and bitter pulp (in Tirunelveli district called *Palmurungai* and *Punamurungai*), *Kodikkal Murungai* and *Moolanoor* also more popularly cultivated (Muthuswamy 1954; Wealth of India 1962; Sundaraj et al. 1970). Some regional types *Chemmurungai* (red tipped fruits, which flowers throughout the year) and yield heavy crops and a wild type *Kadumurungai* producing small inferior fruits also occur in southern Tamil Nadu.

The wild and domesticated types exhibit a range of variation in tree size (erect-spreading, moderately loose canopy), leaf size, colour, shape (elliptic, obovate), flower colour (pink, white streaked with yellow), pod length (small-thin, long-thick), taste of pulp (bitter, tasteless), colour of pod (pale green, green, dark green), fruit tip (red, green) and pericarp surface (striated, smooth). The wild types have bitter/semi-bitter, hard and fibrous pods with tasteless flesh (Arora and Pandey 1996).

Concerted efforts involving introduction, conservation, evaluation and breeding have resulted in the development of two improved annual moringa varieties (PKM-1, PKM-2) superior over perennial types have been released for commercial cultivation. These varieties have performed well in many traditional and non-traditional areas (Sathashathi 1999).

Germplasm collection and conservation

The National Bureau of Plant Genetic Resources (NBPGR), New Delhi, being a nodal organization for management of plant genetic resources in the country, has collected over 200 accessions mainly of cultivated *M. oleifera* from different phyto-geographical regions of the country (Plant Germplasm Reporter 2000–2010). Major variability was gathered from peninsular region (Tamil Nadu, Andhra Pradesh, Karnataka, Kerala and Maharashtra). Sporadic collections were assembled from parts of tribal tracts of Bastar, Chhattisgarh, Rajasthan, Haryana, Uttar Pradesh, Madhya Pradesh and Punjab. At the national level, research efforts were initiated on this crop under the Indian Council of Agricultural Research funded project on "Improvement of Underutilized Vegetable Crops" in 2004 at several cooperative centres of Indian Institute for Horticultural Research (IIHR), Bangalore. Activities involving germplasm augmentation, characterization for identification of promising accessions, breeding and conservation of *M. oleifera* have resulted in the development of promising high yielding annual cultivars (Rajangam et al. 2001; Varalakshmi and Devaraju 2007).

Accessions of perennial and annual types representing diversity in plant height (dwarf and medium stature), fruit (fruit bearing, cluster bearing) and resistance to biotic and abiotic stress (drought tolerance, pest and disease resistance/tolerance) have been assembled at TNAU, Periyakulam. Under the crop improvement programmes in the country some work on agronomical aspects has been carried out (Gasti et al. 2006). However, the germplasm of *M. oleifera* genepool is meagerly represented in the national genebank at NBPGR and efforts have been initiated in this direction.

Use

The value of *M. oleifera* for edible pods, seed oil, fodder, and for medicinal use was well known to Indians from the time of immemorial (Watt 1889). An exceptionally nutritious vegetable tree with a variety of potential uses was grown as backyard species originally by the Dravidians (south Indians) and later by the Aryans (north Indians) (Ramachandran et al. 1980). The genetic resource value of the species finds its entry in the earliest records in Ain-i-Akbari (400 years old) listing of plants used as favourite pickles by the north Indians (Watt 1889). Only in last two centuries it was introduced to other parts of the world mainly as an ornamental and multipurpose species (Fawcett and Rendle 1914; Massal and Barrau 1956; Berger et al. 1984; Morton 1991; Folkard and Sutherland 1996; Muluvi et al. 1999; Odee et al. 2001). Presently this species is cultivated nearly throughout the Old World Tropics and also occurs as naturalised.

In the southern states of India, especially in Tamil Nadu and Kerala, *M. oleifera* was frequently cultivated in homesteads, around cattle sheds, and on farm boundaries, fences and village waste lands and as an intercrop. Due to wide variations in temperature in northern part of the country this crop is not very successful. This potential crop of the tropical and subtropical regions still largely remains under cultivation on marginal and small farm holdings as source of vegetable for domestic use and local markets and less preferred for edible use.

Major use as edible pods, leaves and flowers

This species has been principally utilized for fruit and leaves as vegetable, and to some extent for edible flowers and seed oil particularly in India, Pakistan, Philippines, Hawaii and many parts of Africa (Watt 1889; Anwar et al. 2005; Lost Crops of Africa 2006). Very young pods (10–15 days old) taste like asparagus and are commonly consumed as vegetable and for culinary preparations. In Bihar and Orissa tender pods garnished with mustard seed paste are cooked like beans and consumed with rice (pani bhaat). Mature pods are used in preparation of soups and stews. Scraped drumstick pulp is made into a tasty dish called 'moringa bhartha' (like the dish prepared from brinjal). Drumstick curry is prepared by adding boiled pieces or pulp into pigeon pea curry). In South India pods of medium maturity (35–50 days old) are used in recepies like 'Sambhar' preparation (pigeon pea pulse cooked with seasonal vegetables) and for others as 'Avial' and 'Meenkulampu' (fish curry).

Towards the end of dry season when other leafy vegetables are few in market the younger leafy tips and tender leaves are used as vegetable, condiment and in salads as the coriander leaves. In Orissa the leafy vegetable and fully ripe green fruits are marketed and consumed with rice during summer months (Fig. 3). The local people relish the vegetable prepared from fruits of local types (small fruited) because of desirable flavour. Vegetable called "sanjana saag" or "sanjana tarkari" is prepared from fresh young leaves (cooked with green gram, pumpkin, potato or taro) is commonly recommended as a special food supplement for pregnant women, lactating mothers, in patients suffering from osteoporosis and bone fracture (Dr. DR Pani, NBPGR, Cuttack; pers. comm.). Dried leaves are powdered and stored for off season use. They are routinely sold in parts of Orissa, Tamil Nadu, Andhra Pradesh and Karnataka and also in markets of metropolitan cities of the country at the rate of Rs 45–50 per kg (approx. $1.0; Fig. 3).

The flower buds and young flowers with tender leaves are prepared as leafy vegetable in Orissa. In parts of West Bengal and adjoining regions of Bangladesh they (called *sojne fool*) are generally cooked as a delicacy prepared using green peas and potato and consumed especially during spring. In northern India mainly the Punjabi, Sindhi and Multani communities prepare flowers as a delicacy after boiling/frying with curd (Ms NK Chaudhari, ex NBPGR, New Delhi; pers. comm.). Young flowers (both pink and white form) packed in packets are commonly sold during February–March in city markets of northern India (Arora and Pandey 1996). During exploration to Bilaspur district (foothills of Himachal Pradesh) the second author recorded sale of flowers/buds in wholesale market (pers. comm.). In Bihar and Orissa flower buds and tender leaves are

Fig. 3 Pods (*in centre of left photo*) and leaves (*in centre of right photo*) of *Moringa oleifera* being sold in market (courtesy: Dr. DR Pani, Cuttack)

mixed in batter (gram flour) and consumed after deep frying. In some areas immature seeds are consumed raw or cooked (Ramachandran et al. 1980).

Other uses

The oil from the seeds of *M. oleifera* is used as edible oil, an excellent salad oil, illuminant, lubricant, as biofuel and in cosmetic industry (Rashid et al. 2008). The seeds yield 38–40% of non-drying, sweet, odourless and clear oil that resembles the olive oil (Anwar et al. 2007). Other multipurpose uses of the species are met from- plant (as hedge and agro/social forestry), leaves (fodder), seeds (seed cake as fertilizer), roots (especially from seedlings; pickle with vinegar), fuel wood (soft, porous and yellowish), bark gum (used for food seasoning and in calico printing), flowers (good source of nectar) and coarse fibre (Wealth of India 1962; Guha et al. 1968). The coagulating ability of the seed powder has been used to purify water to make it suitable for drinking in arid regions. It is a cheaper bioabsorbent for removal of heavy metals and organic compounds (Sharma et al. 2006). It is used in treatment of rheumatism, venomous bites, fever, cardiac and circulatory diseases, abdominal tumours, counter-irritant, external stimulant of skin, purgative, expectorant, mild diuretic, epilepsy and hysteria (Rao 1985; Mughal et al. 1999; Singh and Kumar 1999; Anwar et al. 2007).

Many regions of the world are in the forefront in the commercial market for value added products (seed oil, leaf powder, tinned beans) of *M. oleifera*. In India fewer products have entered even in the domestic markets. Methodology has been standardized for processing, dehydrating and packaging of pods and leaf powder for marketing (Amutha and Krishnamurthy 1999; Joseph 2007). TNAU is exploring the potential use of seed oil as biofuel on an industrial scale with the Western Australian Agriculture Authority (WAAA; Business Line 10 July 2008).

Use of *M. oleifera* in addressing malnutrition is a challenge for India and other developing nation (Rahim et al. 2007). The tree is a good source for calcium, phosphorus and iron. The leaves are rich in protein content (27%), vitamins A and C, beta carotene, potassium, calcium, iron and phosphorus and are good source of natural antioxidants and thus enhance the shelf life of fat containing foods (Gupta et al. 1989; Dillard and German 2000). Leaves, flowers and young fruits are rich in gluconsinolates (Wealth of India 1962; D'souza and Kulkarni 1993).

Domestication trends

Analysis of diversity distribution pattern, utilization based socio-economic study and dependence of population on local useful genetic resources throw light on folk domestication trends in diversity rich regions (Arora 1987; Pandey and Arora 2004). In *M. oleifera* areas of natural distribution (the west and central Himalaya and the foothills and parts of central India) exhibit rich variability in fruit types in wild/semi-domesticated populations, with minimal recorded use of plant (Samant and Dhar 1997; Tiwari et al. 2010). Similar trends were recorded for use of edible oil by Indian folks of tribal regions (Vishnu 1981), vegetable by the Gonds and Santhals of Central India, pickled fruits by the tribals of eastern regions (Jain 1981; Arora 1981; Sawian et al. 2007) and edible leaves, flowers, fruits by natives of Andaman and Nicobar Islands (Bhargava 1981). However, in the southern states of India frequent cultivation and wider use of *M. oleifera* as vegetable crop and as multipurpose species suggested a long history of domestication.

Conclusions

In *M. oleifera* unique accessions from the diverse regions are to be identified, collected and screened for variability in fruit and leafy types as done in the West Indies cultivars (reported to flower rarely and principally cultivated for foliage, and abundantly fruiting types; see Ochse 1977; Ramachandran et al. 1980). Popularization as a crop of this region requires attention on profitable marketing and export of the commodities in international trade. For this, cultivation practices and systematic production are needed to gain momentum on commercial scale as an alternate crop in northern region especially in parts of dry/arid regions of India. The following thrust areas have been identified:

- Assessment, augmentation and conservation of the moringa genepool having desirable traits.
- Identification of plant traits: relatively short stature plant, plants with low gestation period,

annual bearing, year round fruit bearing, fruits bearing in clusters, good yield and quality of fruits (pulp taste) and seed yield.
- Studies on breeding biology, genetic improvement and hybridisation especially with the close relatives; identifying ecotypes for industrial value with higher percentage of seed oil, proteins, medicine and wide adaptability to agro-climate.
- Development of value added products for export.
- Molecular studies for identification of provenance source before conservation and exploitation of genetic resources (as done by Muluvi et al. 1999).

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