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MORINGA OLEIFERA : A POTENTIAL MEDICINAL TREE WITH HIGH NUTRITIVE FOOD AND FODDER VALUE - BREEDING OVERVIEW

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SUMMARY

For arid and semi-arid regions of India, *Moringa oleifera* Lam. is reflected as an important tree of medicinal value for commercial cultivation. It is also known as *Shajana* and drumstick and related to the Moringaceae family. Since ancient time, its green leaves, tender and fresh flowers, succulent and immature pods are used for vegetable purpose. Present day, demand of *Moringa oleifera* Lam. and its products is increasing, due to its diverse uses in nutritional and medicinal areas. It has potential to grow on different soils and environmental conditions. All parts of this tree i.e. pods, flowers, leaves, roots and seeds are utilized due to their richness in antioxidants and essential nutritional components such as vitamins, minerals, bio-chemicals etc. In India, green leaves of *Moringa oleifera* are utilized as green fodder because of its immense potential to produce green biomass under hot environmental conditions to make availability of green fodder round the year with minimal efforts. A lot of genetic diversity is available in Moringa and by using the available genetic variability and employing the conventional and molecular breeding techniques, the process of development of new varieties is continue.

Key words: Moringa, antioxidants, food, fodder, malnutrition, nutrients and medicinal plant

Moringa (*Moringa oleifera* Lam.) also branded as drumstick tree or *Sahjana* is the supreme resourceful underutilized potential perennial plant, particularly for arid and semi-arid regions of India. It can tolerate to saline conditions (Nouman *et al*., 2012). It has an immense potential as industrial and agricultural crop (Mulugeta and Fekadu, 2014; Alam *et al*., 2014). Since ancient time, its green leaves, tender and fresh flowers, succulent and immature pods are used for vegetable and pickle purposes. It's all plant parts i.e. leaves, flowers, roots, succulent pods and mature seeds have extraordinary properties because of the existence of required nutrients such as antioxidants and essential nutrimental components such as vitamins, minerals, bio-chemicals. Therefore, this plant seems to be a highly valuable nutritive food with health utilities for human beings and fodder utilities for animals (Masih *et al*., 2019**;** Jattan *et al*., 2021; Dhillon *et al*., 2023).

In addition to vitamins, minerals, and antioxidants, *Moringa oleifera* also contains so many amino acids and fatty acids which are helping agent in increasing enzymatic, and hormonal activities and also help on osmotic-adjustment of the body. Thus, it has excellent impact on growth-development and life functions of the body (Anjorin *et al*., 2010; Jattan *et al*., 2021). Therefore, in the developing countries, *Moringa oleifera* may be utilized as a remedy against malnutrition. In addition to this, it is excellent nutritive feed and green fodder for animals (Soliva *et al*., 2005; Stelwagen, 2003; Mendieta-Araica *et al*., 2011; Nouman *et al*., 2014; Sultana *et al*., 2015; Aharwal *et al*., 2018; Falowo *et al*., 2018). Moringa also has potential to be utilized as poultry feeds (Hermogenes *et al*., 2014).

According to Sharma *et al*., (2012), it also keeps anti-spasmodic, anti-diabetic, anti-tumour, anti-hypertensive and anti-inflammatory, activities That's

why, numerous bio-active molecules identified and isolated from *Moringa oleifera* are exploited as medicine (Abalaka *et al.,* 2009). This plant has so many phytochemicals and nutrients as compared to vegetables; and also helpful to increase immunity power. The dry leaves of *Moringa* have 30% crude protein, 19% amino-acids, fiber, polyphenols, tannins, and 17% fatty acids, including capric-acid, palmitic-acid, alpha linolenic acid, and gamma linolenic acid. Some bio-chemicals, i.e. quercetin, vanillin, gallic acid, ferulic acid, and chlorogenic-acid, have healing properties (Kumar *et al.,* 2025).

Now-a –days, the area for crop cultivation particularly for green fodder production is declining drastically due to the cultivation of cash crops; in such a situation, *Moringa oleifera* may be cultivated as a good source of green fodder. It's green leaves can be used as animal fodder, or as an additional nutritional supplement to enhance digestibility of fodder (Arya & Kumar, 2021). It is also reported that feeding of animal on leaves of *Moringa oleifera* enhances weight as well as milk production. In addition to this, mixing of *Moringa oleifera* leaves in fodder of crops also contributes in better animal performance. Thus, according to Sanchez *et al.* (2006), it can be utilised as fodder supplement for cattle due to its high nutritive profile and good biomass production.

Anjorin *et al*. (2010) reported significant differences in biochemical compounds in the different plant parts of *Moringa oleifera* from location to location. These differences in biochemical compounds may be due to differences in climatic conditions, cultivation practices and genotype of the plant (Brisibe *et al*., 2009). The availability of varieties of *Moringa oleifera* for commercial is not available and information on genetic improvement methods is also very less (Padulosi *et al*., 2013; Jattan *et al*., 2021). Therefore, keeping the importance of this tree in view particularly for developing countries; further investigation is required for breeding and genetic enhancement of this tree species. The information compiled on *Moringa oleifera* will be supportive in exploiting the full prospective of this highly nutritive and incredible tree.

Origin and Distribution

Moringa trees belong to Moringaceae family. This family has thirteen different species of Moringa genus which belongs to different geographical areas of world (Shahzad *et al.,* 2013). Commercially, *Moringa oleifera* is grown in some areas of India and Africa. Four species *i.e. M. ovalifolia* (Namibia & south-west Angola), *M. drouhardii* (Madagascar), *M. stenopetala* (Kenya and Ethiopia) and *M. hilderandtii* (Madagascar) are considered by bloated water-storing trunks. Three species *i.e M. concanesis, M. peregrine,* and *M. oleifera* are recognised for their slender trees having tuberous roots juvenile phase. The remaining six species (*M. longituba, M. arborea, M. pygmaea, M. borziana, M. peregrina* and *M. rivae*) are tuberous type. *M. oleifera* is primarily cultivated tree species of genus *Moringa*. This tree is characterized as fast a softwood growing deciduous type tree. This tree is native to India's Himalaya foothill region. This tree is also extensively grown in tropical areas of South Asia (Afganistan, north part of Pakistan, north part of India, Nepal, and north-eastern Bangladesh, Sri-Lanka), West Asian countries, sub-Saharan and Africa Caribbean, Latin-America, Florida and Pacific-Island areas (Sachan *et al.,* 2010).

Plant Biology

Moringa oleifera tree is speedily growing and spreading tree, its crown is open type and its branches are drooping and fragile (Fig. 1). It bears alternate compound tripinnate leaves. The leaves have leaflets in opposite pairs. The length of leaf varies from 45 to 90 cm. Its leaves are dark green in colour with red-tinged mid-veins, entire margins and rounded leaf apex (Rollof *et al.,* 2009).

The wood of stem is soft and light in weight and bark is thick and corky, and whitish-grey in colour. Tree has deep tap-root system having tuberous lateral roots spreading in all directions to support to plant. Its plant generally bear flowers twice in a year or round the year. Its flowers come in clusters on 10-25 cm long loose axillary panicles and produce pleasant-smell. The colour of flowers is generally white or creamy-white. Flowers are pentamerous and zygomorphic (Sachan *et al.,* 2010). Calyx consisted of five green sepals which are tubular and lobed. Corolla also consisted of five creamy-white petals with narrow spathelate and veined.

Androecium has five productive yellow-stamens having alternate five small sterile-stamens (staminodes). Gynoecium is consisted of a single stalked superior ovary having cylindrical style. Ovary has two lines of ovules, ranging from 10 to 25 in number. The fresh and tender pods of *Moringa* looks like drum-stick that why its name is drumstick tree. Pods may be10-60 cm in length and at maturity green pods convert in brown colour. The seeds are round but have three papery wings thus looks triangular.

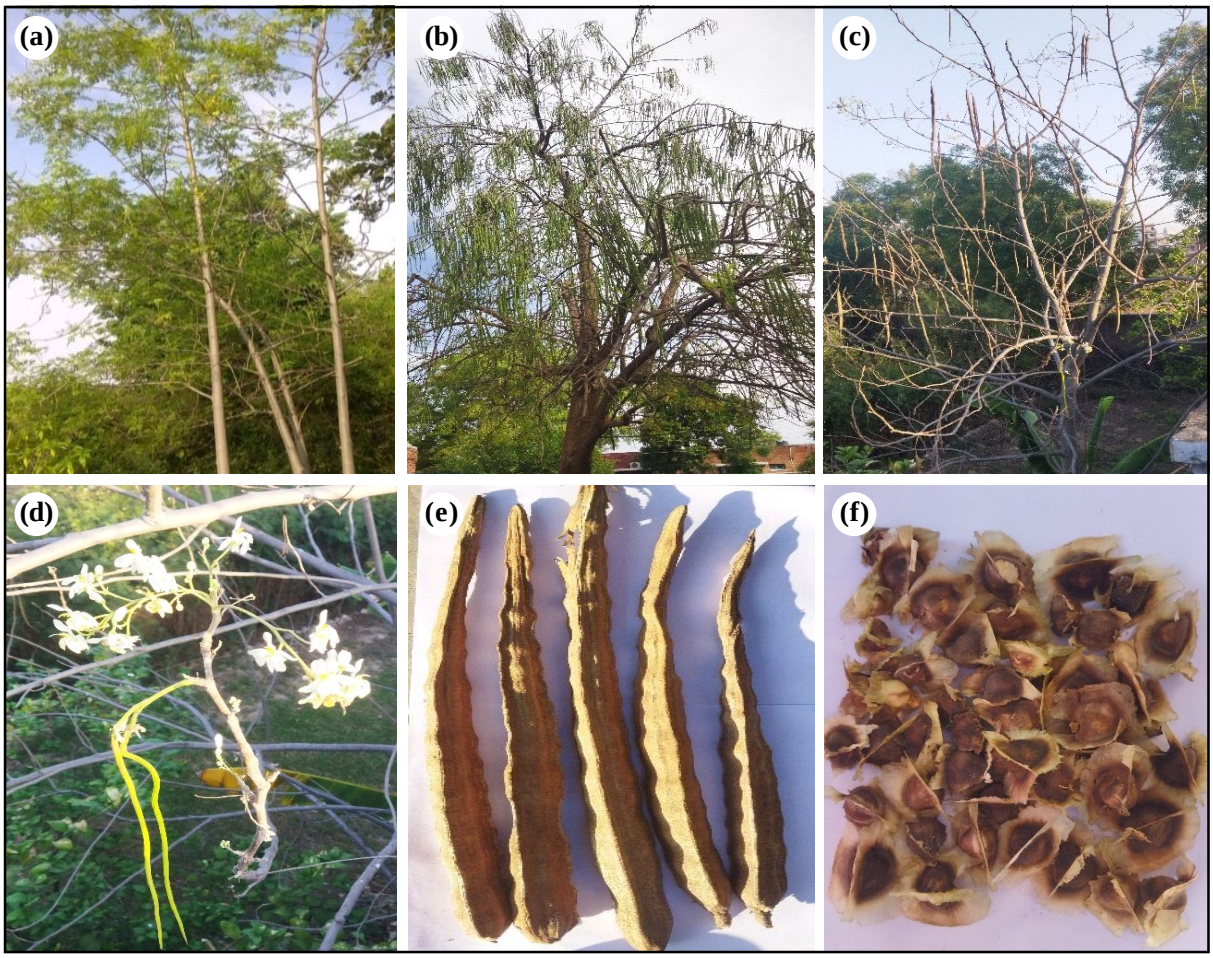

Fig. 1. Moringa plants (a) bearing leaves, (b) profused fruiting, (c) sparse fruiting (d) flowers (e) mature pods (f) seeds

Seeds are one cm in diameter, white to dark-brown and sometime black also (Jattan *et al*., 2021).

The finding of work conducted in South-West Burkina Faso on breeding system of *Moringa* suggested facultative allogamy, which is also supported by other researchers. In moringa, the diverse mating-system have the facility of self pollination (Krieg *et al*., 2017).

Agro-Technology

For taking good crop production, proper agronomic management as per recommendations is field is required in all the crop plants. In *Moringa oleifera* cultivation, field preparation should be completed by incorporating about 10 MT FYM per hectare and required fertilizers. The dose of fertilizers application varies as per the fertility status of field soil. In general, for fodder purpose, *Moringa oleifera* cultivation required 150 kg N, 60 kg P, 40 kg K, 30 kg S and 10 kg Zn for one hectare. Nitrogen is applied in five splits; first dose of 30 kg at field preparation time and later split on, in doses (30kg each) *i.e*. after 45 days of sowing, and at each subsequent cuttings (Jattan *et al*., 2021).

When, *Moringa oleifera* is grown for the tender pods or seeds purposes, apply 20 kg FYM per plant pit at plantation and may also apply fertilizers *i.e*., 100 g each of urea, super phosphate and murate of potash per plant to obtain greater pod/seed produce (Kader and Shanmugavelu, 1982). The use of 7.5 kg FYM and 0.37 kg ammonium sulphate per tree can proliferate pod production up to three times (Morton, 1991). For good production, suitable weed management must be completed by weeding at specified times as and when it is essential.

Demand of irrigation water for *Moringa* crop cultivation mainly be determined by the rainfall availability in the region. In *Moringa*, just after sowing /plantation, first irrigation must be applied, if there is no rain at the time plantation or soil is deficient in moisture. During early stages of plant growth and

development, proper irrigation management is essential for the well establishment of plants. After the establishment of crop plants, if irrigation is available, it should be applied as per requirement, particularly in summer. For the management of insect pests bio-pesticide like neem-seed core extract (5 % solution) have to be sprayed (Jattan *et al*., 2021).

Genetic Variability

The pollination behaviour of *Moringa oleifera* is cross-pollination type. This tree species have chromosome number, 2n=28. Being cross-pollination behaviour, it has high variability in morphological, physiological and quantitative characters. This tree gifts us, the diverse plant types such as, annual plants to perennial tree types, semi spreading to tall upright growing. Also, some of the tree bear flowering twice in a year (during March and September) and others bearing flowering throughout the year in all seasons (Raja *et al*., 2013). Therefore, the genetic variations available for different traits may be utilized for the plant's genetic enhancement. But, non-availability of leading cultivars adjusted to resident environmental conditions and utilization of open-pollinated seeds for commercial crop generally limits its productivity.

Moreover, across the world, the number of genotypes / accession lines and active germplasm seed banks are available. In spite of India, other scientific research institutes such as, Rural Development Initiative, Zambia; AVDRC, Taiwan) and Moringa Philippines Foundation, Philippines; are also working on Moringa in the world, on genetic improvement of *Moringa*. Many eco-types i.e. Jaffna-type, Kadumurungai, Chavakacheri-murungai, Kodikkal murungai, and Chemmurungai has been already described in India (Kumar *et al*., 2014). Regardless of huge available genetic diversity of *Moringa*, none of the organization created database of *Moringa* commercial varieties or naturally available germplasm lines.

For any kind of tree breeding for genetic improvement the availability of genetic diversity is foremost pre-requisite (Lakshmidevamma *et al*., 2021). Very less publications are available on the genetic-diversity of Moringa tree species. Some note able researchers revealed a huge genetic diversity in Moringa (Shahzad *et al*., 2013; Ramachandran *et al*., 1980; Suthanthirapandian *et al*., 1989; Jattan *et al*., 2021). These researcher also highlight the unlimited potential of this species for genetic-improvement to increase its production for according the end use of plants, such as for green leaves, fresh flowers, tender pods and mature seeds.

Conventional Breeding

In addition to nutritional components, some anti-nutritional compounds also found in Moringa plant products which generally hinders the protein and minerals absorption (Richter *et al*., 2003; Teixeira *et al*., 2014). Therefore, research on availability of anti-nutritional compounds among the different genotypes should be explored in the available genetic diversity to identify the genotypes with low anti-nutritional compounds. Being cross-pollinated tree species, the breeding method used for the genetic improvement of this plant, includes plant introduction, selection, evaluation, hybridization and selection methods which have been engaged to develop novel high yielding varieties with short statured plants with high biomass, profuse flowering, maximum pod bearing, high seed yield and oil content production, associated along with better quality, and resistance to biotic and abiotic factors (Balakumbahan & Boopathi, 2021).

The research investigation on Moringa also highlighted the excessive potential towards the genetic enhancement of species particularly to increase the utility of this potential tree. There are some anti-nutritional elements also reported in Moringa, these generally reduces the protein and minerals absorption during the digestion (Richter *et al*.,2003; Teixeira *et al*., 2014). Therefore, it need of time to obtain anti-nutritional free products for better results, diverse methods must be explored to harness the total existing genetic variability. The real thoughtful knowledge about the Moringa genetic-diversity might be extended through the characterization of all the released and cultivated as well as all the wild /natural genotypes existing in the world. In Tanzania Moringa breeders, though, are selecting genotypes for more oil content. In India, moringa breeding program most likely devised for high pod production (Iqbal & Bhanger, 2006). The diversity available in wild plants imparts a noble base for genetic improvement. In some nations, where it was introduced for cultivation, genetic-diversity is very less among the cultivated verities. Mutation breeding may be practiced by using the physical and chemical mutagenic agents (Prasanth *et al*., 2020).

The introduction of *Moringa oleifera* in Taiwan was also done for adaptation and evaluation for the yield and its contributing traits (Palada *et al*.,

2007). For the genetic improvement, Jaffna variety of *Moringa* was introduced from Sri-Lanka and now under cultivation in Southern part of India. Likewise, another variety, Chavakacheri-murungai is one of the introduced cultivar for commercial cultivation in India from Sri-Lanka. Later on plant selection work was started with openly pollinated plants. The selected best trees were identified based on potential yield and evaluated over different locations. Then, the controlled pollination was practised and a new variety, PKM 1, was developed by using the pure line method of breeding and found best suited annual variety for tropical region. After that with the help of hybridization and selection method the variety, PKM 2 was developed by crossing MP 28 and MP 31. This is an annual-type cultivar which produces 48% more yield over check, PKM 1 and also found best suited for annual crop in tropical plains of India (Jattan *et al*., 2021).

Moringa oleifera tree have diverse forms i.e., annual to perennial types, deciduous to evergreen, semi-spreading to upright. Moreover, some of them bear flowering in two seasons and others flower throughout the year (Raja *et al.,* 2013). Hence, the genetic variability can serve for genetic enhancement. However, non-availability of improved varieties for commercial cultivation and utilization of open pollinated seed for the nursey rising may be the main limiting factor in its productivity.

Molecular Breeding

Now-a-days, biotechnological tools such as dominant markers are available for *Moringa* molecular breeding. The amplified fragment length polymorphism (AFLP) markers were utilized to discover the genetic diversity among introduced genotypes in Malawi & Kenya and the natural plants from India (Muluvi *et al*., 1999). The investigation revealed, the significant genotypic differences among the genotypes of different geographical origin. Further, randomly amplified polymorphic DNA (RAPD) marker technique was found useful to differentiate among cultivated and non-cultivated genotypes of *Moringa* (Abubakar *et al.,* 2011; Mgendi *et al*., 2010; Rufai *et al.,* 2013; Da Silva *et al.,* 2012 Saini *et al.,* 2013). In all above investigations**,** considerable amount of genetic diversity was described among the naturally available genotypes with reverence to cultivated accessions. Hence, less magnitude of diversity among the cultivars indicates that there is an utmost necessity to broaden the genetic basis of breeding program. Later on, with the discovery of co-dominant molecular markers such as simple sequence repeats (SSRs), the molecular diversity investigation work was improved significantly (Boopathi *et al.,* 2021).

Moringa oleifera germplasm collection of diverse countries (India, Pakistan, Senegal, Tanzania, Mozambique, Florida, Zimbabwe, Belize, Haiti and Mexico) have been assessed previously and it was noticed that wild accessions of Pakistan reflected the maximum genetic-diversity, in comparison to the accessions of other counties (Shahzad *et al.,* 2013). for characterization of 300 genotypes of *Moringa* collected from different locations of India, both morphological and molecular markers (SSRs) have been used and revealed huge diversity in *Moringa* collection (Ganesan *et al.,* 2014). Above both the markers were also utilized for screening of 34 accessions of *Moringa oleifera* obtained from different parts of Tamil Nadu (Natarajan and Joshi, 2015). This investigation was helpful in identification of some superior genotypes which can be utilized in hybridization program to improve oil yield. In this way, morphological-markers along with molecular-markers can prove a faithful instrument to boost and strengthen crop improvement schemes (Boopathi and Raveendran, 2021).

Development and release of new cultivars of *Moringa* for commercial cultivation is the most demanding research owing to their nutritional importance. Though, traditional breeding methods (introduction, pure line selection and hybridization) developed successful the new *Moringa* cultivars, it is off late preached that such approaches requires more efforts, time and money. Alternatively, the advancement in the genomics and other omics fields for further the improvement of *Moringa* for different economical traits may secure and streamline the method of development and release of new varieties of *Moringa*. Predominantly, hereditary enhancement of its yield, nutritional quality, resilience, and aptitude to counter to a variation of agro-ecological situations would benefit to completely recognise of *Moringa* as a nutrient-rich, sustainable food crop for global nutrition security. Enhancing characteristics including pod shape & length, seed size, leaf size, and architecture of plant can advance the commercial production and economics of *Moringa*. The therapeutic importance and nutritional value of *Moringa* can be further amplified through breeding for greater concentrations of bio-molecules found in *Moringa* (including anti-oxidants, phyto-chemicals, anti-inflammatory agents) cultivars (Manikanda Boopathi, 2025).

Plant phenomics

Plant phenomics dealing with diverse techniques of crop phenotyping, demonstrating morphology, internal make-up, and physiology data, which covers phenomics, genomics, and other domains, multi-level data from traditional to omics levels. To capture the *Moringa* tree data efficiently with more accuracy, the knowledge of artificial-intelligence, deep learning, hybrid intelligence, data fusion etc. is required in plant phenomics. For advancement of tree breeding, to realise the phenotype and environment intrection, through the power of AI to display a connection between gene functions, yield and environment responsiveness (Arya *et al*., 2025).

CONCLUSIONS

Moringa oleifera has potential utility as a food, feed, fodder and pharmaceuticals. Being enormous potential, it also has several challenges, such as being tree its utilization in agricultural practices is difficult, and anti-nutritional compounds in its food and fodder have harmful effects on mankind and animals, are still needed to be answered. Therefore, more attention and research are warranted in this direction i.e., how it should be used in diets. In addition to this, agronomic studies revealing high fodder biomass production still awaited. Therefore, more emphasis is required on Moringa research for the development of new varieties for potential utilization of the tree by using conventional and molecular breeding techniques.

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