

Moringa cultivation in semi-arid regions: A sustainable solution to malnutrition

Achieving the targets outlined in Sustainable Development Goal 2 (SDG 2) by 2030 may seem challenging, necessitating nothing less than a miraculous intervention. Fortunately, such a miracle exists in the form of *Moringa oleifera*, commonly known as the Miracle Tree. Originally native to India, it is now cultivated across tropical and sub-tropical regions of Asia, Africa, and Latin America. This remarkable tree, often dubbed as the Tree of Life, offers a range of benefits as every part of it holds value and utility, making it one of the most nutrient-rich plants known. *Moringa oleifera* is highly valued as a fundamental dietary component, often recognized as the ‘native nourishment of tropical regions’. Nearly all components of the plant, spanning from its roots, bark, gums, leaves, fruits (pods), flowers, seeds, to seed oil, are utilized in diverse traditional medicinal practices throughout South Asia. With *Moringa oleifera* at our disposal, we can address not only hunger and malnutrition, the primary objectives of SDG 2, but also make strides toward achieving other Sustainable Development Goals.

The *Moringa oleifera* Lam. tree, a tropical species belonging to the Moringaceae family, encompasses around 13 distinct tree species, with *M. oleifera* being the most renowned. Due to its global spread, it has acquired various names such as ‘benzolive tree,’ ‘drumstick tree,’ ‘horseradish tree,’ ‘mulangay,’ ‘moonga,’ ‘saijhan,’ ‘marango,’ ‘sajna,’ ‘mlonge,’ or ‘Ben oil tree’. Historically, its use dates back to 150 B.C., when rulers consumed its leaves and fruits for cognitive and skin health. Mauritanian warriors also relied on its extracts for energy and stress relief in battles. A single harvest from *M. oleifera* plantation with 705 trees can provide enough calories for 340 adults for a day, regardless of gender. *M. oleifera* is promoted as a solution to climate change due to its ability to sequester carbon and an income source due to its fast growth and minimal maintenance. It absorbs 20-times more CO₂ than typical vegetation, aiding in global warming mitigation. Industrially, its leaf powder is widely commercialized for iron, calcium, and amino acids, serving as a multivitamin supplement. The tree’s leaves provide nutrition, seeds purify water, oil serves as biofuel, gum comes from the trunk, and flowers support honey production, making it highly versatile. Moringa leaves are circular in shape and have a distinct wild leafy taste with a hint of bitterness. Rich in protein, they are especially beneficial for vegans, vegetarians, and newborns, as they contain essential amino acids like arginine and histidine. Given widespread protein deficiency in India and sub-Saharan Africa, *M. oleifera* holds great potential in combating malnutrition in impoverished regions.

Plant parts and its characteristics

- **Leaves:** Characterized by having compound leaves, alternate and non-stypulous, deciduous, odd or bi-tripinnate leaves, with opposite and whole leaflets. They are usually 25-60 cm long.
- **Flowers:** Bisexual and arranged in axillary panicles 10-25 cm long. Flowers are cream white with 5 thin spatulated petals, 5 linear lanceolate sepals and 5 yellow stamens. The stamens are inserted at the edge of the disc, with free filaments and unilocular anthers, bent downwards and oblong.
- **Pods:** Long capsule, dehiscent and 20-40 cm in length and contain 12-35 seeds per fruit. During vegetative growth, they are white and change to brown at maturity.
- **Seeds:** Fleshy and winged. 2.5-3 mm long.
- **Root:** Pivoting with abundant branching reaching 0.4-3.0 m in length.

Area and distribution

Moringa, native to northern India and parts of northern Europe, is now grown worldwide, mainly in tropical and subtropical regions of India and Africa. It is also cultivated in countries like Egypt, the Philippines, Sri Lanka, Thailand, Malaysia, Pakistan, and Nigeria. In eastern and southern India, it is commonly used as a vegetable and commercially grown for its pods and leaves. India is the largest producer, yielding 2.6 million tonnes annually from 43,600 hectares, with Tamil Nadu, Andhra Pradesh, and Karnataka as major contributors. Tamil Nadu alone cultivates 20,684 hectares, mainly in regions



PKM-1 variety of Moringa

of Dindigul and Theni. Around 80% of Moringa leaf production supports exports, with key buyers including China, USA, Germany, Canada, and South Korea. India meets about 80% of global demand, making it the top supplier in the Asia-Pacific region.

Commercial varieties of Moringa

KM 1, PKM 1, PKM 2, GKVK 1, GKVK 2, GKVK 3, Dhanaraj, Bhagya (KDM 01), Konkan Ruchira and Rohit.

Nutritional features of moringa

Moringa leaves are highly nutritious, containing 19–29% protein, 4 times more vitamin A than carrots, and 7 times more vitamin C than oranges. They also provide over four times more calcium than milk and

3 times more potassium than bananas. Moringa pods and seeds are equally rich, with 9.98–51.80 g of crude protein, 17.26–20.00 g of crude fibre, 3.36–18.00 g of carbohydrates, 38.67–43.60 g of fat, and 3.6–5.0 g of ash per 100g.

Uses

While primarily recognized for its nutritional and medicinal benefits, moringa also finds application in various other fields, including industrial purposes. These encompass utilizing moringa seed oil for biodiesel production, as a lubricant for delicate machinery, and as an ingredient in cosmetic formulations. Moreover, the seeds and seed cake serve in water purification processes.

- **Seed:** Cooking, cosmetics industry, perfume industry
- **Pods:** Eaten as raw or prepared as peas, relieve pain and swelling caused by arthritis
- **Roots and bark:** Condiment, prophylactic, and antiseptic properties
- **Leaves:** Fresh salads, vegetable curry, seasoning, medicinal properties, fodder
- **Flowers:** Insecticidal, larvicidal, and ovicidal activity

Agricultural uses

- Animal feed stock (leaves and treated seedcake)
- Biomass production (alley cropping)
- Bio-pesticide (soil incorporation of leaves to prevent seedling damping-off)
- Fencing (living trees)
- Fertilizer (seedcake)
- Foliar nutrient (juice expressed from the leaves)
- Green manure (from leaves)

Cultivation

Moringa grows well in various soil types except for heavy clay, with deep sandy loam (pH 6.5–8) being the most suitable. Its economic cropping period lasts three years, and it can be propagated from seeds (for annual Moringa) or limb cuttings (for perennial Moringa) between July and October. The crop undergoes high cross-pollination due to its heteromorphic and entomophilous nature, with honey bees (*Apis mellifera*) as the primary pollinators.

Seeds, at a rate of 500 g per hectare, should be sown 2.5–3.0 cm deep in pits of 45 cm × 45 cm × 45 cm. Spacing should be 2 m × 2 m for annual moringa (yielding 2,500 plants per hectare) and 5 m × 5 m for perennial moringa (400 trees per hectare). Alternatively, seedlings can be grown in poly bags and transplanted after 35–40

Table 1. Agronomic characteristics of moringa

Propagation/sowing	Sexual and asexual means (direct seeding, transplanting, or using stem cuttings)
Nutrient and water demand	Low
Climate	Warm and semi-arid tropics
Tolerance to drought, frost and high temperature	High
Rainfall	250–3,000 mm per year
Altitude	Below 600 m as well as at 2,000 m
Optimum temperature	25–35°C
Maximum temperature tolerance	48°C
Soil type	Well-drained sandy, sandy loam or even clayey soils
Rate of growth	Fast
Tree height	5–10 m



PKM-1 variety of *Moringa oleifera* L. and its intercropping with mustard in Agronomy Research Farm, IARI

days. Organic fertilizers, including 10–15 kg of Farm Yard Manure (FYM) and 135:23:45 g of NPK per pit, should be mixed with the topsoil before application. Gap filling can be done within a month of sowing. After pruning, 45:15:30 g of NPK per plant, along with 25 kg of FYM or compost, should be applied within a week of cutting back each year.

Seedlings should be pinched off at a height of approximately 75 cm or by the 60th day after sowing to promote branching. In perennial moringa, medium pinching of shoots at 70 cm from the tip helps regulate flowering and enhance yield. Short-duration vegetables like cowpea, okra, and tomato can be grown as intercrops. Irrigation should be applied before sowing, on the third day after sowing, and then at 10–15-day intervals, depending on soil type. The first harvest is typically ready 180 days after sowing. After harvesting, trees should be pruned to 90 cm from ground level for ratooning, allowing regeneration within 4–5 months for another harvest. This ratooning cycle can be repeated for up to three years.

International Moringa Ingredient Market: Current and Future

The exceptional nutritional attributes of the moringa tree, encompassing its various parts such as seeds, leaves, bark, pods, and flowers, among others, have led to its global expansion in the market. Its bioactive components and nutrients such as carbohydrates, proteins, calcium, vitamins, phosphorus, potassium, iron, and beta-carotene have made it renowned for addressing various health concerns. The pharmaceutical industry has also found applications for moringa components due to their anticancer, antioxidant, antimicrobial, and anti-ulcer properties. In 2020, the global market for moringa constituents was estimated at approximately 6.9 billion USD. The worldwide market for moringa constituents is projected to witness a compound annual growth rate of 9.5% from 2021 to 2028, reaching a value of USD 14,270.6 million. This growth is attributed to the increasing demand for nutritional supplements in the food, pharmaceuticals, and cosmetics industries.

Challenges

Before achieving sufficient production levels, policymakers and administrators must establish suitable platforms to kickstart the marketing of horticultural products such as moringa. Given their high perishability, it is crucial to address issues related to production, processing, value addition, and export. While existing marketing arrangements for farm produce are commendable, there may be gaps in institutional connections and the empowerment of farmers' organizations in the marketing of moringa. It is hoped that the government will fulfill these arrangements to facilitate the marketing and export of moringa through institutional setups, providing valuable opportunities for researchers to explore. Therefore, an effort has been made to evaluate current marketing, value addition, and export practices concerning farmers and traders in Western and Southern Tamil Nadu. Although India enjoys significant market access for moringa globally, some consignments of fruits are still rejected by certain countries due to sanitary and phytosanitary issues, as well as non-compliance with importing countries' specifications, leading to visible rejections.

CONCLUSION

In summary, growing *M. oleifera* could serve as an alternative in regions where climate change hampers the growth of traditional crops. Moreover, since all parts of *M. oleifera* are edible—leaves, roots, flowers, pods, and seeds—they can be incorporated into various food formulations, enhancing their nutritional value due to their richness in proteins, fibre, vitamins, and antioxidants. Given its relative obscurity in developed nations, there is a need to disseminate more information about *M. oleifera* to promote its cultivation and ensure that various industrial sectors can benefit from all its parts, thus fostering a circular economy more sustainably.

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