Advances in Production of Moringa

All India Co-ordinated Research Project- Vegetable Crops
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Contents

1. CROP IMPROVEMENT AND VARIETAL STATUS OF MORINGA

Moringa oleifera Lam. belonging to the family Moringaceae is a handsome softwood tree, native of India, occurring wild in the sub-Himalayan regions of Northern India and now grown world wide in the tropics and sub-tropics. In India it is grown all over the subcontinent for its tender pods and also for its leaves and flowers. The pod of moringa is a very popular vegetable in South Indian cuisine and valued for their distinctly inviting flavour.

1.1. Biodiversity

The genus *Moringa* includes 13 species distributed in sub-Himalayan, ranges of India, Sri Lanka, North Eastern and South Western Africa, Madagascar and Arabia. The best known and most widely distributed species is *Moringa pterygosperma* Gaerthn (syn. *Moringa oleifera* Lam). Next in importance is the white or pink flowered *Moringa Peregrina*. Forsk, *Moringa optera* Gaerthn, *Moringa arabica* , *Moringa zeylanica* sieb. These are indigenous species of North Eastern tropical Africa, Syria, Palestine and all of Arabia in the driest areas.

The tree of *Moringa sternopetala* grows wild at 1000-1800 metres above MSL in Ethiopia and is also native to the Northern Province of Kenya. Its leaves are eaten in dry seasons and have local medicinal uses. A small bush type *Moringa longihiba* Engl. occurs in the Wajir, Garissa, Teita and Moyale districts of Kenya. *Morniga concanensis* Nimmo, grows abundantly in the Yercaud area of the Salem district in Tamil Nadu of South India. *Moringa drouhardii* sumelle, a native of Madagascar with an immense trunk is extremely drought tolerant and able to thrive on saline soils where the seeds exhibit long dormancy but the seedling grows rapidly.

1.2. Botany of Moringa

Though apparently native only to restricted areas of the Southern foothills of the Himalayas, *Moringa oleifera* is present in all the countries in the tropics.

Botanical classification of Moringa

Kingdom	-	Plantae
Division	-	Magnoliophyta
Class	-	Magnoliopsida
Order	-	Brassicales
Family	-	Moringaceae
Genus	-	Moringa
Species	-	oleifera

Moringa belongs to the family Moringaceae. The family consists of the single genus Moringa and the botanical name of the tree is *Moringa oleifera* Lam. The family is distinguished by parietal placentation, 3-valved fruit, elongated, non-dehiscent berry and winged seeds. Philips (1951) reported four species; while Pax (1936) and Puri (1942) reported ten species, native to the Old World Tropics. Bessey (1915) placed the family under Rheoadales. Datta and Mitra (1942) considered it more closely related to the Violaceae of the Violales. There are two common species, *M. oleifera* and *M. concanensis*. *M. oleifera* is characterized by leaves usually tripinnate, leaflets 12-18 mm long, petioles yellow or white without red streaks and the tree is medium-sized. *M. concanensis* is characterized by bipinnate leaves, leaflets 15-30 mm long, petals with red streaks or reddish at base and the tree is large.

1.3.Breeding objectives

- Breeding varieties with dwarf statured plant
- Varieties suitable for leaf purpose

- Development of high yielding types
- Breeding varieties with more seed and oil content
- Development of types resistant to pest and diseases

1.4. Genetic resources where collections exist

- The World Vegetable Research and Development Center, Taiwan
- Tamil Nadu Agricultural University, India
- ECHO, North Fort Meyers, Florida

1.5. Crop Improvement Methods

1.5.1 Mass Selection

Selection of types starts with open pollination. Select one line with the highest potential and test it in various conditions and various sites. Then, go for controlled pollination. PKM 1 annual moringa was released through this method.

1.5.2. Hybridization

Annual moringa PKM 2 is a hybrid derivative from the cross between MP31 and MP28. PKM 2 exhibits 48% increase in yield over PKM1.

1.5.3 Mutation Breeding

Very little work has been carried out in annual moringa through mutation breeding.

1.5.4. Biotechnology

Limited information is available on biotechnology of moringa. Recently, due importance has been stressed on micropropagation and characterization of germplasm through molecular markers for its improvement.

Kantharajah and Dodd (1991) standardized the technique for in vitro propagation of *M. oleifera* using nodal segments collected from a mature field grown tree. An average of 22.1±6.3 shoots/plant developed in the woody plant medium containing 2% sucrose, solidified with 0.8% agar and supplemented with 1 mg/l BA. Root formation was readily achieved using

MS basal medium with 0.5 mg/l NAA. The resulting plantlets were transferred to soil and successfully grown in the green house. Tissues from seedlings were found to be less useful as sources of explants for micropropagation than those from mature nodal segments from older trees.

Stem segments from 10-day old seedlings were transferred onto MS medium supplemented with varied combinations and concentrations of auxin (NAA) and cytokinin (kinetin and BAP). Regeneration of plantlets with profuse rooting was obtained after three weeks on MS medium supplemented with 0.2 mg/l NAA +0.2 mg/l kinetin + 100 mg/l glutamine. (Mughal *et al.,* 1999). Direct somatic embryogenesis was obtained in immature zygotic embryos of moringa cultured in continuous light in media with GA3, BA and activated charcoal. Long term, fast growing callus cultures were established from rapidly elongating epicotyls of *in vitro* plants of moringa in media with 2,4-D, NAA and coconut milk.

1.6. Description of the perennial eco-types of moringa cultivated in Tamil Nadu

The cultivation of moringa in India occurs mainly in the southern states of Tamil Nadu, Karnataka, Kerala, and Andhra Pradesh. Principally perennial types have been known for cultivation for a very long time. However, perennial types are beset with many production constraints, such as a relatively long pre-fruit bearing period, non availability of planting materials (stem cuttings), requirement of a greater number of rainy days in regions where water is scarce, and vulnerability to pests and diseases. Important varieties of moringa are Moolanur moringa, Valayapatti moringa, Chavakacheri Moringa, chemmurungai, Jaffna type, Kattumurungai, Kodikkalmurungai, Palmurungai, Punamurungai, Palamedu moringa.

1.6.1. Moolanur moringa

Farmers in and around Moolanur, Karur, Dharapuram areas of Tamil Nadu, predominantly cultivate perennial moringa which has a pod length of 45-50 cm, pod weight of 120 g and a yield of 200 kg/tree. Trees are maintained upto 15 years without pruning.

1.6.2. Valayapatti moringa

Another perennial type cultivated in and around Usilampatti, Andipatti areas is valayapatti moringa. The pods are around 65 cm long, and weigh about 120 g. Yield is reported to be 1000-1200 pods/tree.

1.6.3. Chavakacheri moringa

An ecotype of Jaffna moringa, it bears pods as long as 90-120 cm. It is also cultivated in Tamil Nadu.

1.6.4. Chemmurungai

Another ecotype of Jaffna murungai, it flowers and fruits throughout the year, yielding a heavy crop. The tips of the pods are red. The tree is medium sized and bearing long pods.

1.6.5. Jaffna type

A Yazphanam type moringa introduced from Sri Lanka. Its fruits are 60-90 cm long with soft flesh and good taste. This type yields around 40 pods from the second year of planting which increases upto 600 pods/tree from the third year onwards. It is cultivated commercially in Tirunelveli and Tuticorin districts of Tamil Nadu.

1.6.6. Kattumurungai

A wild form of moringa, *M. concanensis* found in the forest of Tamil Nadu.

1.6.7. Kodikkal murungai

It is cultivated predominantly in the betel vine gardens of Tiruchirapalli district of Tamil Nadu. The pods are shorter (20-25 cm long) and are thick fleshed. The pods and leaves are very tasty. Trees are short statured with smaller leaves.

1.6.8. Palmurungai

It is preferred for its thick pulp and tasty pods.

1.6.9. Punamurungai

It is grown in home gardens of Tirunelveli and Kanyakumari districts.

1.6.10. Palamedu Moringa

The pods are 60 cm long, with a pod weight of 95-100 g and an yield of 100 pods/tree.

1.7. Annual moringa varieties released from HC&RI, Periyakulam

The Horticultural College and Research Institute of Tamil Nadu Agricultural University, Periyakulam, had an assemblage of 85 moringa accessions. The germplasm collection block contains perennial and annual moringa accessions with heavy fruit-bearing, cluster bearing, drought tolerance, dwarfing stature and pest and disease resistance.

Scientists at the Horticultural College and Research Institute, Tamil Nadu Agricultural University, Periyakulam have succeeded in developing seed-propagated moringa types, which has revolutionised the moringa cultivation in the country. By judicious breeding programmes, including introduction of elite mother plants, evaluation, selection and hybridization, The Horticultural College and Research Institute of Tamil Nadu Agricultural University has released two improved annual moringa varieties (PKM-1, PKM-2) within a span of 10 years, for commercial cultivation. These varieties have developed up well in many traditional and non-traditional areas (Sadashathi ,1995).

1.7.1. PKM 1 Annual Moringa

It is a pureline selection developed by continuous selfing for six generations, collected from Eppothumvendran of Tirunelveli region. In each generation, only long pods and desirable characters are selected and advanced. It was released in the year 1989. The fruits are fleshy and tasty. It comes to flowering within 5-6 months of sowing and comes to harvest in 7-8 months. The peak harvest is during March-August.The plants grow to a height of 4-6 m in a year and produce 6-12 primary branches.The pinnate leaves are about 40 cm long with small leaflets which are dark green on the upper side and pale green on the lower side. Though the flowers are in clusters of 25-150/cluster, only one pod develops usually and rarely 2-4 develop per cluster. The pods are 75 cm long with a girth of 6.3 cm and weigh 150 g with 70% flesh.

The average yield is 220 fruits/tree. The estimated yield is around 52 t/ha. The pods attain edible maturity 65 days after flowering. The leaves can be used as a nutritive green. Ratoon crops can be maintained for 3-4 years. After every year the trees have to be cut back to 1 m from ground level. This variety can be grown as inter crop in coconut orchards during the early period. Chilli, onion and groundnut can be grown as intercrop in moringa fields.

1.7.2. PKM 2 Annual Moringa

It is a hybrid derivative of a cross between MP 31 (Eppothum vendran local) and MP 28 (Arasaradi local). It can be propagated through seeds. The tree comes to bearing six months after planting and is suitable for growing in different cropping systems. The pods are 126 cm long, with a girth of 8.3 cm and individual fruit weight of 280 g with 70% flesh. The pods are less seeded and delicious. The average number of pods per tree is 220/tree/year. It yields 98 tonnes/ha. Ratoon crop can also be taken up for three years. It is suitable for growing in Tamil Nadu and is adapted to most soil types varying from sandy loam to clay loam with good drainage.

1.8. Other annual types

1.8.1. KM 1

It is an annual moringa developed by pureline selection. Propagated by seeds, it yields around 400-500 fruits/plant annually. The fruits are 25-30 cm long. Harvesting is easy as the plants are like shrubs. After first harvest, the plants are headed back leaving 1 m above the ground and used as ratoons. Ratooning is done for 2-3 years. It starts bearing from 6^{th} month onwards.

1.8.2 Dhanraj

This is also an annual moringa propagated through seeds and was evolved at KRC College of Agriculture, UAS, Arabhavi, Karnataka.

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2. FLORAL BIOLOGYAND HYBRIDIZATION IN MORINGA

2.1. Floral Biology

Moringa flowers are white or ceamy-white, scented, pedicelled in larger spreading panicles with linear bracts. Calyx contains 5 sepals, lobed, linear lanceolate, refluxed and tubular outside. Corolla has 5 white petals, free narrowly spathelate and veined. Stamens are yellow and of 5 in numbers, fertile and alternate with 5-7 staminales. Filaments are villous at their base. Ovary is superior on a short gynophore, 3 carpelled and are locular with many biseriate pendulous ovules on 3 pariental placentas. Pods 30-120 cm, triangular and elongated with 13 ovules, unit locules capsules.

2.2. Anthesis

Anthesis has been reported to commence as early as 4.30 am and continues till 6.30 am with a peak at 5.30 am. In another report from Horticultural College and Research Institute, Periyakulam it is stated that anthesis time ranged from 5 am-9 am in association with a temperature range of 27.3 - 29.30ºC and RH of 68-78%. The anther dehiscence is reported to occur from 4 am to 6.30 am. The anther of the longest stamen dehisces first followed by stamens in the descending order of filament length. At full maturity, the anthers are greenish yellow and after dehiscence, they turn to pale colour. On an average, each anther has 7,400 pollens and the diameter of each pollen measures 5-4 microns. The stigma becomes receptive a day before flower opening and continues to be receptive on the day of opening cross pollination occurs through honey bees. Pollen viability is 72% at anther dehiscence. The fertile pollen may go even upto 100% while it is only 11-15% under natural pollination. The chromosome number is 2n=28.

2.3. Mode of Pollination

The plant is highly cross pollinated due to heteromorphic and is entomophilous, bees being the pollinators. Emasculation is done in the previous days evening. Usually pollination is done the next morning, prior to 11.00 am. Before pollination, stigmatic surface of the female flower should be checked for the presence of self or foreign pollen. Flowers bagged prior to opening in order to avoid contamination. Either pollen is collected from the flower or the flower is used as such for pollination. Pollen collection is needed for later pollination. Pollen can be collected for large quantity for large-scale pollination or for later pollination. In moringa, pollen is accumulated in keel petal which can be squeezed out of keel and transferred to the stigma. Pollen can be stored safely for later use for a few days under dry room conditions.

2.4. Pollination mechanism in Moringa

Flowering is observed in moringa from January to April with a peak around February. The flowers are white, with unequal petals and have a slight odour. Flower anthesis occurs in the forenoon (6.00 hrs. to 12.00 hrs.) after which pollen dehisces and nectar secretion take place. The burst anthers hold a clump of pollen grains which gradually becomes shiny indicating secretion and a Papilionidae, Pieridae and beetles pay their visits to the flower. Floral characters of *Moringa oleifera* are given in Table 1 and list of Pollinators are given in Table 2.

Among these *Xylocopa sp*., which carries a considerable amount of viable pollen grains on leg parts, acts as an effective pollinator. Besides *Xylocopa sp* . different types of thrips, *Apis sp*. and some members of Lepidoptera visit flowers to nourish themselves. Thus, a strong insect pollination system is present in *M. oliefera* which is eventually pollinated by geitonogamy or xenogamy, with the latter being the more significant. The pistil remains parallel with stamens just after opening but it gradually extends with time finally reaches above anther level. The separation of stamen and pistil from each other after few hours of anthesis, suggests

that external agents might be required for pollination and so favour cross pollination.

2.5. Studies on Floral Biology of Moringa

Moringa oleifera showed diurnal anthesis. Pollen ovule ratio per flower was found to be variable. Netting and bagging of flowers indicated that the external agents might be required for successful fruit setting which varied depending upon the availability of effective pollinators (Haldars, 2000). At Visakkapatnam, India, *M. oleifera* flowered twice a year in February to May and in September to November. Xeno gamous pollinations gave 100% fruit set, 81% seed set and 9% fecundity, compared with 62, 64 and 6% respectively for geitonogamous pollinations. Flowers were zygomorphic and of the gullet type; they opened during 03.00 to 19.00 and visited by diurnally active insects during 6.00 to 15.00 h. Carpenter bees (*Xylocarpa latipes* and *X. pubescens*) were the most reliable pollinators (Jyothi *et al.*, 1990).

Floral biology and pollen characteristics of 2 - years old plants of *Moringa oleifera* genotype AD 4 and its 5 one-year-old progenies were studied between August 1995 and January 1996. Plants flowered in August - September and again in December-January, the latter resulting in fruit set. Plants were protandrous, with flower opening, anther dehiscence and stigma receptivity occurring in a phased manner. Flower opening occurred between 14.30 and 09.00 h. In August-September, pollen grains did not disperse due to their very sticky nature and they had shriveled and become unviable by the time the stigma became receptive. In early December, pollen stickiness was reduced and they became more powdery. At the same time, activity of black ants and flea beetle peaked thereby increasing the likelihood of cross pollinations, and fruit set was achieved (Babu and Rajan,1996).

Table 1. Floral characters of *Moringa oleifera*

Floral Characters	Observations
Flowering Period	January - April
Flower Type	Irregular
Flower Colour	White with greenish base
Odour	Present
Nectar	Present
Anthesis time	Forenoon/6.00 hrs. - 12.00 hrs.
Anther degiscence time	7.00hrs - 13.00 hrs
Mean No. of anthers per flower	5
Mean No. of pollens per anther	4705
Mean No. of pollens per flowers	23525
Mean No. of pollens per ovule	523
Pollen type	3 corporate
Pollen shape	Prolate spherical to subprolate
Pollen size	±47.25 x 41.28 µ m
Stigma type	Above anther level and wet type
Fruit setting (%) in natural open flower	10.28
Fruit setting (%) in netting condition	1.00
Fruit setting (%) in bagging condition	Nil

Table 2. Pollinators of Moringa

Name of the visitors with order/family	Visiting time	Foraging nature
Thysanoptera		
i) *Haplothrips ceylonicus*	Day and Night	Pollen, nectar
ii) Microcephalothrips abdominalis	Day and Night	Pollen, nectar
Hymenoptera		
i) *Xylocopa sp.*	Day	Pollen, nectar
ii) *Apis sp*	Day	Pollen, nectar
iii) *Vespa sp.*	Day	Pollen, nectar
Lepidoptera		
i) Papilionidae	Day	Nectar
ii)Pieridae	Day	Nectar
Coleoptera	Day	Nectar

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3. ADVANCED PRODUCTION SYSTEMS IN ANNUAL MORINGA PKM 1

Moringa oleifera Lam. belonging to the family Moringaceae is fast growing, drought tolerant and easily adapted to varied ecosystems and farming systems. It occupies a unique and consistent position in the Indian vegetable industry. In lieu of its many uses, free flowering nature and the ease with which it can be cultivated, the demand for its products and hence the area under its cultivation is on the increase.

The cultivation of moringa in India is mainly in the southern states of Tamil Nadu, Karnataka, Kerala, and Andhra Pradesh. Though perennial types have been known for a very long time, its cultivation is beset with many production constraints, such as a relatively long pre-fruit bearing period, non availability of planting materials, requirement of a greater number of rainy days in regions where water is scarce and vulnerability to pests and diseases.

The research efforts by the scientists at the Horticultural College and Research Institute, Tamil Nadu Agricultural University, Periyakulam of South India have succeeded in developing seed propagated moringa types, which has revolutionised the moringa cultivation in the country.The concerted efforts involving introduction, conservation, evaluation and breeding have resulted in the development of two promising high yielding annual moringa cultivars *viz.*, Periyakulam 1 (PKM 1) and Periyakulam 2 (PKM 2).

These two seed grown annual moringa cultivars have replaced perennial moringa area in the Southern states of India, spreading fast due to their adaptability to varied soil and climatic conditions. They represent a major share of moringa production in marginal and small farm holdings. In Tamil

Nadu it is widely cultivated almost in all the districts in plains under irrigated conditions.

3.1. Season and planting

The annual moringa is propagated through seeds and the seeds are directly dibbled in the pit to ensure accelerated and faster growth of the seedlings.The best suited season for sowing the seeds is September under Southern Indian conditions. The time of sowing has to be strictly adhered to because the flowering phase should not coincide with monsoon rains which may result heavy flower shedding. An espacement of 2.5 x 2.5 m is adapted with a population of 1600 plants per hectare.The pits of 45 x 45 x 45 cm in size are dug out and then the seeds are sown in the centre of the pit. The seed germinates 10 to 12 days after sowing. The seed requirement per hectare is 625 g. When planted in single rows along with irrigation channels, a spacing of 2 m is sufficient.

The pre-sowing seed treatment of moringa with *Azospirillum* cultures at the rate of 100 g per 625 g of seeds resulted in early germination, increased seedling vigour, growth and yield.

3.2. After care

It is necessary to pinching the terminal bud on the central leader stem when it attains a height of 75 cm (two months after sowing). This will promote the growth of many lateral branches and reduce the height of the tree. Vijayakumar *et al.*, (2000) found that early pinching of growing tips carried out 60 days after sowing was better than pinching 90 days after sowing for obtaining a higher yield.

3.3. Ratooning

In annual moringa, when the harvest is over, the trees are cut down to a height of one metre above ground level for ratooning. These ratoon plants develop new shoots and start bearing four or five months after ratooning. Three ratooning operations are recommended during the production cycle. During each ratooning operation, the plants are supplied

with the recommended level of N, P and K nutrients along with 20-35 kg of FYM.

3.4. Harvest and yield

The annual moringa types are seasonal in terms of fruit- bearing and the crop sown during September comes to harvest within six months. Fruits of sufficient length and girth are harvested before they develop fibre. The harvest period extends for 2-3 months and each tree bears 250-400 fruits/year/tree

3.5. Intensive moringa leaf production

Whether produced for use as a green manure, for livestock or for human consumption, moringa can be grown intensively with yields of up to 650 metric tonnes of green matter per hectare. This compares very well to other green manure crops such as lablab beans, which yield up to 110 tonnes per hectare of green matter as a pure crop.

These high yields were obtained through sub soiling to a depth of 60 cm using a rotavator to encourage drainage and good root development. In this system planting is done at 10 x 10 cm density (one million plants per hectare) with sufficient fertilizer (cow dung is preferred). The green matter is harvested when plants reach a height of 50 cm or more (every 35 to 40 days), cut at a distance of 15 to 20 cm above the ground. Although losses of seedlings may be 20 to 30 per cent in the first year, the vigorous regrowth of the remaining seedlings will produce 3 or 5 new shoots after each cutting. Up to nine harvests can be obtained annually. An yield of 650 metric tonnes of leaf yield was obtained in sandy and well-drained soil.

3.6. Annual moringa as intercrop

In high density multi-species cropping system in old coconut garden in Tamil Nadu annual moringa have been profitability cultivated (Marimuthu *et al.*, 2001). In temperate hills of Sikkim, apple orchards are generally poor, so the major returns of farmers are from the intercrops like moringa scattered on farmlands in different crop combinations (Singh *et al.*,1991). Bhendi,

French bean or cowpea can be cultivated as intercrops in young moringa plantations.

3.7. Conditions for small and large scale moringa farming in India

Rajangam *et al.*, (2001) studied the constraints faced by the annual moringa growers and reported.

The key factors governing profitability of large scale production are:

- Selection of high yielding varieties with suitable marketable quality
- Sowing in a proper season, in compliance with the latest agro techniques

3.8. Pest control

- Management of ratoon crops
- Adoption of post harvest management
- Analyzing the possibility for processing and exporting fresh young pods

3.9. Constraints and limitations of large scale cultivation are:

- The crop is highly heterozygous because it is highly cross pollinated in nature and there is a wide variability in yield and components. As a result, the maintenance of genetic purity is the limitation
- The sowing period must be strictly adhered to August-September
- The commercial crop requires irrigation during summer and windy seasons when the water table is always at its lowest
- There is no proper control measure for fruit fly (*Gitona* sp) incidence
- Packing systems are poor (uncovered bundles or in gunnies)
- Seasonal glut necessitates cold storage facilities

The advantages of moringa cultivation for small farmers are:

- Moringa requires minimum irrigation facilities

- It does not require much labour and family members can easily manage the variious operations
- It requires small quantity of manures and fertilizers
- Because small farmers cultivate less than one hectare of moringa, they can easily transport their produce to the local market
- Pruned materials can be effectively recycled by pulp and paper industries, which is an additional advantage for small farmers

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4. CROPPING SYSTEMS IN MORINGA

A cropping system refers to growing a combination of crops in space and time. An ideal cropping system should:

- Use natural resources efficiently
- Provide stable and high returns
- Do not damage the environment

4.1. Commonly practiced cropping systems are:

- Intercropping system
- Alley cropping system
- Agri- silvi- horticulture system
- Agro-forestry system

4.2. An ideal cropping system should aim to

- Produce higher yields per unit area through better use of natural resources
- Offer greater stability in production under adverse weather conditions and with disease and insect infestation;
- Meet the domestic needs of the farmer;
- Provide an equitable distribution of farm resources

Moringa is a slender, fast growing, deciduous shrub or small tree reaching 9 to 15 m in height, with an umbrella shaped, open crown. It is an exceptionally nutritious tree with a variety of medicinal properties, Anwar *et al.,* (2007) and Jiru *et al.,* (2006).

Almost every part of plant is of value for food. Seed is said to be eaten like a peanut in Malaya. The thickened root is used as a substitute for

horseradish. Foliage is eaten as greens, as salads, as vegetable curries, as pickles and for seasoning. Seeds yield 38 to 40% of a non-drying oil, known as "ben oil", used in arts and for lubricating watches and other delicate machinery. Ben oil is clear and odorless, has an unusually long shelf life, never becoming rancid. (Bwana simbha,2006)

4.3. Cropping systems in moringa

4.3.1. Intercropping

Moringa is a drought handy plant and hence require less water for growth and production. In general, sandy loam and laterite soils are suitable for moringa cultivation. For intercropping in moringa field, the companion crops should be related is such a way that they are also drought tolerant and their soil preference are also same alike moringa. Over irrigation to intercrops will affect the moringa by keeping the trees in vegetative stage for quiet long time. Hence water requirements of the main and intercrops are the key factor which determine the combination of crops in intercropping system.

Moringa trees are planted in gardens that can also provide support for climbing crops such as bitter gourd, snake gourd, ribbed gourd, greens and pole beans, although only mature trees should be used for this purpose since the vine growth can choke off the young tree. Moringa trees can be planted in gardens to provide shade to vegetables less tolerant to direct sunlight. Annual moringa cultivars are mainly cultivated as pure plantations on upland conditions with plenty of sunshine and no water stagnation on a large scale. Moringa has a large tap root and few lateral roots so it will not compete for nutrients with the crops. It will also add to the nutrients available as it produces many protein rich leaves. They grow very quickly but do not provide too much shade due to the structure of their leaves. They are also very good at reclaiming marginal land.

Spacing of moringa depend on the type of soil and end-use of trees. Recommended spacing is 3 x 3 m while for intensive production of green matter, moringa can be densely seeded (100 seeds per sq meter) and the

edible shoots cut like grass every two to three weeks. Trees are often spaced one meter apart in a line to create live fencing posts.

In recent years, several integrated cropping systems are being practiced by farmers in Southern India. It can be taken up as intercrop in coconut and mango plantations during initial growth stages. Short duration vegetable crops can be taken as intercrops.

Studies conducted at IIHR and in several on farm trial, clearly indicated that vegetable crops like onion, chilies and cluster beans can be successfully grown as intercrops in annual drumstick (IIHR, 2002). In parts of Tamil Nadu, annual drumstick is cultivated as a border crop and also as mixed crop in chilli and brinjal fields.(Kader mohideen and Shanmugavelu, 1982). The yield range was 6-10 kg/ha with about 150- 200 fts/plant.

Moringa can be intercropped with maize, sunflower and other field crops. Sunflower is particularly recommended for helping to control weed growth. However, moringa trees are reported to be highly competitive with eggplant and sweet corn and can reduce their yields by up to 50% (Fuglie and Sreeja; AVRDC).

The farmers can be encouraged to intercultivate millets or vegetables *viz.,* tomato (*Lycopersiconesculentum*), chili (*Capsicum annuum*), beans (*Phaseolus vulgaris*),gourds curry leaf (*Murraya koenigii*) and other leafy vegetables. In the silvi-pasture system it was observed that farmers preferred tree species (other than fruit trees) like teak (*Tectona grandis*), neem (*Azadirachta indica*), and subabul (*Leucaena leucocephala*) mainly on the farm bunds and in some cases as plantations.

4.3.2. Alley cropping

Trees are planted in hedgerows forming wide alleys where vegetables are planted within. Choose vegetables that are adapted to alley cropping, such as shade-tolerant leafy vegetables and herbs, since moringa hedgerows are highly competitive and can reduce yields of companion plants significantly.

Alley cropping with their rapid growth, long tap root, a few lateral roots, minimal shade and large production of high protein biomass, moringa trees are well suited for use in alley cropping system. Alley cropping is the practice of growing food crops in alleys between hedge rows of trees or shrubs which are regularly coppiced or severely pruned. This agro forestry technique is used with PKM 1 annual moringa in Southern India. The prunings are placed on soil as a mulch around food crops, providing valuable nutrients on decomposition.

Alternatively leaves may also be used for human food and animal feed. *Moringa oleifera* possesses general characteristics of useful species for alley cropping.

4.3.3. High density planting for leaf production

In different parts of the world, moringa leaves are harvested mainly for use as vegetables. In African countries it is also used as fodder. High density cultivation of moringa is practiced by adopting 15 x 15 cm spacing and normally seven harvests / year are taken to realize a fresh yield of 43 - 52 t/ha.

The highest biomas yield of foliage for green leaf vegetable purpose was obtained at a spacing of 60 x 30 cm accommodating 55 thousand plants/ha.

4.3.4. Agri-silvi-horticulture

Agri-silvi-horticulture is the system in which a combination of trees, horticultural crops and agricultural crops are grown on the same unit of land in some form of spatial mixture or sequence. In the present model *Casuarina equisetifolia* is the tree species. *Moringa oleifera* is the horticultural component and maize is the agricultural crop.

4.3.5. Agricultural crops

Crops such as maize, fodder sorghum, bajra, ragi, pulses, seasamum, groundnut etc. can be cultivated with casuarina and moringa under rainfed conditions. In the present model maize (Zea mays) was intercropped with casuarina and moringa and the economic production worked out.

Shanmugavelu *et al.* (2003) reported Agri-silvi - cultural models involving drumstick with casuarina or accasia along with maize for obtaining higher yield and income in Tamil Nadu region.

4.3.6. Fencing

A common use of moringa trees is as a living support for fencing around gardens and yards.

4.4. Cropping geomentry

Moringa trees grow easily from seeds or hard-stem cuttings. When using seeds they can be directly sown in the field or used for raising seedlings in nursery bags and transplanted.

Direct seeding is preferred when plenty of seed and water are available and labour is limited. In a large field, seeds can be sown directly in prepared pits at the beginning of the wet season. Transplanting allows flexibility in field planting but requires extra labour and cost in raising seedlings. The advantage of using seedling are more parentage of establishment and uniformity in crop growth. Stem cuttings are used when the availability of seed is limited but labour is plentiful. Moringa seeds have wings and are about the size of a large pea. In order to enhance germination soak the seeds in water overnight before planting. Moringa can also be planted on 30-cm-high raised beds to facilitate drainage (AVRDC).

4.4.1. To plant seeds directly in the ground

Plant 2 or 3 seeds in each hole, 5 cm apart. Plant the seeds at a depth of 2 cm (approximately the size of one's thumbnail). Do not water heavily for the first few days. Keep the soil moist enough so that the top soil will not dry and choke the emerging saplings. Excess moisture will lead to phytophthora rot. Two weeks after germination, or when the seedlings reach four to six inches height (10 to 15 cm), keep the healthiest seedling in the ground and remove the rest.(Fuglie, Trees for Life, AVRDC)

4.4.2. In the nursery

Seedlings for transplanting can be grown in divided trays, individual

pots, plastic bags, or seedbeds. Use of divided trays and individual containers such as poly bags is recommended because there is less damage to seedlings when they are transplanted. Grow seedlings under shade or in a screen house.

Use poly bags with dimensions of about 18 cm in height and 12cm in diameter. The soil mixture for the bags should be light, i.e. three parts soil to one part sand. Sow two or three seeds in each bag, one to two centimetres deep. Keep moist but not too wet. Germination will occur within 5 to 12 days, depending on the age of the seed and pre-treatment method used. Immediately after germination the poly bags may be drenched with copper oxy chloride to seedling mortality against rot disease. Remove extra seedlings, leaving the strongest seedling in each bag. Prior to transplanting the seedling hardened sufficiently by with holding irrigation for five - seven days so that fibres can develop in the fragile stem. Seedlings can be transplanted in the field when they are 60 to 90 cm high. While transplanting, cut a hole in the bottom of the bag big enough to allow the roots to emerge. Be sure to retain the soil around the roots of the seedling (AVRDC, 2003).

4.4.3. Transplanting to the field

The day before transplanting, water the filled pits (see land preparation) or wait until a good rain before out-planting the seedlings. Fill in the hole before transplanting the seedling. In areas of heavy rainfall, the soil can be shaped in the form of a mound to encourage drainage. Do not water heavily for the first few days. Keep the soil moist enough so that the topsoil will not dry and choke the emerging saplings, but not too wet or else the seedlings can drown and rot. If the seedlings tend to lodge or fall over, tie them to stick 40 cm high for support.

4.4.4. Growing from cuttings

To grow trees from cuttings use hard wood, avoid using young green stem tissue. Cut off the branches after the trees have stopped producing fruits. This will promote fresh growth and the cut branches provide excellent cuttings for growing new trees. Compared to trees planted from seed, trees

from stem cuttings grow faster but develop a shallow root system that makes them more susceptible to moisture stress and wind damage.

Cuttings can be planted directly or planted in sacks in the nursery. When the cuttings are planted in the nursery, the root system is slow to develop. Cuttings planted in a nursery can be transplanted after 2 or 3 months. Cuttings can be 45 to 180 cm long with diameters of 4 to 16 cm. Cuttings can be dried in the shade for three days before planting in the nursery or in the field.

4.4.5. When planting direct in the field

Dig a hole 1m x 1m wide and one m deep .Place cutting in this hole and fill with a mixture of soil, sand and composted manure. Pack firmly around base of the cutting. This will facilitate drainage. It is not desirable that water touches the stem of the new tree. Water generously, but do not drown the cutting in water. If the soil is too heavy or wet, the roots may rot. In India, some cow dung is put on top of the open end of the cutting to protect the cutting from pests, diseases and rain water (Rajangam,2001).

For intensive moringa production, a spacing of 3 m x 3 m should be adopted. When the trees are part of an alley-cropping system, there should be 10 meters between the rows. The area between trees should be kept free of weeds (Fuglie and Sreeja, 2000).

AVRDC recommendation for planting in raised beds For

fruit production - 2m (plant to plant) x 3 to 5m (row)

For leaf production (Normal) - 60 cm (plant to plant) x 100 cm (row)

For leaf production (Intensive) - 10-20 cm (plant to plant) x 30 to 50 cm (row)

Closer spacing allows harvest of young edible shoots every two to three weeks. Trees are often spaced in a line one meter apart or closer to establish living fence posts. (Palada and chang, 2003)

Crop yields are lower for any single crop in a polyculture, although total production of the system can be significantly higher than in

monocultures. In moringa, lower leaf yields may be expected as tree spacing increases to allow for companion crops. Wider spacing (2.5 m × 2.5m, [8.2 ft × 8.2 ft]) can increase pod yields relative to dense plantings.

Recommended planting density spacing for leaf production is 0.75 m (2.5 ft) within rows and 1 m (3 ft) between rows. For pod production, recommended spacing is 2.5 m × 2.5 m (8.2 ft × 8.2 ft).Moringa leaf may be produced intensively in beds with seeds spaced 10 cm×10 cm (4 in × 4 in) like an annual leafvegetable. Spacings of at least 2 m×3 m (6.6 ft × 10 ft) are recommended for perennial polycultures, depending on pruning frequency of the trees, the shade tolerance and other requirements of the companion crops, as well as space required for equipment access. Spacing of 5 m × 5 m (16.4 ft × 16.4 ft) may be considered generally appropriate for most situations.

4.5. Small-scale production

Intensive leaf production using beds with 10 cm × 10 cm (4 in × 4 in) spacing may be the most feasible commercial application for the home gardener. For urban lots or small fields, leaf production from trees at 0.75 m × 1 m (2.5 ft × 3.3 ft) spacing is perhaps the best option. Intensive bed production produces very high yield of leaf in a small area, but is not feasible over larger areas because of the high amount of seed needed. Wider spacing at 0.75 m × 1 m (2.5 ft × 3.3 ft) is more feasible for leaf production in lots approaching 0.5 hectare (1.2 ac) and will also provide some pod production.

4.6. Intensive production

The spacing of plants should be 15 x 15 cm or 20 x 10 cm, with conveniently spaced alleys (for example: every 4 meters) to facilitate plantation management and harvests. Another option is to space the seeding lines 45 cm apart and to sow every 5cm on those lines. One can also space the lines only 30 cm apart and sow at a larger distance on the lines (10 to 20 cm). These intensive

systems are appropriate for commercial production but require careful management.

4.7. Semi-intensive production

Plants are spaced 50 cm to 1 m apart. This is more appropriate for small-scale farmers and gives good results with less maintenance.

4.8. Agro-forestry

Moringa trees can be sown in alleys and associated with other crops. The distance between moringa rows must be 2 to 4 meters, and they must be oriented East-West to ensure that intercrops receive enough sun.

4.9. It is advisable to avoid associating moringa with

Crops that require a lot of nitrogen, such as maize or cassava; Crops that require chemical treatments; Crops that can compete for light with moringa trees (millet, sorghum). It is better to associate crops that can enrich the soil in minerals, especially in nitrogen like leguminous plants such as groundnut, soy or beans. Spacing must be much wider for fruit or seed production. Trees must be at least 2.5 m apart. Line and peg using a 3 x 3 meter triangular pattern for seed-producing farms. This will optimize plant population density.

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5. SOIL MOISTURE MANAGEMENT FOR FLOWERING IN MORINGA

Moringa (*Moringa oleifera*) is a tropical plant and exhibits certain degree of xerophytic behaviour. Botanically the perennial moringa types are featured with large size water storage cells in limbs and low transpiration rate to tolerate against drought and also have the adaptation of shedding all its leaves to reduce transpiration loss. Moreover the developing fruits are autotrophic since they also contain high chlorophyll content and also draw water from the storage cells for photosynthesis. This mechanism was helpful in the retention and development of fruit. Basic understanding of the growth and development physiology of moringa is very much important before to chalk out the soil moisture management for flowering.

Moringa can be successfully grown in soils with good drainage *viz.,* red loam, red sandy loam, clay loam and sandy loam soils. Moringa roots are highly sensitive to water logging. Annual moringa types raised through seeds requires frequent and regular irrigation compare to perennial or country types. In annual moringa types the roots are highly succulent and fast spreading and draw more water from the subsoil region hence it needs frequent and regular irrigation with an interval of 7-10 days whereas the perennial moringa types are hardy and can be irrigated with an interval of 10-15 days interval based on the soil type during its vegetative growth respectively. Shorter period of 10-15 days water stress immediately after the pinching is very much useful for the development of more number of laterals in annual moringa. Soil moisture stress for the period of 20 - 30 days depending upon the soil types will be beneficial in flower induction of moringa.

Soil moisture stress for limited period of time has the positive role on flower bud development by suppressing the excessive vegetative growth

in moringa. However the water stress is not advisable for during the peak flowering and fruit setting stage. Moisture stress during this stage would be highly detrimental for moringa crop and results in flower drop, pollen dryness, immature fruit drop and desiccation of immature fruits from tip to downwards. Hence regular and frequent irrigation with 7-10 days interval depending upon the soil type is necessary to improve the fruit set and fruit development of moringa. Excess watering and water stagnation has to be completely avoided during this stage since that also leads to flower drop and immature fruit drop. During peak fruit development and maturation stage requires moderate irrigation otherwise the fruits are highly succulent, less palatability and poor post harvest life. Complete stoppage of irrigation is recommended during the fruit maturation and fruit colour changes into straw yellow for seed production purpose.

During the severe drought and in hot summer period, the moringa tree can be sprayed with anti - transpirants like green miracle, PMA, kaolin etc., to safeguard against the trees from drought and also to check the flower drop or fruit drop.

The base of the moringa trunk should always well protected by earthing up or mounding the soil around the tree base and also against termite and bark borer incidence. Since the roots are highly succulent and fragile in nature and heavy wind will pull out the whole plant and limbs and roots are tends to easily breaks down. If conventional irrigation systems in beds and channel method are followed care should be taken to avoid the water contact directly on the trunk surface or base. Since this will weaken the plant against wind. Whereas if the drip irrigation is followed the laterals and emitters should be placed 1 to 1.5 feet away from the main trunk or base of the moringa tree.

Agronomic practices *viz.*, summer ploughing, broad bed and furrow system, adoption of drip irrigation system, mulching with crop residues, use of organic manures and humic substances can be integrated for successful soil moisture management of moringa for high flowering and fruit yield.

6. NUTRIENT MANAGEMENT IN MORINGA

Nutrient management is managing crop fertility inputs and other production practices for efficient crop growth and water quality protection. Nutrient management plans for site-specific situations minimize undesired environmental effects while optimizing farm profits and production.

6.1. Planning for nutrient management

- Before planting moringa soil fertility status of moringa should be assessed
- Nutrient removal status of moringa are to be assessed
- Nutrients available from previous applications are to be assessed
- Assess environmental risk of nutrient movement
- Record maintenance on the application of nutrients is very important

6.2. Fertilizing

Moringa trees will generally grow well without adding very much fertilizer. Manure or compost can be mixed with the soil used to fill the planting pits. Phosphorus can be added to encourage root development and nitrogen will encourage leaf canopy growth. In some parts of India, 15cm-deep ring trenches are dug about 10cm from the trees during the rainy season and filled with green leaves, manure and ash. These trenches are then covered with soil. This approach is said to promote higher pod yields. Research done in India has also showed that applications of 7.5 kg farmyard manure and 0.37 kg ammonium sulphate per tree can increase pod yields threefolds.

Fertilizer and irrigation are recommended for maximum productivity. Muthusamy (1954) reported that manuring of moringa was rarely practiced, as the tree was capable of growing in very poor soils. Seemanthani

Ramadoss(1964) identified the problems in moringa and stated that application of manures could help to promote larger yields without sacrificing the margin of profit. Research work at the Tamil Nadu Agricultural University has shown that application of 7.5 kg of farmyard manure and 0.37 kg of ammonium sulphate per tree gave three-fold increase in yield over the unmanured trees. (Sundararaj *et al.*, 1970). Martin and Ruberte (1979) stated that usually moringa receives no horticultural attention, but mulching and fertilizing will produce better growth and result in quality of products.

Khader Mohideen and Shanmugavelu (1982) reported that application of farmyard manure @ 20 kg per pit, top dressing with 100g in each of urea, super phosphate and muriate of potash per tree gave higher yield. Moringa trees can be fertilized with 10-20 kg FYM per pit, 60 g N,. 80 g P and 40 g K per pit (Anonymous, 1994). *Moringa oleifera* seedlings when grown in natural or artificial sodic soils significant decrease in plant height, number of leaves, stem diameter, plant spread, total leaf area and root length occurred at ESP 41.0 (Valia *et al.*, 1998).

An investigation on the nutrient requirements of one year old moringa cultivars revealed that the highest number (117) and weight (5.24 kg) of pods per plant were recorded in selection 6/4 with the fertilizer combination of 250:125:125g NPK per plant. However, a highest net return per rupee spent on fertilizers was obtained in selection 6/4 with 200:100:100g NPK per plant (Hanchimani and Madalageri, 1994).

To get higher yields in moringa trees should be fertilized with 100g Urea, 100g super phosphate and 50g muriate of potash at third month and again at sixth month of planting, 100g urea should be top dressed. Moringa trees generally grow well without fertilizer.

Beaulah (2001) reported that integrated nutrient management in annual moringa encompassing organic manures, bio-fertilizers and varying levels of N, P and K. The results obtained a positive response from moringa to the application of manures and fertilizers. Initial vigour was higher in

treatment with poultry manure (500 g / pit) + Neem cake (250g/pit)+ panchakavya (2%) spray along with 150:150:100g NPK/tree. In ratoon crops, similarly, the same treatment resulted in early and vigorous growth confirming the superiority of integrated nutrient management in moringa.

In the integrated nutrient management system manures can also be incorporated to increase the fertility status of soil. The following manures are recommended for application to moringa.

6.3. Farm Yard Manure

The term Farm yard manure or Farm manure refers to the refuse from farm animals, mainly cattle, sheep and poultry. This is one of the oldest manure known and highly valued for its many beneficial effects when applied to farm soils, viz. maintaining soil physical and chemical fertility.

Farm yard manure consisting of a mixture of four components viz; dung, litter (bedding material) waste fodder left over in the cattle shed and urine.

6.4. Average composition of FYM

On an average FYM contains 0.5% N, 0.25% P_2Os and 0.50% K_2O A ton of the material will supply 5 kg N, 2.5kg P_2O and 5 Kg K_2O.

6.5. Compost

It refers to the material collected from the farm, town or village surroundings and allowed to decompose for a considerable period of time. It is the product of plant and animal wastes with various additives.

6.6. Vermi composting

Dig 2 m long x 1 on breadth x 1m deep trench. Then add broken bricks upto 5cm at the bottom for draining water. Then add 20cm thick clay or silt. This is called vermibed. In this spread FYM randomly. Now introduce 100 Nos. of earthworms for multiplication. Over this vermibed spread straw and sprinkle water periodically. Then after 30 days spread waste materials upto a height of 5cm and cover it with coconut leaf. Go on adding the waste twice in a week till the pit is filled up. Now only stir the portion above

the vermibed. Water upto 45 days and stop afterwards. The earthworms feed on the waste material and convert them into a dark brown / black colour compost. It will take 60 days for preparing vermicompost. 2x1x1 pit gives 500-750kg compost. Generally 2000kg/acre is recommended. Moringa trees: 1-10 kg / tree is recommended.

6.7. Sheep and goat manure

The droppings of sheep and goats make very good manure. Panning is, therefore, a common practice of ensuring the use of sheep and goat droppings in the fields. Sheep and goat manure contains 3 per cent N, 1 per cent P_2O_5 and 2 per cent K_2O.

6.8. Green Manure / Green Leaf Manure

Green manure / Green leaf manure is the fresh plant material which is ploughed into the soil for the purpose of incorporating organic matter, thus supplying humus as well as the nutrients contained in the plant tissues. Generally if a crop is grown and incorporated into the same field, it is referred to as green manuring and if the plant materials are brought from outside and applied to the field; the practice is called as green leaf manuring. Such crops includes legumes and non legumes.

6.9. Green manuring

The crops, mainly legumes are grown and incorporated in the same field. This is the general practice adopted in India. But in other countries, both legumes and non-legumes are grown and the mixture is always preferred. The following are the commonly grown legumes and their manurial values.

Green Manure	**Yield (t/ha)**	**Nutrient content (dry wt. Basis)**		
		N%	**P%**	**K%**
1. Sur hemp (*Crotalaha juncea* }	15-25	2.3	0.5	1.8
2. Daincha (*Sesbania aculeata*)	10-20	3.5	0.6	1.2
3. Sesbania (*Sesbania speciosa*}	25-30	2.8	0.4	1.4
4. Pillipesara (*Phaseclus trilohus*}	8-10	2.9	0.6	1.1
5. Cluster beans (*Cyamopsis tetraqonaloba*)	15	1.9	0.4	0.9
6)Kolinchi (*Tephr osia purpurea*]		2.8	0.4	1.2

6.10. Oil cakes

Oil seeds are generally rich in manurial ingredients. After oil extraction, the oil-cakes are rich in nitrogen and also contain phosphorus and potash. Cultivators apply both edible and non-edible oil-cakes to the soil as manure. Edible oilcakes are more profitable as cattle feeds. As such, non-edible cakes should be used as manures.

The percentage of nitrogen ranges from 2.5 in mahua to 7.9 in decorticated safflower cakes. The P_2O_5 contents in oil-cakes vary from 0.8 to 3 per cent and K_2O from 1.2 to 2.2 per cent.

Oil cakes though insoluble in water are quick-acting organic manures, their nitrogen becoming quickly available to the plants in about a week or ten days after application. Mahua oil-cake, however, takes about two months to nitrify. The solvent-extracted oil cakes are somewhat more quick-acting than the ghani-hyraulic or expeller-pressed oil-cakes. The quantity of organic matter that gets added in normal application of oil-cakes is too small to cause improvement in physical properties of soil.

6.11. Poultry manure

This is a rich organic manure, since liquid and solid excreta are excreted together resulting in no urine loss. Poultry manure ferments very quickly. If left exposed, it may lose up to 50 percent of its nitrogen within 30 days.

Poultry manure can be applied to the soil directly as soon as possible. After application, it should be worked into the surface of the soil. If the droppings come from the cages or dropping pits, superphosphate may be added to these at the rate of 1kg per day, per hundred birds. This improves the fertilizing quality and helps the control of flies and odour. The average chemical composition of the poultry manure is as under:

Type	Moisture %	Nitrogen%	Phosphorus %	Potassium %
Fresh	75	1.47	1.15	0.48
Floor litter	24	3,03	2.63	1.40

6.12. Generally in India the following fertiliser schedule is adopted

Integrated nutrient management system

- 150:150:100g NPK/tree basal application
- 500g poultry manure + 250 g neem cake per pit

If only chemical fertilizer used

- 44 : 16 : 30 g NPK/ tree at the time of pinching
- (75 days after sowing). Nitrogen @ 44g / tree at first flowering

If only organic

10 kg/tree compost as basal application at sowing + 20 kg/tree at pruning.

Fertigation in moringa

- Nutrient required per ha area - 144:24:48Kg (N:P:K)
- Fertigation dose - 144:6:48 kg(N:P:K)

Name of the fertilizer	Dose(kg/ha)
Super Phosphate	113
19-19-19	32
13-00-45	94
Urea	274

The entire dose of super phosphate 113kg should be applied three months after planting as basal, since super phosphate is insoluble in water.

6.13. Fertigation schedule for moringa

Stage of Crop	Duration of Fertilization	Name of the fertilizer	No. of times	Dosage (kg/ each time)
First stage	Three months after planting to 145 days	19-19-19 13-00-45 Urea	11 times 11 times 11 times	2.9 0.7 7.2
Second stage	146 days after planting to 190 days	13-00-45 Urea	9 times 9 times	3.6 13.0
Third stage	191-235 days	13-00-45 Urea	9 times 9 times	5.9 8.8

6.14. Summary

Moringa is a fast growing tree, drought tolerant, easily adapted to varied ecosystems and farming systems, it occupies a unique and consistent position in the Indian vegetable industry. The cultivation of moringa in India occurs mainly in the Southern states of Tamil Nadu, Karnataka, Kerala, and Andhra Pradesh. Principally perennial types have been known about for cultivation for a very long time. However, perennial types are beset with many production constraints, such as a relatively long pre-fruit bearing period, non availability of planting materials, requirement of a greater number of rainy days in regions where water is scarce, and vulnerability to pests and diseases. Integrated nutrient management in moringa will be useful to get more yield and quality produce.

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7. USE OF BIOFERTILIZERS FOR ENHANCING THE PRODUCTION POTENTIAL OF MORINGA

'Biofertilizer' is a substance which contains living microorganisms which, when applied to seed, plant surfaces, or soil, colonizes the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the host plant. The biofertilizers add nutrients through the natural processes of nitrogen fixation , solubilizing phosphorus, and stimulating plant growth through the synthesis of growth promoting substances. Even though soil may contain vast amounts of N and P, most is not readily available for plant use. Most of N is tied into the soil organic matter. Even after fertilization, plants have to compete with soil microbes for easily available soluble N. In acidic soils, even when added in substantial quantities as fertilizer, P precipitates with iron or aluminum, whereas in alkaline soils P precipitates as calcium phosphates. Accordingly, P limitation may be a difficult problem to overcome through the addition of P-containing fertilizers. Hence, the biofertilizers can be expected to reduce the use of chemical fertilizers and restore the soil's natural nutrient cycle and build soil organic matter. Through the use of biofertilizers, healthy plants can be grown while enhancing the sustainability and the health of soil.

7.1. Biofertilizers for moringa

7.1.1. Nitrogen fixing bacteria

Atmospheric N_2 composes approximately 80 per cent of the air. Although abundant and ubiquitous in the air, N is the most limiting nutrient to plant growth because the atmospheric N is not available for plant uptake. Some bacteria are capable of N_2 fixation from the atmospheric N pool. The amount of N fixed by different systems is considerable, although variation

resulting from environmental conditions or different plant-microbe combinations is vast. The close proximity of these microorganisms to their host plants allows efficient plant use of fixed N and minimizes volatilization, leaching, and denitrification.

The genus *Azospirillum* possesses a great potential as a general root colonizer, whose use is not limited by host specificity. The *Azospirillum* biofertilizer contains 109 cells per gram of the inoculant. This microorganism fixes the atmospheric nitrogen and makes it available to plants in associate symbiotic manner. The yield increases can be substantial, up to 30 per cent, but generally range from 5 to 30 percent. These yield increases by *Azospirillum* are possibly a result of the production of growth-promoting substances and N_2 fixation.

7.1.2. Phosphate solubilizing bacteria

Phosphorus is the second most limiting plant nutrient after N. Total P content in soil is usually high, but most of this soil P pool is not in forms available for plant uptake. Bacteria that can solubilize P from unavailable soil pools and increase P availability to plants are of great importance. Most predominant phosphorus-solubilizing bacteria (PSB) belong to the genera *Bacillus* and *Pseudomonas*. PSB may be of greatest value in allowing use of cheaper P sources (e.g.,rock phosphate instead of superphosphate). The phosphobacterial biofertilizer also contains 109 cells per gram of the inoculant and reduce the P requirement by 25 per cent of the recommended phosphorus

7.1.3. Arbuscular mycorrhiza (AM) fungi

Moringa plants are more productive when well colonized by AM fungi. The AM symbiosis increases the phosphorus and micronutrient uptake and growth of their plant host. The mycorrhizal fungi may also improve soil quality by having a direct influence on soil aggregation and therefore aeration and water dynamics. An interesting potential application for mycorrhizal fungi is their ability to allow plant access to nutrient sources generally unavailable to the host plants. Various potential benefits of

mycorrhizal symbiosis on plant performance and crop yield suggest that they have substantial applications in agriculture and horticulture

7.2. Biofertilizer Application

7.2.1. Seed treatment

Seed treatment with *Azospirillum* @ 200 g/kg of seeds

7.2.2. Nursery

Apply *Azospirillum* 5g/m^2, Phosphobacteria 5g/m^2 and AM fungi 60g/ m^2.

7.2.3. Main field

Apply *Azospirillum* 2kg/ha, Phosphobacteria 2 kg/ha and AM fungi 4 kg/ha

8. STRATEGIES AND STATUS OF WEED MANAGEMENT IN MORINGA

Negligence towards weed management is the most important, as the losses due to weeds range from 11 to 74% under various agro-ecological situations. Due to slow germination and initial growth, wider row spacing, slow lateral spread, and adequate supply of nutrients and moisture and long duration, moringa suffers from tremendous weed problems. Weeds have been perceived as unwanted intruders into agro-ecosystems that compete for limited resources. When improved agricultural technologies are adopted, efficient weed management becomes even more important, otherwise weeds rather than crops benefit from costly inputs.

In India, moringa is planted in spring (February-March), autumn (September-October) and adsali planting (July-August). Being a long duration crop, it is heavily infested with a variety of weeds. Large number of species including manuals, perennials and parasitic have been observed in moringa fields. The weed flora differs from location to location due to variation in agro-ecological conditions and management practices.

8.1. The most important weeds associated with moringa crop are listed below

Grasses

Barnyard grass,	*Echionochloa crusgalli*
Goosegrass (yardgrass, silver crabgrass),	*Eleusine indica*
Large crabgrass (large hairy crabgrass),	*Digitaria sanguinalis*
Bermuda grass (devilgrass),	*Cynodon dactylon*
Quackgrass (couchgrass),	*Agropyron repens*

8.2. Broad Leaf Weeds

Annual morningglory, *Ipomoea purpurea*

Black nightshade, *Solanum nigrum*

Jimsonweed, *Datura stramonium*

Lambsquarter, *Chenopodium album*

Prostrate pigweed (mat amaranth), *Amaranthus graecizans*

Rough pigweed (redroot), *Amaranthus retroflexus*

Purslane (pusley), *Protulaca oleracea*

Canada thistle (creeping thistle), *Cirsium arvense*

Field bindweed (creeping jenny, small morningglory), *Convolvulus arvensis* Groundcherry, Physalis spp.

8.3. Sedges

Yellow nutsedge, *Cyperus esculentus*

8.4. Critical period of crop-weed competition

Moringa being initially slow-growing crop faces an acute competition from weeds. Weed problems vary according to agro-ecological regions and management practices and the losses due to weeds comprise (i) direct yield losses resulting from competition, (ii) indirect losses from reduced crop quality, (iii) increased costs in harvesting, land preparation and similar operations and (iv) harbouring insects' pests and diseases. Besides, weeds remove large amount of nutrients from soil. Direct yield losses in widely spaced crops ranged from 11-74% depending upon the nature and intensity of weed flora and period of occurrence of weeds.

Removing weed at any time during growing season may not be beneficial. It is necessary to identify critical period of crop-weed competition to render weed control practices more effective. Critical period can be defined, as "the shortest span of time in the ontogeny of crop growth when weeding will result in higher economic returns". In sub-tropical India, weed infestation during 30-90 days after sowing may be detrimental for the final crop yield in moringa.

8.5. Methods of weed control in annual moringa

8.5.1. Mechanical and physical methods

Mechanical and physical methods of weed management are relatively easy, inexpensive, and do not create chemical residues. However, they may damage soil structure and promote erosion. Large areas or unfavourable weather conditions may make these methods impractical.

Since moringa rows are widely spaced, shallow-rooted weeds can be managed by hoeing with hand tools or with intercultural operations during growing season of crop. Generally, 3-4 hoeing are required each after every irrigation during vegetative growth phase of crop to check crop-weed competition. The removal of weeds by mechanical means is laborious and expensive and weeds in intra-row spaces are not killed. Besides, sometimes due to unfavorable weather/soil conditions, mechanical weeding may not be possible.

8.5.2. Physical control

8.5.2.1. Hand Weeding

Annual and biennial weeds and non-creeping perennials can be destroyed by simply pulling them out. This is best done when the soil is moist and before seed is produced. This is only practical of course for small patches or individual plants.

8.5.2.2.Mowing

When weeds are too numerous to hand pull, too large to effectively destroy by cultivation, or in an area where cultivation is impractical or impossible, they can be destroyed by mowing. This should be done before they produce seed and as close to the ground as possible.

Perennial weeds usually require several cuttings before the food reserves in the roots are exhausted. If only a single cutting can be made, the best time is just prior to blooming because (1) the reserve food supply in the roots is at its lowest level and (2) viable seed is often produced just

after blooming. Perennial sow-thistle begins producing viable seed only three days after blooming and after nine days, 73 per cent of the seeds may be viable.

8.5.3. Cultural methods

Weeds in moringa could be managed to a large extent by cultural practices such as crop rotation, intercropping, mulching, etc.

a. Crop rotation: Certain weeds have association with moringa crop and hence, monocropping of moringa may lead to severe crop-weed competition. Inclusions of green manure crops or fodder crops like sorghum not only suppress weeds but also help in crop diversification.

b.Tillage: Tillage and cultivation are the most traditional means of weed management in agriculture. Both expose bare ground, which is an invitation for weeds to grow. Bare ground also encourages soil erosion, speeds organic matter decomposition, disturbs soil biology, increases water runoff, decreases water infiltration, damages soil structure, and costs money to maintain (for fuel and machinery or for hand labor). Some specific tillage guidelines and techniques for weed management include the following.

Preplant tillage: Where weeds such as quackgrass or johnsongrass exist, spring-tooth harrows and similar tools can be effective in catching and pulling the rhizomes to the soil surface, where they desiccate and die. Discing, by contrast, tends to cut and distribute rhizomes and may make the stand even more dense.

Inter row cultivation: It is best done in between the rows of moringa as soon as possible after precipitation, once the soil is dry enough to work. This avoids compaction, breaks surface crusting, and catches weeds as they are germinating- the most vulnerable stage.

Flame weeding: Pre plant, pre-emergent, and post-emergent flame weeding has been successful in a number of crops. The pre plant application has commonly been referred to as the "stale seedbed technique." After seedbed tillage is completed, weed seeds, mostly in the upper two inches

of the soil, are allowed to sprout. Assuming adequate moisture and a minimum soil temperature of 50º F (to a depth of 2 inches), this should occur within two weeks. A fine to slightly compacted seedbed will germinate a much larger number of weeds. The weeds are then "seared" with a flamer, or burned down with a broad-spectrum herbicide, preferably when the population is between the first and fifth true-leaf stages, a time when they are most susceptible. The moringa crop should then be seeded as soon as possible, and with minimal soil disturbance to avoid bringing new seed to the surface. For the same reason, subsequent cultivations should be shallow(less than 2 inches deep).

c. Intercropping: Moringa is planted in wider-row spacing. This provides better opportunity for weeds to emerge in a large numbers and infest crop. Inclusion of short duration and quick growing intercrops in these row spaces can suppress weed growth to a great extent. From the second year onwards, moringa can be inter-cropped with maize, sunflower and other field crops. Sunflower is particularly recommended for helping to control weed growth. However, moringa trees are reported to be highly competitive with eggplant (*Solanum melongena*) and sweet corn (*Zea mays*) and can reduce their yields by up to 50%. The Net Present Value (NPV), Benefit/Cost Ratio (B/C) and Relative Net Return (RNR) were higher with *Cymbopogon* and Stachytarpheta herbs (Brian, 2004).

d. Cover cropping: The cover crops that have shown allelopathic effects on weeds include sunflowers, sorghum, and rapeseed. Weed control ability varies among varieties and management practices. Sweet potatoes have been shown to inhibit the growth of yellow nutsedge, velvetleaf, and pigweed. Field trials showed a 90% reduction of yellow nutsedge over two years following sweet potatoes. This can be better utilized by growing in the inter space of moringa. In general, typical levels of cover crop residues, when left on the soil surface, can be expected to reduce weed emergence by 75 to 90%. As these residues decompose, the weed suppression effect will decline also. Residues that are more layered and more compressed will

be more suppressive. Small-seeded weeds that have light requirements for sprouting are most sensitive to cover crop residue. Larger-seeded annual annual and perennial weeds.

e. Mulching: The principle of mulching is to exclude light from the tops of the weeds until the reserve food supply in the roots is depleted and the weeds starve. Mulches include clean straw, hay or manure, tar paper, sawdust and black plastic. When the vegetation under the mulch has been destroyed, the resultant bare patch must be reseeded with competitive vegetation to prevent new weed introductions.

Black polythene mulching: Mulching is an age-old practice especially in horticultural crops in many countries. Though various natural and synthetic materials are suggested, black polythene mulching is found predominant as it is reported very effective in control of weeds in vegetable gardens. Photosynthesis of weeds is arrested and they ultimately die as the sheet totally blocks the sun light. Further, black polythene mulch increases soil temperature as well as conserves the soil moisture by preventing the evaporation of water from soil surface. The method is eco-friendly and effective against all types of weeds in moringa.

Trash mulching: It can be practiced, soon after emergence of moringa to 12 cm thickness. Trash cover restricts sunlight and checks weed emergence. Besides, suppressing weeds, trash mulching also conserves soil moisture, and provides a potential source of organic matter.

8.6. Chemical weed control

The best approach to minimize inputs and to avoid any environmental problems is to apply herbicides in the crop row to a width of 10-30 cm (Labrada, 1996). Band application reduces herbicide use by up to 75 percent compared to an overall application. Weeds along the cropping row are then controlled and the inter row ones can be removed through cultivation.

In moringa, use of weedicides for controlling weeds has not yet been standardized so far. However, as a prophylactic measure, the non-selective

herbicide, glyphosate (Roundup or Kleenup) can be used in the garden before field preparation to control emerged perennial weeds. After 30 days, the seeds, rooted cuttings, or transplants of moringa can be planted. Future research should focus on finding an appropriate strategy for using pre emergence and post emergence herbicides for controlling weeds in annual moringa.

8.7. Biological method

It uses living organisms to control weeds. One example is allowing geese to feed on certain grasses. Future biological control methods may include plant varieties with increased vigor, and insects and disease organisms that selectively attack weeds.

Integrated weed management: Integrated weed management (IWM) is the control of weeds through a long-term management approach, using all the above said weed management techniques.

8.8. Advantages

By using several techniques to control weeds you reduce the chance that weed species will adapt to the control techniques, which is likely if only one technique is used. For example, if a herbicide is used over a long period of time, a weed species can build up a resistance to the chemical.

A long-term integrated weed management plan, that considers all available management control techniques or tools to control weeds, can be developed for a particular area. Any integrated weed management plan or strategy should focus on the most economical and effective control of the weeds and include ecological considerations.

The long term approach to integrated weed management should reduce the extent of weeds and reduce the weed seed stock in the soil. It should consider how to achieve this goal without degrading the desirable qualities of the land, such as its native ecology or agricultural crops.

Now, farmers are showing increased interest for growing annual

moringa. It is the need of the hour to initiate research work on weed management in annual moringa to find out integrated weed management strategy considering all the advantages mentioned and to increase the overall profit of the growers.

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9. OFF SEASON PRODUCTION OF MORINGA

Moringa is an important vegetable of South India. It has helped mankind in combating malnutrition in children and increase immunity. It is a multi function plant cultivated in the tropics around the world for high protein, vitamins, minerals and carbohydrate content, nutrition for both human and live stock. It has high oil content with medicinal uses and water purifier. In India it is cultivated in an area of 30,000 ha with an annual production of 12 lakhs tonnes of pods. Both perennial and annual moringa are cultivated in Tamil Nadu. The crop comes to bearing during the month of March to August and the price of pods per kg on an average will be around Rs. 5.

Further the price of the pods will shoot up to Rs. 15-20 kg during September and October as the productivity starts to decline. The pods are available in a very meager number during November to February owing to the season which coincides with heavy rainfall, low temperature which leads to the drop in flowers leading to poor pod set which is considered to be the off season period of the year.

The demand during this season is high due to religious functions *viz.*, Diwali, Ramzan, Christmas, Pongal etc. apart from this there are marriage ceremonies and other functions in the rural and urban areas. During this particular period the cost of the pods will raise even up to Rs. 60 / kg which is higher than the profits obtained during the glut period i.e. (March - August). Keeping this in mind and the extra profits that could be given to the farmers the off season production in annual moringa was tried and the technology is discussed in detail.

The moringa crop performs well during summer season and not much during the winter season. Hence there is a lean period during November to February. A study was conducted to induce off season flowering and pod set during November to February. In this study, the following treatments were imposed to induce flowering and fruit set.

1. Staggered sowing and followed by spraying chemicals / growth regulators
2. Pruning the trees and followed by spraying chemicals / growth regulators

The staggered sowing was done during 30th April (M_2), 15th May (M_3), 30th May (M_4) , 15th June (M_5), 30th June(M_6) and 15th July (M_1) followed by spraying with chemicals with potassium nitrate, salicylic acid, calcium chloride and nitrobenzene.

The sowing was done according to the above treatments from 30th April to 15th July. Pits of 1 cubic feet were dug and filled with FYM and the seeds were dibbled @ 2/pit and irrigated. The germination started from the 10th day after sowing and the pinching was done when the plants were 2 feet tall and subsequent pinching was done 25 days after the first pinching. This helps the tree to form a umbrella like shape which induces more branching followed by better holding capacity of the tree for flowering and fruiting. After this the crop has to be sprayed with the chemicals 0.5 % potassium nitrate (S_2) , 0.1% salicylic acid (S_3) , 0.5 % calcium chloride (S_4), 0.5 % nitrobenzene (S_5) at the rate of two sprays during the end of August to 1st week of September followed by another spray at 15th day after first spray, no spraying is also recorded (S_1).

The crop comes to flowering from 88 to 91 days after sowing. The combination of May sown and spraying with nitrobenzene and potassium nitrate had significant effect on number of panicles per plant and number of flowers per panicle.

Table 1 . Effect of different sowing dates along with chemical application for off- season production in moringa PKM 1

Tre atment	Plant he ight (180 days) m	Days to first flower.	No. of flow. pani. /tr ee	No. of pods /pani .	No. of pods/ tree	P ods set %	Fr uit le ngth cm	Fruit girth cm	Fr uit we ight g	Total yield t/ha	B:C ratio
1 1											
M_1S_2	2. 77	98.0	70 .5	1.30	12. 55	4 .83	50.80	1.71	67. 65	2.18	1. 31
M_1S_3	2. 71	107.8	59 .2	1. 0	9.05	3 .25	50.50	1.55	74. 75	1.67	1. 05
M_1S_4	2. 87	11 .05	48. 35	1. 2	8.25	4 .31	51.00	1.55	65. 00	1.36	0. 83
M_1S_5	2. 79	107.18	44. 90	1.43	11. 75	4 .61	58.37	**1. 94**	86. 00	2.67	1. 60
M_2S_1	3. 69	89.6	200 .8	1. 0	4. 5	2 .65	54.65	1.65	77. 50	0.87	0. 56
M_2S_2	3. 86	90 .20	**292.95**	1. 30	15. 27	2 .60	**67.20**	1.77	90 .0	3.42	2. 05
3											
4											
M_2S_5 - III	**3. 27**	91 .50	214 .30	**1. 70**	**32. 50**	**4. 43**	64.32	**1. 97**	93. 35	**7. 25**	**4. 34**
M_3S_1	3. 86	89 .53	227 .0	1. 10	16. 00	2 .44	47.89	1.54	62. 75	2.70	1. 73
M_3S_2	3. 91	**80.15**	224 .15	1. 30	22. 10	2 .79	49.52	1.74	78. 85	4.40	2. 65
M_3S_3	3. 53	**87.45**	226 .40	1. 20	7.90	2 .85	55.62	1.70	76. 25	1.51	0. 94
M_3S_4	3. 61	89 .35	222 .05	1. 60	10. 80	4 .36	61.50	1.70	78. 30	2.10	1. 29
M_2S_6 – I	**4. 16**	**88.10**	**233.15**	**1. 90**	**37.5**	**4. 44**	59.42	1.86	93. 25	**8. 58**	**5. 13**
4 1											
4 2											
4 3											
M_4S_4	3. 82	92 .70	198 .25	1. 23	13. 25	3 .26	55.20	1.75	70. 25	2.31	1. 41
M_4S_5 - II	**3. 71**	93 .40	224 .20	1. 60	**29. 00**	3 .39	**68.35**	1.92	**110 .13**	**7.99**	**4. 78**
M_5S_1	3. 81	92 .25	147 .05	1. 00	10. 64	1 .87	53.62	1.61	73. 30	1.93	1. 23
M_5S_2	3. 95	92 .40	173 .90	1. 33	13. 15	2 .96	63.80	1. 76	87. 50	2.93	1. 76
M_5S_3	4. 08	89.8	203 .75	1. 10	15. 35	2 .43	50.52	1. 82	76. 25	2.96	1. 85
5 4											
5 5											
6 1											
M_6S_2	4. 19	104.5	179 .80	1. 22	15. 50	3 .80	60.87	1.73	84. 00	3.25	1. 95
M_6S_3	3. 98	106.2	211 .35	1. 30	8.25	2 .58	57.75	1.56	71. 00	1.46	0. 91
M_6S_4	4. 24	105.85	167 .55	1. 10	6.35	2 .56	53.25	1. 68	80. 35	1.25	0. 77
M_6S_5	4. 35	105.20	**237.55**	**1. 80**	17. 05	**4. 56**	**65.00**	**2. 02**	**106 .80**	4.51	2. 70

The pod set percentage was also highest during the treatment combination of May sown with nitrobenzene 0.5% spray. The parameters like number of pods per panicle total number of pods per tree, pod weight, yield per tree and yield per hectare, all these were found to the highest in the treatment 15th May sown and spraying with nitrobenzene 0.5%.

Table 2. Effect of staggered sowing and chemical application on the physiological parameters for off-season production in moringa PKM 1

M / S	Total chl., cont.		Soluble Protein		Nitrate reductase		Relative water cont.	
	(Veg. Stage) mg/g	(Flow. Stage) mg/g	(Veg. stage) mg/g	(Flow. Stage) mg/g	Activity (Veg. stage) µg NO^{-2} / g	Activity (Flow. stage) µg NO^{-2} / g	(Veg. stage) %	(Flow. stage) %
M1S1	1.85	2.83	29.25	30.00	23.00	22.50	95.65	80.65
M1S2	2.49	3.06	33.25	33.50	17.00	18.00	97.46	82.96
M1S3	2.02	2.19	17.75	28.00	7.60	17.50	96.82	81.82
M1S4	1.90	2.46	28.30	28.75	22.00	22.00	97.96	82.02
M1S5	1.54	2.86	37.25	37.75	22.50	23.00	97.66	82.66
M2S1	2.24	2.40	35.25	37.25	16.00	15.00	95.77	80.77
M2S2	2.57	3.33	48.00	43.00	14.00	15.00	97.52	82.58
M2S3	1.89	2.66	35.25	35.25	20.50	25.00	96.66	81.66

M2S4	2.53	2.71	29.75	46.75	16.50	23.00	96.39	81.65
M2S5	1.94	3.19	45.00	57.75	23.50	18.00	97.10	82.40
M3S1	2.58	2.63	24.25	29.25	17.00	9.00	96.42	81.62
M3S2	2.31	3.32	19.00	29.00	16.00	10.50	96.53	81.52
M3S3	2.52	3.03	21.75	31.75	22.50	20.00	97.25	82.25
M3S4	2.42	2.75	17.00	30.25	15.00	17.50	97.34	82.20
M3S5	2.23	3.18	24.75	30.50	22.00	8.50	97.72	82.72
M4S1	2.29	2.18	31.00	38.25	15.50	17.00	93.78	78.68
M4S2	2.66	3.42	23.75	43.50	21.30	18.50	96.46	81.46
M4S3	1.82	2.25	40.50	37.25	24.50	19.50	94.10	79.10
M4S4	1.94	2.54	38.75	35.75	22.0	19.50	94.03	78.78
M4S5	2.51	3.08	47.25	42.75	25.0	15.00	95.80	80.80
M5S1	1.93	2.74	32.25	38.25	16.50	11.00	95.02	80.02
M5S2	2.18	3.42	29.25	29.75	17.50	12.00	96.54	81.35
M5S3	1.71	3.08	31.50	33.25	14.50	13.00	97.51	82.51
M5S4	1.61	3.01	18.25	29.50	14.00	11.50	97.54	82.89
M5S5	2.24	3.31	32.75	41.50	21.50	13.50	97.56	82.56
M6S1	1.56	2.08	34.25	41.00	15.00	17.00	95.96	80.96
M6S2	2.02	2.77	44.25	42.25	30.00	26.00	97.52	82.42
M6S3	1.75	2.01	35.75	38.50	18.50	20.0	96.78	81.78
M6S4	2.29	2.09	38.00	40.75	33.00	19.50	97.08	81.41
M6S5	2.17	2.91	44.75	46.00	33.50	22.00	97.82	82.81

Physiological parameters like total chlorophyll content, soluble protein, nitrate reductase activity and relative water content had significant effect on the off-season flower induction and fruit set. The C: N ratio was also the highest during the May sown and spraying with the nitrobenzene 0.5%.

In another experiment which involved pruning the trees during varying months i.e., May (M_2), June (M_3), July (M_4) and September (M_1) along with the application of chemicals i.e. potassium nitrate 0.5% (S_2) salicylic acid 0.1% (S_3), calcium chloride 0.5% (S_4) and nitrobenzene 0.5% (S_5) no spray is also taken up (S_1).

One year old trees could be chosen to do the pruning, where the trees all selected to be healthy and the heading back to a height of 2 feet from the ground level is done and the tree is manured with FYM - 10 kg / tree along with 100 g area 100 g super phosphate and 50 g of muriate of potash is given per tree and irrigated. The sprouting of the stem takes place within 10 days and in a months time the branches will develop and there branches are pinched in such a way that the umberalla formation is made and again this is sprayed with the following chemicals i.e. 0.5% potassium nitrate 0.1% salicylic acid, 0.5% calcium chloride and 0.5% nitrobenzene. This is repeated again after 15 days after the first spray.

In this the July pruned trees along with application of potassium nitrate 0.5% recorded highest number of panicles per tree, number of flowers per panicle and total number of pods per tree, pod weight and pod yield per tree.

Table 3. Effect of staggered pruning along with chemical application for off-season production in moringa PKM 1

M / S	Plant height at harvest (m)	No. of flow. Panl./tree	No. of flow./pani.	Pods set %	No. of pods /tree	Pod length (cm)	Pod girth (cm)	Pod weight (g)	Est. pod yield t/ha	BC ratio
M1S1	1.85	44.16	19.33	2.20	17.66	48.66	1.33	75.83	2.67	1.92
M1S2	1.74	62.5	22.33	1.09	25.49	57.83	1.45	78.33	3.14	2.18
M1S3	1.93	79.13	21.49	1.68	28.30	53.0	1.33	76.66	3.50	2.46
M1S4	1.74	70.83	18.49	1.53	19.99	50.0	1.28	63.33	2.00	1.38
M1S5	2.09	54.99	15.33	2.78	23.33	60.8	1.36	75.83	2.72	1.89
M2S1	1.73	63.33	20.80	1.66	20.50	52.0	1.46	77.50	2.52	1.78
M2S2	1.80	112.49	20.33	2.53	58.96	60.83	1.38	84.16	7.52	5.14
M2S3	1.89	52.49	18.96	**2.98**	29.66	58.83	1.48	86.66	3.52	2.43
M2S4	1.95	60.83	20.00	2.17	25.33	61.33	1.43	79.16	3.04	2.05
M2S5	1.83	112.5	24.16	1.55	45.99	59.83	1.40	75.0	5.44	3.71
M3S1	4.98	197.5	18.69	0.62	53.33	51.16	1.44	73.33	2.89	2.04
M3S2	4.75	224.99	26.30	1.63	82.66	56.66	1.44	61.66	12.83	8.77
M3S3	4.39	172.49	26.60	1.05	47.16	57.83	1.53	78.33	6.04	4.17
M3S4	4.04	194.16	21.30	1.02	44.98	50.99	1.48	75.83	5.42	3.66
M3S5	4.34	206.66	28.66	2.18	105.83	58.49	**1.58**	84.16	15.79	10.77
M4S1	**5.69**	132.49	25.30	2.60	62.16	61.33	1.43	85.83	8.48	5.99
M4S2	4.56	**258.53**	**47.60**	1.38	**159.99**	57.30	1.46	83.33	**21.47**	**14.67**
M4S3	4.88	244.99	36.00	1.70	81.99	60.49	1.53	**97.49**	13.20	9.12
M4S4	5.36	178.33	16.69	2.81	94.66	45.99	1.43	61.66	9.37	6.33
M4S5	4.69	**260.83**	29.00	2.02	129.16	**65.50**	1.50	80.00	**16.29**	11.11

In both the experiments the staggered sowing and pruning has different approach i.e. in sowing of seed which would involve the initial growth to the maturity where as in pruning the tree is already matured and only branches needs to be grown and initiate flowers. So there is difference in sowing month and pruning month. The environmental condition that prevails during vegetative stage and a gradual shift in the climate would have necessitated the floral induction which is prerequisite for onset of early flowering. The chemical spray would induce flower initiation by bud formation and onset of flowering. Similarly the interaction effect could accumulate sufficient carbohydrates and synthesized protein during early stages for production of higher number of flowers. The translocation of assimilates into the sink including elevating nitrogen level synchronizing

bud break from apices with existing floral stimulus. The flowering induces the pod set and number of pods per panicle and number of pods / tree and pod weight there by increasing the yield attributes. This could induce the off-season production of moringa during November to February. This fetches good price in the market. The rainfall if coincides with flowering could induce dropping of flowers but later dates after flowering will not affect the pod set and pod yield.

Since the prices of the pods are high the cost of benefit ratio could be as high as 1:7:5 which means the farmers would have higher net returns.

10. MAJOR INSECT PESTS OF MORINGA AND THEIR MANAGEMENT

The most serious pests of moringa were leaf feeders, Noorda blitealis Walk., hairy caterpillars, *viz.*, *Eupterote mollifera* Walk., *Metanastria hyrtaca* C., *Pericallia ricini*, (Fab.), *Taragama siva* (Lef.), leaf weevil, *Myllocerus* spp., flower feeders, Noorda moringae Tams., bud midge, *Stictodiplosis* moringae Mani., fruit fly, *Gitona distigma* Meigen, bark caterpillars, *Indarbela tetraonis* (Moore), stem borer, *Batocera rubus* L., aphid, *Aphis craccivora* Koch. and scale, *Ceroplastodes cajani* (Mask.), whitefly, *Trialeurodes rara* Singh.

10.1. Flower feeders

10.1.1. Bud worm: *Noorda moringae*

Damage : The Larva bores into flower buds and causes shedding to a large extent. *N. moringae* occured in South India which caused 78 per cent bud damage when the infestation was severe. Adults are small sized moths with dark brown forewings and white hind wings with dark brown border. Creamy oval eggs are laid in singly or in groups on buds. Fecundity is 248 eggs/female. The larva is dirty brown with a prominent mid dorsal stripe and black head. It pupates in soil or on the ground surface in earthern cocoon

10.1.2. Bud midge *Stictodiplosis moringae*

Damage: The larva feeds on the internal content of the flower buds causing shedding of buds in large numbers. Adult fly is free living , small and brown coloured . Female fly thrusts her eggs in clusters 5-80 on the anthers within the buds. It pupates in soil cocoon. Larval and pupal periods last for 6-9 and 5-9 days respectively.

Management

- Plough around trees to expose and kill pupae
- Collect and destroy damaged buds along with caterpillar
- Set up light trap @ 1/ha
- Spray insecticides like Carbaryl 50 WP@ 1gm/ lit or malathion 50 EC 2 ml/ lit of water

10.2. Leaf feeders

10.2.1. Leaf caterpillar: *Noorda blitealis*

Damage: The caterpillars build silken webs by joining the ventral side of the adjacent leaflets and remain inside the web on the leaves and make them papery. Severe infestation causes complete defoliation.

Females lay cream, oval eggs on leaves which hatch in 2-3 days. Larvae feed on leaflets in a thin silken web on the lower surface. So, the leaves appear papery and get dried. If left free, the whole tree is defoliated. Grown-up larvae pupate in the soil. Adults emerge in 6-9 days and life cycle continues. Severe infestation occurs on new flush of the crop during June-August which later recedes.

Management

- Plough around trees to expose and kill pupae.
- Collect and destroy silken webs and caterpillars in the initial stages of infestation.
- Set up light trap @ 1/ha
- Provision for sitting arrangement for birds above the height of the moringa crop in field enabling the birds to visit and prey them
- Spiders are found inhabiting in large numbers on new flush which exert natural control on the increasing population
- Spray insecticides like Carbaryl 50 WP@ 1gm/ lit or malathion 50 EC 2 ml/ lit of water or fenthion (0.05 %)

10.2.2. Hairy caterpillar: *Eupterote mollifera*

Damage: They are seen in groups in tree trunks feed gregariously and scrap the bark. It feeds on leaves voraciously causing sever defoliation.

The adult moth is large sized with uniform light yellowish brown colour. It lays eggs in groups on shoots and leaves. The newly hatched caterpillars are brownish and densely hairy. They are found in large numbers on the stem during day time. It pupates in the soil.

10.2.3. Hairy caterpillar, *Metanastira hyrtaca*

Damage: The hairy caterpillar feeds on leaves causing defoliation

The adult is stout grayish brown moth exhibiting sexual dimorphism. Male moth has pectinate antenna and chocolate brown patch in the middle of forewings. Female moth is bigger in size with longer and broader wings having wavy transverse bands. The larva is nocturnal cylindrical grayish brown , stout and hairy.

10.2.4. Hairy caterpillar, *Pericallia ricini*

Damage: The hairy caterpillar feeds on leaves causing defoliation

Management

- Collect and destroy egg masses and caterpillars
- Set up light trap @ 1 / ha to attract and kill adults immediately after rain
- Use burning torch to kill congregating larvae on the trunk
- Spray FORS @ 25 g/lit or endosulfan 35 EC @ 2ml/ lit or carbaryl 50 WP @ 2 g/lit

10.2.5. Ash weevils

Damage: The adult weevils cause notching of leaves. Grubs feeds on roots and causes wilting of plants

Management

- Collect and destroy the adult weevils
- Apply carbofuran 3 G at 15 kg/he at 15 days after planting

10.3. Sap feeders

10.3.1. Cotton Aphid : *Aphis gossypii*

Damage: Both nymphs and adults damage the tender shoots.

Management

- Release First instar larvae of Chrysoperla carnea @ 1,00, 0000 per hectare.
- Use methyl demeton or dimethoate 2ml/lit. All the pods should be removed before spraying

10.3.2. Scale, *Ceroplastodes cajani*

Damage: Both nymphs and adults suck the sap and affect the vigour of plants. Though each insects takes only a few drops of sap during its life time presence of enormous number of insects sucking the sap continuously at times, weakens trees and ultimately affects size of fruits.

10.4. Borers

10.4.1. Pod fly/Fruit fly : *Gitona distigma*

Symptoms of damage

The maggots of moringa fruit fly causes forthing and gummosis leads to drying of fruits from tip. In addition to drying it also causes splitting of fruits from tip. Oozing of gummy exudate from fruit

The adult fly is small, yellowish with red eyes. It lays eggs in grooves between the ridges of fruits. The newly hatched out maggot enters into the fruits and starts feeding on the internal content of fruits. The maggots pupates in the soil.

Management

- Collect and destroy all the fallen and damaged fruits

- Use attractants like citronella oil, eucalyptus oil, vinegar (Acetic acid), dextrose or lactic acid
- Set up fish meal trap to attract and kill them
- Rake up the soil under the trees or plough the infested field to destroy puparia
- After apply endosulfan 4% D @ 25 kg/ha
- Spray insecticides like Nimbecidine 3ml/lit during 50 % fruit set and 35 days later

10.4.2. Bark caterpillar: *Indarbela tetraonis*

Damage: It has a number of hosts plants including drumstick trees in south India has causes severe damage. Attack is more pronounced on neglected trees and at places where crop sanitation is poor. Eggs are laid in cuts or cracks in bark of trunk or main branches of tree. On hatching, caterpillars feed superficially below bark, making zig-zag galleries and later bore inside bark or main stem, remain within these burrows during day but come out at night and feed on bark.

The larva chews out the bark resulting zig-zag galleries and silken webbed masses comprising of chewed materials and excreta.

Adult moth is pale brown with forewings having brown spots and streaks and white hind wings. The larva is 40-45 mm long, stout and dirty brown in colour.

10.4.3. Stemborer : *Batocera rubus Linn.*

Damage: It is widely distributed all over the Indian sub-continent. Eggs are laid singly in cracks or crevices in the bark of the tree. On hatching, grubs make zig-zag burrow beneath the bark, feed on internal tissues, reach sapwood and cause death of affected branch or stem. Pupation takes place within these tunnels.

Adults come out and feed on the bark of young twigs and petioles. Grubs are stout, about 10 cm long, yellowish with well-defined segmentation. Adults are medium sized beetles and yellowish brown with

white spots on elytra. Eggs, grub and pupal periods last for 1-2, 24-28 and 12-24 weeks respectively. There is only one generation in a year.

Management

- Clean all webbed material and excreta
- Plug the holes with cotton wool soaked in fumigants like chloroform, formalin or petrol and seal it with mud.

10.5. Root feeders

10.5.1. White grub

Damage: The grub feeds on roots of moringa trees. The adults beetle feeds of leaves

The adult beetle is dark brown in colour measuring about 18-20 mm. It lays eggs in moist sandy soils 2.5-15 cm deep at 2-4 eggs in a hole. The grub is white C shaped feeds on the roots. It pupates in the soil. The pupae undergoes diapause and it continues up to the monsonic rains. The adults come out with monsoon during June- July

Management

- In March-April deep ploughing of fallow lands should be undertaken with a view to expose the immature state *i.e.* grubs and pupae of this pest for predation by the avian predators' *viz.* crow, mynahs. Besides grubs and pupae exposed during the ploughing should be collected and destroyed.
- Farmers should apply only well decomposed farmyard manure in fields. The partly decomposed FYM provides congenial conditions to survive the newly hatched grubs.
- Mechanical collection of beetles be done during the night by jerking the host trees, collecting the fallen beetles and killing them in kerosenized water. Cut branches of host trees like neem may be planted in the evening to attract the beetles for collection.
- Light trap be set up in endemic areas to collect the beetles with the onset of monsoon in June July coinciding with emergence of beetle and the trapped beetles be destroyed.

Moringa stem borer

Bark cater pillar

Adult

Bore hole damage

Moringa fruit fly

Moringa Ash weevils

Moringa budworm

Moringa leaf eating caterpiller

Hairy caterpillar

11. DISEASES OF MORINGA AND THEIR MANAGEMENT

Vegetables production in the context of Indian scenario with the burgeoning human population warrants sustainability. Being an integral part of human diet, it serves rich sources of vitamins, minerals, phytochemicals and antioxidants. In addition, it is valued for the much needed roughage in the diet. The cultivation of moringa, an annual as well a perennial vegetable, is rapidly expanding but with this rapid increase, there is a corresponding increase in disease retarding its potential growth. With the introduction of high yielding cultivars, adoption of modern production techniques such a high input agronomic practices, changes in cultural practices, free movement of planting materials and changes in weather conditions over the years have contributed to the disease problems, several of which have become major constraints in their successful cultivation resulting into both qualitative as well as quantitative losses. The diseases *viz.*, leaf spot, powdery mildew; fruit rot and root rot are caused by air and soil borne pathogens. The foliar diseases are caused by the fungi *Cercospora* spp, *Septoria lycopersici. Alternaria solani*, *Asperisporium moringae* and *Leveillula taurica* while the fruit rot is reported to be caused by *Drechslera hawaiiensis* (perfect stage:
Cochliobolus hawaiiensis). The root rot pathogen *Diplodia* sp and fruit wilt caused by *Fusarium oxysporum* f.sp. moringae has also been reported.

11.1. Leaf Spots

Brown leaf spot

Symptom: The symptoms appear as scattered brown spots appear on the leaves and then spread to cover them entirely. Coalescing of spots leads to irregular and blighted appearance of the leaves. The leaves turn yellow and fall off prematurely.

Pathogen: *Cercospora* spp is responsible for the disease. The fungus is characterized by dark brown stromata form which arise fasciculate straight or slightly curved, continuous simple, yellowish brown conidiophores producing polymorphous cylindrical, fusoid, 1 -3 septate, yellow to brown conidia tapering towards the apex.

Mode of spread: Conidia are disseminated by wind and rain splashes to the leaf surface where they germinate and cause infection. The spots are produced on the leaves on which conidia are formed serving as source of secondary infection. When the weather becomes unfavorable the fungus survives in the infected plant debris and the cycle is repeated next year.

Epidemology: Disease development is favoured by high humidity and temperature. The pathogens sporulate abundantly at 20 to30ºC.

Management: Foliar sprays of Carbendazim, Difolatan, mancozeb, maneb, zineb, metiram have been reported effective for the control of the disease.

11.2. Septoria leaf spot

Symptom: Circular spots with whitish grey centre and dark brown margins are seen on the leaves, stem and calyx. Centre of the spots shows minute black glistening pin head sized pycinida. Severe infection causes defoliation during rainy season.

Pathogen: The disease is incited *Septoria lycopersici*. The young mycelium is hyaline thin walled and sparingly septate. Older mycelium is brown infrequently branched and septate. In the initial stage of pycinial formation several hyphae aggregate at certain point and after intertwining, form a mass of hyphal tissues that assumes the appearance of pseudoparenchyma. Pycinida are subglobose composed of 2 - 3 layers of brown cells. Pyciniospores are filiform slightly curved hyaline and septate with pointed or rounded ends.

Mode of spread: The pathogen overwinters in the infected plant debris in the form of mycelium or spores or in the debris of solanaceous weed hosts. The conidia are splashed by rains causing infection.

Epidemology: The fungus has wide host range including solanaceous crops and weeds growing in and around moringa field. Temperature of 20 to 25ºC with 75 to 92 % relative humidity is congenial for disease development.

Management: Spray applications of various fungicides such as benomyl, carbendazim, mancozeb, copper oxychloride, folpet, metiram, captafol is found to be effective against the disease.

11.3. Alternaria leaf spot

Symptom: The symptoms appear on leaves as circular to angular, dark-brown spots with concentric circles. The spots coalesce and cause drying and defoliation of leaves. Black or brown marks appear on the branches.

Pathogen: *Alternaria solani*. The mycelium is septate, branched light brown hyphae which become darker with age.Conidiophores emerge through the stomata from the dead centers of the spot. Conidia are beaked, muriform dark and borne singly or in chains of two. Five to ten transverse septa and a few longitudinal septa are present in the each conidia.

Mode of spread: Primary infection takes place through conidia on crop debris in the soil. The secondary spread of the disease occurs through conidia developed on primary spots. These conidia are blown by wind, water and insects to the neighboring leaves or plants

Epidemology: The disease is favoured by high soil moisture, relative humidity, dew and rainfall. The optimum temperature ranges between 28º to30ºC.

Management: The onset of the disease is hard to detect. Once the spots have appeared it is often too late to treat and defoliation is inevitable. Clearing of weeds which are often hosts to diseases should be practiced. Leaves and young shoots should be checked regularly for symptoms of fungal attacks. Neem seed extract can be sprayed on the plants to control the disease. Spraying with fungicides like mancozeb, maneb, zineb, metiram have been reported effective for the control of leaf spots.

11.4. Powdery Mildew

Symptom: The symptoms appear as white to light grey powdery growth on the under surface of the leaves and the corresponding upper surface exhibits yellow lesions with brown necrotic centres. Affected leaves curl upwards and shed profusely. Affected plants lose their vigour and remain barren. Yield is very much reduced.

Pathogen: The fungus *Leveillula taurica* is responsible for this disease. It is an obligate parasite having endophytic mycelium. Conidiophore are long and multibranched. Conidia are pyriform and cylindrical, borne singly or in short chains.

Epidemology: Temperatures of 25 to30ºC and cloudy weather are highly favourable for the disease development

Management: Spraying wettable sulphur 0.2 per cent at gives better control

11.5. Root Rot

***Diplodia* root rot**

Symptom: The symptoms of the disease appear as oozing of gum from the affected bark which remains as an encrustation on the bark. Droplets of gum trickles down the stem. In the later stages the bark cracks and shreds longitudinally. Leaves turn pale and yellow. Fruit yield is greatly reduced.

Pahtogen: The fungus inciting the disease is *Diplodia* spp.

Mode of spread: The pathogen spreads through pycnidiospores with the help of wind and rain splashes

Epidemiology: Reduced tree vigour, insect damage, poor nutrition to the trees, water logging and old age factors.

Management: The trees should be kept in a vigorous growing condition. Broken limbs should be cut properly and wound in the bark especially on limbs and forks should be scraped and protected with Bordeaux mixture.

Spraying of carbendazim or thiophanate methyl or chlorothalonil gives effective control

11.6. Fusarium Wilt

Symptom: The affected plants exhibit yellowing of lower leaves in initial stages and discolouration of younger leaves soon follows. The leaves drop, wilt and dry. The disease affects a few branches in a plant or the entire plant may wilt irreversibly. The affected plants or branches dry up. The vascular bundles become brown. Plants are usually stunted in growth and fruits ripen prematurely.

Pathogen: The inciting agent of the disease is *Fusarium oxysporum* f. sp. Moringae. The mycelium is sepate. Microconidia, Macroconidia and Chlamydospores are produced.

Mode of spread: The fungus is soil-borne and survives in the soil as chlomydospores or as saprophytically growing mycelium in infected crops debris. Wind-borne spores, surface drainage water and agricultural implements also help in distribution of the pathogen from field to field.

Epidemiology: Disease development is favoured by alternating high and low soil temperatures and high humidity levels. Other favourable factors include light sandy soils, low soil moisture level and pH. The presence of nematodes greatly increase infection.

Management: Seeds should be planted in disease and nematode free soil. Seed treatment with Carbendazim 2 g/kg reduces incidence of the disease. The infected plants should be removed and destroyed. Long crop rotation with non host crops helps in reduction of the inoculum. Incidence of wilt has been significantly reduced with the application of carbendazim, benomyl as oil drench.

11.7. Fruit Rot

Symptom: Pods reaching maturity showed extensive rot. The disease symptoms are observed all over the surface of the pods, more

conspicuously at the stigmatic end. On green pods, elliptical or elongated sunken spots with reddish brown raised margins can be observed. The pods appear shrunken with thinner dimensions at their stigmatic ends, than healthy ones. In advanced stages of the disease, the pods rot and dried up pre-maturely leaving uneven raised spots over them.

Mode of spread: The causal organism was identified as a fungus *Drechslera hawaiiensis*.

Management: Spraying with chlorothalonil, iprodione and maneb were found effective.

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12. ORGANIC PRODUCTION PROTOCOL FOR MORINGA

Organic agriculture started a century ago in European countries. Though it was neglected initially, the importance of organic agriculture has been felt in the lasts two decades. The hazardous effects of the chemical fertilizers on human and environment has created awareness among the farming community in switching over to the organic production practices. Also use of organic fertilizers would also reduce the depletion to natural resources. Organic production excludes the use of synthetic pesticides and fertilizers used in the cultivation of crops.

Organic farming systems rely upon crop rotations, crop residues, animal manures, legumes, green manures, off-farm organic wastes, mechanical cultivation, mineral-bearing rock powders and biological pest control. These components maintain soil productivity and tilth, supply plant nutrients and help to control insects, weeds and other pests. (Selvarajan *et al.*, 2005).

Among the vegetable crops, moringa can fit very well as a candidate crop for organic cultivation. Drumstick (*Moringa oleifera*) is an important perennial multipurpose vegetable grown widely in India. Popularly known as 'Ganigana', 'Mullakkai' 'Murrugi', 'Sahjan' and 'Muringa' its tender leaves and immature or half-mature fruits are eaten. It is a delicacy in the south Indian households. It is most popular for its distinct, appealing flavouring fruits. The flower buds are also used for culinary purposes. Besides, it has medicinal value also. India is the largest producer of this nutritionally rich, fast growing, drought tolerant, hardy crop capable of getting adapted to varied ecosystems.

12.1. Organic cultivation practices

12.1.1. Farmyard manure

Farmyard manure is applied as basal dressing by broadcast and immediately incorporated into the soil by ploughing. It contains 0.6% nitrogen, 0.35% phosphorus and 0.6% potash in general. It takes a long time for decomposition nearly a year. For cultivation of almost all the vegetable crops, farmyard manure is applied during field preparation, planting and thereafter annually to basins.

For moringa planting, pits of 45cm × 45cm × 45cm size are dug at 2.5m × 2.5m spacing one week before planting. The farmyard manure @ 15kg/pit is applied. A 60cm circular irrigation basin is made around the pit and the pits are closed. Farm yard manure 75kg/plant can be given to 1-year-old plants and above during June in trenches 1m away from plants.

12.1.2. Biofertilizers

Biofertilizers are carrier based preparations, containing beneficial micro organisms in a viable state intended for seed or soil application and designed to improve soil fertility and help plant growth by increasing the number and biological activity of desired microorganisms in the root environment. They are supplement to chemical fertilizers and comparatively cheap. Biofertilizers are otherwise called as 'Microbial inoculants'.

Use of biofertilizers is another practice of organic production. *Azospirillum* is a popular biofertilizer used in crop production. *Azospirillum* is a micro-aerophilic, associative bacteria, capable of fixing nitrogen in the presence of diffused levels of atmospheric oxygen. The bacterium develops capsules (otherwise being vibrioid), which impart an adhesive nature and reduced motion by adaptation for rhizosphere life (Berg *et al.,* 1980). *Azospirillum* can be applied as seed treatment, soil application or seedling dip. Treatment of moringa seeds with *Azospirillum* cultures at the rate of 100 g per 625 g of seeds before sowing resulted in early germination, and increased seedling vigour, growth and yield.

Phosphobacteria are some freeliving bacterial in soil that possesses the ability to bring insoluble phosphates in soil into soluble forms by secreting organic acids. The phosphobacteria are also known to mineralize the organic phosphates through enzymatic actions. Pre-treatment of moringa seeds with phosphobacteria has been reported to help in reducing phosphate fertilizer requirements of the crops and increasing the yield.

12.1.3. Vermicompost

Vermicompost is the organic fertilizer prepared from the excrements of earthworms which is rich in organic carbon content (47%) and humus substances which help in building the soil structure and stimulating plant growth particularly that of roots. It can be applied to moringa along with biofertilizers and other organic manures.

An investigation was carried out to study the performance of annual drumstick (cv. PKM-1) under organic culture for three consecutive years from July 2003 on red sandy loam soil of Indian Institute of Horticultural Research, Bangalore. Five organic nutrient treatments and one conventional nutrient supply as check were compared. The crop was raised with protective irrigation and warranted plant protection measures were adopted using biopesticides. The results showed that the crop performance with respect to tree growth, yield and yield components were significantly influenced by organic treatments tested. Tree trunk diameter was higher with farm yard manure (FYM) applied at 15 kg/tree or with vermi compost applied at 5 kg/tree along with biofertilizers (Azospirillum and phosphate solubilizing bacteria) at 5 kg/hectare as compared to other organic treatments such as green leaf manuring combinations or reduced FYM application rates. Similar trend was noticed with respect to fresh pod yields which was higher (9.7 t/ha /year) with treatments receiving higher dose of FYM followed by green leaf manuring supplemented with rock phosphate and wood ash (8.5 t/ha/year). These yields were on par with conventional treatment receiving recommended dose of chemical fertilizers and manures (8.6 t/ha/year). The higher yields were mainly due to higher number of

pods produced per tree rather than fruit size. It can be concluded that organic drumstick production is feasible and is sustainable economically as well as socially in the present context of reducing pollution of natural resources and cost of farm production (Prabhakar and Hebbar, 2007).

12.1.4. Mulching

Mulching is a field practice to conserve the soil moisture and to control the weeds. Crop residues like straw, cotton stalks, leaves, saw dust, pine needles and coir dust can be applied in tree basins and in interspaces between trees. Mulching adds humus to the soil, keeps soil cool in day and warm at night hours.

Moringa trees are generally grown successfully without fertilizers. In Kerala (Southern India), ring trenches are dug about 10 cm from trees during the rainy season and filled with green leaves, manure and ash, and then covered with soil. This is said to promote higher fruit yields (Ramachandran *et al.*, 1980).

12.1.5. Panchagavya

Panchagavya is an organic preparation made from the following ingredients.

Cow dung	-	7 kg
Cow urine	-	10 litres
Water	-	10 litres

These ingredients are mixed and kept separately in mud pots. After 15 days, the following ingredients are added.

Cow milk	-	3 litres
Cow curd	-	2 litres
Cow ghee	-	1 litre
Tender coconut water	-	3 litres
Jaggery	-	3 kg
Banana	-	12 nos.

The ingredients are mixed thoroughly both in the morning and evening

and within twenty-five days the panchakaviyam is ready for spray. 3% solution (3 ml in 100 ml) is generally recommended for spraying at monthly intervals to crop plants. Panchagavya is known to contain the effective micro-organisms which inturn is found to increase the yield and resistance to pests and diseases in crop plants.

Beaulah (2001) reported the integrated nutrient management in annual moringa encompassing organic manures, bio-fertilizers and varying levels of N, P and K. The results obtained a positive response from moringa to the application of manures and fertilizers. Initial vigour was higher in treatment with poultry manure (500 g / pit) + Neem cake (250g/pit)+ panchakavya (2%) spray along with 150:150:100g NPK/tree. In ratoon crops, similarly, the same treatment resulted in early and vigorous growth confirming the superiority of integrated nutrient management in moringa. Higher nutrient uptake and more nutrient use efficiency in both main and ratoon crops of annual Moringa were also observed. Similarly, the quality paratmeters *viz.*, crude fibre, protein, ascorbic acid, carotene content and shelf life in annual Moringa were also higher under organic manure applied with panchagavya as spray (Beaulah *et al.,* 2002).

12.2. Organic plant protection practices

Developing fruit are damaged by the fruit fly *Gitona distigmata* which can be effectively managed by adopting integrated pest management (IPM) measures. The package includes (i) Application of Fenthion 80 EC 0.04 per cent during the vegetative and flowering stage. (ii) Application of Nimbecidine 0.03 per cent at 150 ppm during 50 per cent fruit set and 35 days after (iii) soil application of Neem seed kernel extract (NSKE) @ 2 lit per tree at 50 per cent fruit set and (iv) weekly removal of affected fruit (Anjaneya *et al.,* 1992; Ragumoorthi *et al.,* 1998; Sivagami *et al.,* 1965).

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13. POSTHARVEST MANAGEMENT IN MORINGA

13.1. Harvesting

The moringa tree has a compound leaf: one leaf is made up of multiple leaflets. What is referred to here as a leaf is precisely multiple leaflets attached to the rachis which stems from the branch.

Manual harvesting of shoots and leaves with a pair of shears, a sickle or a sharp knife is recommended. All shoots should be cut at the desired height, *i.e.* 30 cm to 1 m above ground. Mechanical harvesters could also be used for large-scale, intensive leaf production.

Harvesting can also be done by removing the leaves, picking them directly off the tree. They are easily removed at the base of the petiole. It is quicker to harvest this way but the trees will not have benefited from a good pruning and the following growth is therefore less vigorous.

A high level of hygiene should be maintained. Produce should be harvested at the coolest time of the day: early morning or late in the evening. It is important to make sure there is no dew on the produce before harvesting, especially in the morning, to avoid rot during transport.

13.1.1. Harvesting of fresh vegetables

Perennial types raised by cuttings take nearly a year to bear fruit. The yield will generally be low (80-90fruit/year) in the first two years of fruit-bearing. This gradually increases to 500-600 fruit/tree/ year in the fourth and fifth years. The pods are harvested mainly between March and June. A second crop is normally harvested from September to October.

Annual moringa types are seasonal in terms of fruit- bearing and the crop sown during September comes to harvest within six months. Fruit of sufficient length and girth are harvested before they develop fibre. The

harvest period extends for 2-3 months and each tree bears 250-400 fruit depending on the type.

Harvest pods when they are young, tender, and green. They are eaten as green beans. Older pods are fibrous and develop a tough shell, but their pulp and immature seeds remain edible until shortly before the ripening process begins. Immature seeds can be used in recipes similar to green peas. Fresh or dried flowers are used for making teas.

13.1.2. Harvesting of seeds

In seed farms, pods should be harvested as early as possible when they reach maturity,i.e. when they turn brown and dry. Fruits should open easily. Seeds are extracted, bagged, and stored in a dry place. Moringa branches break easily; it is not recommended to climb up the tree to harvest the fruits.

13.2. Cooling methods

Leaves are washed in fungicide (Benlate 500 ppm) prior to storage. The cooling method adopted is hydrocooling and the storage method is cold storage.

13.3. Packaging and storage

Packaging methods to prolong the shelf life of moringa cv.PKM 1 during transit were studied by Damodaran *et al.*, 1999. The physiological loss in weight (PLW) of 77.94% was recorded in fruits packed in wooden boxes with dried grass as filling material after 12 days. The lowest PLW 24.24% was recorded in fruits packed in polythene bags followed by Corrugated Fibre Board boxes with coir waste as filling material (27.20%). The highest carotene (182.02mg/100g) and ascorbic acid (128.17 mg/100g) contents were found in fruits packed in polythene bags.

Product	Method of		Shelf life
	Packing	Storage	
Moringa - PKM 1	Polyurethane	Improvised evapo cooling chamber	15 days
Moringa Jaffna	Polyurethane	Improvised evapo cooling chamber	14 days
Moringa Kodical	Polyurethane	Improvised evapo cooling chamber	11 days

13.4. Seed production, processing and storage

Harvesting of brown coloured moringa fruits at 20 days after anthesis led to recovery of good quality seeds with high germination potential from the proximal and middle portion of the fruit compared to the distal portion. Black followed by brown coloured seeds were superior with higher seedling quality attributes--i.e. germination and vigour index--than white seeds. Harvested pods must be dried for one or two days under shade with good ventilation. The seeds are extracted manually by opening the pods using gentle pressure on them. On opening, the seeds are separated freely. Small, shriveled and damaged seeds are removed.

Grading is carried out with the specific gravity separator. The fraction from 2 and 3 gives higher seedling emergence and vigour. Seed treatment with Azospirillum @ 100g /625g seeds is found to increase the seedling weight and vigour. The optimum temperature range is 20-25ºC. For seed testing, sowing seeds at a depth of 1cm in a sandy medium with 80 per cent moisture-retaining capacity represents the ideal conditions.

Annual moringa seeds can be stored for up to 12 months, when freshly harvested seeds are dried to 8 % moisture content and treated with captan @ 2g/kg of seeds and packed in 700 gauge polythene bags (Palanisamy *et al;* 1995). The black and brown seeds treated with carbendazim 2g/kg of seeds and stored in 700 gauge polythene bags maintained more than 84% germination up to 12 months (Sivasubramanian *et al.,* 1997).

13.5. Value-added processing

Advantages of value addition

- Prevention of colossal wastage of fresh produce
- To extend the shelf life of the produce
- Self employment opportunities
- Provides convenient and preferable forms to the consumers
- Foreign exchange earnings from the export of processed foods

A number of value-added products can be prepared if its availability is in excess. They are moringa pickle, dehydrated moringa, moringa powder and moringa flesh mesocarp powder

If a market is available, leaves and flowers may be dried for use as food additives and tea. Oil may also add value to a small family farm if extraction can be optimized and if it were marketed to high-end venues as a locally produced alternative to imported olive oil. Local and Internet sales of oil for cosmetic use may also add value. The oil has long been valued as cosmetic oil because of its extraordinarily long shelf life and its ability to hold the scent of added fragrances. Infusions of moringa oil with essential oils (jasmine, lavender, etc) may therefore also enhance value.

Fresh moringa products are generally consumed within 2 days of harvest and oftentimes within a day. Leaves are particularly perishable and should be stored under cool temperatures and high humidity to avoid excessive wilting and leaflet abscission. This is most often done by bagging in plastic and refrigerating at approximately 10°C (50°F). Fruit may be canned to preserve it for later consumption.

Leaves and flowers may be dried in the shade or dehydrated and then pounded or ground and used as a food additive to improve protein content of foods. Leaves and flowers are also used for tea.

An example of a commercial health food drink (ZZ contains 30 g (11 oz) of moringa leaf, seed, and pod. This is reportedly the first commercially available drink formulated from moringa. Retailing such a commercial product to the average consumer may be challenging because of high costs. However, local, prepared drink and tea products may offer value-added opportunity for sale at farmers markets or health food stores.

13.6. Harvesting, processing and transportation of leaves

1. Removing leaflets from branches after harvest.
2. Leaflets prepared for transport on racks.

13.6.1. Transportation

Transportation in moringa leaf production is a very critical step in ensuring high quality leaves for consumption.

Two options:

- Cut big branches and transport whole to the processing centre if nearby, before defoliating (stripping or removing the leaves from the branch)
- Strip the leaves off the branches before transporting them to the processing centre
- Leaves can be tied together in bunches by their stem or better, thinly spread out on trays or mesh to reduce temperature build up. Freshly harvested material should be transported to the processing centre as quickly as possible to avoid deterioration

Fresh moringa leaves, transported loosely, should be well ventilated. For shorter distances aerated baskets or perforated plastic containers should be used to transport the fresh leaves. Avoid open vehicles. Under no circumstances should people or goods be placed on top of leaves. Transportation should be during the cooler parts of the day: early morning, evening or night. Leaves being transported over long distances should be in air-conditioned or refrigerated vans to keep them cool until delivery at the processing centre.

13.6.2. Processing the leaves

Processing should start immediately after harvesting and transporting the leaves to the processing point.

13.6.2. 1. Stripping the leaflets

Strip all the leaflets from the leaf petiole. This can be done directly from the branches if the leaves have not been stripped off the main branch before transportation. At this stage, diseased and damaged leaves are discarded.

13.6.2.2. Washing

Wash leaflets in troughs using clean potable water to remove dirt. Wash leaves again in 1% saline solution for 3-5 minutes to remove microbes. Finally wash again in clean water. Leaves are now ready for drying. Drain each trough after each wash: fresh leaves must always be washed with fresh water.

13.6.2.3. Draining

Strain water from the leaves in buckets that have been perforated, spread leaflets on trays made with food-grade mesh and leave to drain for 15 minutes before taking them to the dryer.

13.6.2.4. Drying

There are three main methods for drying moringa leaves.

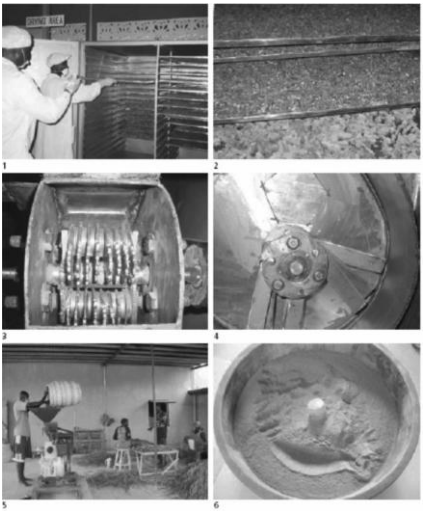
Room drying

Spread the leaflets thinly on mesh tied on racks (mosquito net mesh can be used) in a well-ventilated room. This room should be insect, rodent and dust proof. Air circulation can be improved by using ceiling and floor level vents protected with a clean filter to keep the sun and dust out. It is possible to use a fan, but the air must not be directly oriented towards the leaves, as it can increase contamination with germs in the air. It is advisable to turn the leaves over at least once, with sterile gloves, to improve uniform drying. Leaves should be completely dry within a maximum of 4 days. The loading density should not exceed 1 kg/m^2. However, room-dried leaves cannot be guaranteed mould-free with the maximum recommended moisture content of 10%. Therefore, we do not advise this method.

Solar drying

The solar dryer presented in the pictures is recommended but the polyethylene used should be UV treated or opaque (if the plastic is black, beware of temperature increases and be sure it does not go above 55ºC). The air intake should be filtered to keep out dust. Organza or muslin cloth can be used as a filter.

Solar drier



Spread the leaves thinly on mesh and dry in the dryer for about 4 hours (Temperature range is 35ºC-55ºC on a very sunny day). The final product should be very brittle. We recommend solar drying for both small and large scale processing, particularly for those in rural communities where there is no electricity. Loading density should not exceed 2 kg/m^2.

Mechanical drying

Use electric or gas hot-air dryers. Drying temperatures should range between 50ºC and 55ºC. If temperature exceeds 55ºC, leaves will "burn" and turn brown. Leaves should be dried until their moisture content is below 10%. We recommend this method for large scale leaf processing as

this ensures year round production. Loading density should not exceed 2.5 kg/m^2.

13.6.2.5. Milling

Mill dry leaves using a stainless steel hammer mill. For personal or household use, leaves can be pounded in a mortar, or milled with a kitchen blender. Small-scale processors can use a burr mill or rent a commercial hammer mill for routine milling of their products.

13.6.2.6. Sieving

Sieve the leaf powder if needed. When you mill with a hammer mill, the fineness of the product will depend on the size of the screen used in milling. If too coarse, sift using a sifter with the desired screen size.

Recommended particle sizes are:

- Coarse (1.0 mm - 1.5 mm)
- Fine (0.5 mm - 1.0 mm)
- Very fine (0.2 mm - 0.5 mm)

13.6.2.7. Drying the leaf powder

Moringa leaf powder strongly attracts moisture and the product can reabsorb humidity during or after milling. For this reason, moringa leaf powder should be dried at 50ºc for 30 minutes to reduce moisture content considerably below 7.5%.

13.7. Packaging and storage

Moringa leaf powder can easily be contaminated by moulds as it strongly attracts moisture. In addition finely milled powder makes it easier for bacteria to penetrate the particles.

13.7.1. Personal hygiene

All persons involved in the packaging of moringa leaf products must ensure that, while on duty, personal cleanliness and hygiene are maintained.

Personal protective equipment (PPE) such as head caps, nose masks, disposable gloves, etc. must be used at all times.

13.7.2. Packaging in bulk

The temperature and humidity must be controlled in the packaging room, to avoid rehumidification of the product.

After drying, the powder is left to cool and packed into clean, single-use polythene bags and sealed. This is enclosed in a second polythene bag and heat-sealed. This is to maintain freshness and dryness prior to further use. The bags should be stored in a cool, dry place.

13.7.3. Final packaging

The temperature and humidity must be controlled in the packaging room, to avoid rehumidification of the product. Moringa leaf products should be packaged in clean, dry and opaque containers made of materials that do not affect the quality of the product. Each package must be properly sealed to prevent content leakage as well as moisture absorption.

13.7.4. Labelling

Each package of moringa leaf product must be legibly marked with the following information:

a) Name of product
b) Net content
c) Name and address of producer
d) Country of origin
e) Lot / batch identification number or code
f) Instructions for use
g) Production date
h) Nutritional information (optional)

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14. SEED PRODUCTION STRATEGIES FOR ANNUAL MORINGA

Annual moringa is mainly propagated through seeds. Good seed alone contribute for increased yield to the extent of 10-12%. Only seeds with assured quality (true to type, high germination percentage, high purity, sound health etc.,) can be expected to respond to fertilizers and other inputs in the expected manner.

Among the inputs used by farmers, seed is the cheapest. It is a basic input and forms only a small part of the total cultivation expenses. Yet, without good seed the investment on fertilizers, water, pesticides and other inputs will not pay the required dividends. Seed production is a specialized job and needs more attention to maintain the genetic purity of a variety. In annual moringa, off types such as distribution of pink pigmentation over the stem and pods, late and luxuriant vegetative plants, short and prefaced shape pods exist.

Hence the seed production strategies for annual moringa is important to produce good quality seeds with high standards to ensure uniform crop with high enhance the crop yield.

14.1. Climate and soil

It comes up well in a wide range of soil. A deep sandy loam soil with a pH of 6.5-8.0 is optimum. Highest seedling vigour was noticed in red soil compared to black loam, loamy or sandy soils. It is a tropical plant and grows well in the plains. However, it is found growing in the subtropical climate also. It is predominantly a crop of dry and arid tract. The optimum temperature for better growth is 25 to 35ºC. It is highly susceptible to frost and high temperature exceeding 40ºC causes flower shedding.

14.2. Sowing season

July - October sowing is preferable. The flowering period should not coincide with rainy season. Dry hot weather during flowering is preferable.

Isolation requirement : A distance of at least 500 m is necessary for seed production.

Seed rate : A seed rate of 500 - 600 g / ha is required

14.3. Pre-sowing seed treatment

Seeds treated with azospirillum culture at the rate of 67 g /kg of seeds led to increase in seedling weight (Sivasubramanian, 1996).

14.4. Field preparation and sowing

Pit size of 45 x 45 x 45 cm with a spacing of application of 2.5 to 3 cm either way and 15 kg FYM/ compost is recommended. NPK nutrients with field soil and fill the pit @ 100 : 200: 50 g is applied per tree. N is applied in three split doses. Seeds are sown @ 2-3 per pit at a depth of 2.5-3 cm.

14.5. Nursery

The seeds can be either sown *in situ* in the prepared field or can be transplanted after raising the seedling in polybags. The polybags may be of the size of 15 cm length and 7 cm width. The seedlings will be ready for planting one month after sowing. An additional number of 75-100 plants are to be raised in poly bags for gap filling purpose.

14.6. After cultivation

Gap filling may be done within a month. Pinch off the main shoot when they are about 1.5 m in height to facilitate more branching shoots and two pinching any be done further, at 20 - 25 days interval. Tomato can be grown as inter crop to get more additional income in the early period. It also reduces the weed growth. Mounds are to be formed around the tree trunks upto a height of 30 - 40 cm from the ground level because the branches are liable to be damaged and break easily at the joints especially when fully loaded with fruits and during high wind.

14.7. Irrigation

The field should be irrigated once in a week up to three months and once in a ten days there after. Water stagnation should be avoided. There will be flower drop when the soil is too dry or too wet. Hence optimum moisture should be maintained.

14.8. Manures and fertilizers

Application of 100 g of urea, 100 g super phosphate 50 g murate of potash per pit should be given three month after sowing. Again 100 g of urea per pit at the time of flowering should be applied.

14.9. Foliar application

Flowering starts five - six month after sowing. Pod and seeds take three months to develop. During flowering, irrigation should be restricted to avoid flower dropping and liberal irrigation should be given during pod development. NAA @ 20 ppm followed by urea 2 kg, superphosphate 4 kg + 400 g micro nutrient mixture /ha is to be sprayed 3-4 times at 10 days interval. By this, 3 ratoon crops can be taken up without reduction in quality.

14.10. Weed management

Power tiller plouging is done for effective removal of weeds

14.11. Rouging

Based on the plant stem characters, during early stage, the rogues should be completely pulled out and gap may be filled. During pod development and maturity stages, based on pod character the rouging should be done, for example the pods with more than 70 cm and cylindrical shape alone should be harvested in case of PKM 1. Pods with tri-faced shape should be rejected.

14.12. Pest and disease management

The major pests are fruit fly, aphid and jassids which can be controlled by carboril spray @ 0.2% or any systemic insecticides. The disease like

root rot can be controller by root drenching with copper oxycloride @ 0.2%.

14.13. Maturity and harvesting

Seed propagated annual moringa flowers in about 100-110 days and the first harvest of fruits can be had between 160 - 180 days after sowing. Trees will continue to yield fruits for the next four months. The total duration of the crop from seed to seed ranges from 210 - 240 days.

Harvesting of black or brown coloured moringa fruits at 70 days after anthesis, led to recovery of quality seeds with high germination potential. Seeds of the middle and proximal portion of the fruit compared to distal portion are superior in quality. The hairline formation is the good index of harvestable maturity.

14.14. Ratooning

Ratoon crops can be taken for 3 years without reduction in quality (Siva Subramanian, 1996). As per the certification procedure, one ratooning can be allowed for certified seed production. However three or more ratooning can be practical for truthfully labeled seed production. For ratooning, cut the trees at a height of 90 cm and the same cultural operations for main crop is to be followed.

14.15. Yield

Annual moringa yields 200 - 250 fruits or pods per tree per year. 10-13 seeds may be present in one pod. So seed yield is 2000-3250 seeds per tree per year i.e. 600 g to 1 kg seed per tree. FYM 25 kg /tree for ratoon crop is recommended and the field should be irrigated immediately after ratooning.

14.16. Processing

After harvest the pods are dried under sun for 2 days and seeds extracted manually by splitting open the pods. The seeds are to be dried to the safest moisture level i.e. 8-10 %

14.17. Grading

Separation of small, illfilled and damaged seeds can be done by using 24/64" round perforated sieve. Upgrading of winged moving seed is achieved by using specific gravity separator with heavier and medium seed fractions registering higher emergency and seedling vigour.

14.18. Seed treatment and storage

Normally seeds are viable for one year. Bavistin treated seeds (2g/kg) stored in 700 gauge polyethylene bag stored longer than untreated seeds in cloth bag. Higher viability of stored moringa seeds can be achieved with a storage RH of 75% when the equilibrium moisture content of seed was 10% (Siva Subramanian, 1996).

14.19. Seed certification standards

Field standards

Factor	Maximum FS	Permitted (%) CS
Off-types	0.1	0.2
Plants affected by Seed borne pathogens	0.1	0.5

Standards for offtypes shall be met at and after flowering stage.

15. INDUSTRIAL APPLICATIONS OF MORINGA

Moringa oleifera Lam belonging to the family Moringaceae is a handsome softwood tree, native of India, occurring wild in the sub-Himalayan regions of Northern India, and now grown world-wide in the tropics and sub-tropics. In India, it is grown all over the subcontinent for its tender pods and also for its leaves and flowers. The pods of moringa are very popular vegetables and valued for its distinctly inviting flavour. This is a backyard tree for daily use in more than two million homesteads of South India. Ancient Indian literature makes mention of moringa as an interesting plant due to its widespread use in agriculture, medicine and industry Rajangam *et al.,* (2001).

15.1. Industrial uses of moringa

15.1.1 Moringa oil

The oil content of de-hulled seed (kernel) is approximately 42%. The oil is brilliant yellow. It is used as a lubricant for fine machinery such as timepieces because it has little tendency to deteriorate and become rancid and sticky (Ferrao and Ferrao, 1970; Ramachandran *et al.,* 1980).

It is also useful as a vegetable cooking oil. The oil is known for its capacity to absorb and retain volatile substances and is therefore valuable in the perfume industry for stabilising scents. The free fatty acid content varies from 0.5 to 3 %. The seed oil of Moringa contains approximately 13 % saturated fatty acids and 82 % unsaturated fatty acids. It has a particularly high level of oleic acid (70 %) Other vegetable oils normally contain only about 40 % oleic acid.

15.2. Water purification

Moringa seeds contain between 30-42 % oil and the press cake obtained

as a by-product of the oil extraction process contains a very high level of protein. Some of these proteins (approximately 1 %) are active cationic polyelectrolytes having molecular weights between 7-17 K Dalton. The cationic polyelectrolytes neutralize the colloids in muddy or dirty water, since the majority of these colloids have a negative electrical charge. This protein can therefore be used as a non-toxic natural polypeptide for sedimenting mineral particles and organics in the purification of drinking water, for cleaning vegetable oil, or for sedimenting fibers in the juice and beer industries (Foidl *et al* 2001).

It thus works as a primary coagulant as natural bridges are continuously formed between the colloid particles. In contrast, industrial coagulants such as alumina can be toxic. Their proper use requires qualified personnel and the majority of underdeveloped countries don't have the means of producing them. In addition, these industrial coagulants are expensive and represent a considerable drain on the hard currency reserves of developing countries.

The properties of the natural polypeptides produced from the seeds of Moringa have been known for many centuries in China. With the colonization of India by the British, this knowledge was effectively dispersed to the rest of the world. It has been employed with particular effectiveness in both Egypt and Sudan for cleaning water from the Nile specifically for human consumption. The wings are removed from the dry seeds and then the seeds are ground to powder. The powder is mixed with water, agitated for approximately five minutes and after about an hour it is filtered through a piece of woven fabric to obtain pure water.

Alternatively, a cloth containing the seed powder is suspended in water, generally overnight, to coagulate impurities. The cloth containing the seeds is then removed, and the purified water is decanted leaving behind the coagulated particles on the bottom. Up to 99 % of colloids can be removed. Only one seed is required per litre for slightly contaminated water and two seeds for very dirty water.

After oil extraction of *Moringa oleifera* seeds, the left press cake contains water soluble proteins that act as effective coagulants for water purification. One to two seeds per liter are required for water purification. Seed powders are mixed with water, after hours, the water is filtered to get purified water.

Recently, there is an increasing trend to evaluate some indigenous cheaper material for wastewater treatment. Since the conventional procedure of wastewater treatment has some disadvantages, such as incomplete metal removal, high cost and high energy requirements, biological materials have been recognized as cheap substitutes for wastewater treatment. Current studies report that Moringa seeds and pots are effective sorbets for removal of heavy metal and volatile organic compounds in the aqueous system (Akhtar *et al.,* 2006, Sharma *et al.*, 2006).

15.3. Moringa as a source of biogas

Moringa plants (approximately 30 days old) were milled together with water. The fibre was separated by filtration through a mesh with 5 mm pores and the liquid fraction produced was then added. With an average feed of 5.7 g of volatile solids the gas production was 580 liters of gas per 1 kg of volatile solids. The average methane content of the gas was 81 %.

15.4. Moringa for biodiesel

Moringa oleifera oil is evaluated for the first time as potential feedstock for biodiesel. After acid pre- treatment to reduce the acid value of the *M. oleifera* oil, biodiesel was obtained by a standard transesterification procedure with methanol and an alkali catalyst at 60ºC and alcohol/oil ratio of 6:1. *M. oleifera* oil has a high content of oleic acid (>70%) with saturated fatty acids comprising most of the remaining fatty acid profile. As a result, the methyl esters (biodiesel) obtained from this oil exhibit a high acetane number of approximately 67, one of the highest found for a biodiesel fuel.

Other fuel properties of biodiesel derived from *M. oleifera* such as

cloud point, kinematic viscosity and oxidative stability were also determined and are discussed in light of biodiesel standards such as ASTM D6751 and EN 14214. The 1H NMR spectrum of *M. oleifera* methyl esters is reported. Overall, *M. oleifera* oil appears to be an acceptable feedstock for biodiesel. (Umer Rashid *et al.*,2008)

15.5. Moringa leaf powder

Moringa powder is sold in capsules. It can be certified to prove that there are no additives in it and separate industries have bean developed for this purpose. Moringa leaf powder powder will also find suitable applications in preparation of Instant Sambar mix wherein it has projected demand in the Indian market as well as other nations having Indian residents too.

Reported information in online portal reveals that few agencies looking for value added products are developed from Moringa. In India planting of moringa tree material is also a house hold practice in rural area. In semi urban area the agro farm, self help groups are also engaged in the supply chain business of Moringa to the local market. West African countries are already having this plantation in surplus. The industry prospective of this can be treated as a seasonal business.

There are several research institutes in India which have worked on the process and development of various products form Moringa leaf. Efforts are also on to bring out value-added products to the market.

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16. PHARMACEUTICAL AND NUTRITIONAL VALUE OF MORINGA

Moringa oleifera is already highly esteemed by people in the tropics and sub-tropics for the many ways it is used medicinally by local herbalists. Some of these traditional uses reflect the nutritional content of the various tree parts. In recent years, laboratory investigation has confirmed the efficacy of some of these applications. In India, the East Indies, Philippines and tropical Africa all parts of the moringa and infusions, decoctions and extracts made from them are variously employed in native medicine. In the Tropics of the New World, the tree has served mainly as a source of remedies. All parts have been employed as cardiac and circulatory stimulants (Chopra *et al.* 1965). The seeds are pungent and stimulant (Chopra *et al.* 1958).

16.1. Leaves

Crushed leaves applied to the skin cause burning and blistering (Manfred 1947). Taken internally, they are powerfully purgative (Allen 1943). In Puerto Rico they are utilized as a substitute for senna (Roigy Mesa 1945). Leaf poultices are applied to the abdomen for the purpose of expelling intestinal worms (Burkill 1935) and are applied on bites of dogs, monkeys, snakes and other creatures (Benthall 1946).In India, juice from leaves is believed to have a stabilizing effect on blood pressure and is used to treat anxiety. In Senegal, a infusion of leaf juice is believed to control glucose levels in cases of diabetes. Mixed with honey and followed by a drink of coconut milk 2 or 3 times a day, leaves are used as a remedy for diarrhea, dysentery and colitis (inflammation of the colon). Leaf juice, sometimes with carrot juice added, used as a diuretic (to increase urine flow). Eating leaves is recommended in cases of gonorrhea on account of the

diuretic action. In India and Nicaragua, leaves and young buds are rubbed on the temple for headache. In India and the Philippines, a poultice made from fresh leaves is applied to reduce glandular swelling. Leaves are considered to be anthelmintic (able to kill intestinal worms). Leaves are used as an irritant and as a purgative. The ayurvedic medicine of India has many uses for moringa tree products, such as a natural antibiotic, an aid in child birth, for treating liver disorders, and many other uses.

16.2. Flowers

Flowers are traditionally used as a tonic, diuretic and aborifacient. Flowers are considered to be anthelminitic. Used to cure inflammations, muscle diseases, tumors and enlargement of the spleen. In India, juice pressed from the flowers is said to alleviate sore throat and catarrh. In Puerto Rico, an infusion of the flowers is used as eyewash and a decoction from the flowers has been used to treat hysteria. The flowers and root contain pterygospermin, a recognized antibiotic (Watt and Breyer - Brand wijk 1962) highly effective in cholera (Lizzy *et al.* 1968); in high concentrations, a fungicide (Anonymous 1962). Juice pressed from the flowers is said to alleviate sore throat and catarrh (Benthall 1946; Burkill 1935) and is given in milk as a digestive, diuretic and anthelmintic (Dastur (1952); Oliver 1960). An infusion of the flowers is used in Puerto Rico as an eyewash and a floral decoction has been taken as a cough remedy.

16.3. Pods

Pods are believed to be anthelminitic, Pods are used in affections of the liver and spleen and in treating articular pains (pain in the joints).

16.4.Roots

Roots are considered useful against intermittent fevers and are sometimes chewed to relieve cold symptoms. Juice from roots is applied externally as a rubefacient (skin tonic), counter irritant or vesicant (agent to induce blistering). A decoction of roots is used to cleanse sores and ulcers. In India and Indo-China roots are used to treat cases of scurvy.

Root juice mixed with milk is considered useful against in hiccoughs, asthma, gout, lumbago, rheumatism, enlarged spleen or liver, internal and deep-seated inflammations and calculous affections. Crushed root mixed with rum has been used as ailment on rheumatism. A snuff made from roots is inhaled to relieve earache and toothache. A juice made from a combination of fresh roots, bark and leaves is inserted into the nostrils to arouse a patient from coma or stupor. Some people chew a 15 cm length of the root to relieve a cold (Morton 1981).

To relieve a cold or gargle a root decoction to overcome hoarseness (Dastur 1952). A paste made of the grated root, with or without salt, is employed as a counter - irritant in treating skin diseases and as a general substitute for mustard plasters (Irvine 1961). A teaspoon full of the tincture of the dried root, in syrup, taken every three hours, is a potent diuretic. The chewed root is applied to snakebite in the belief that it will prevent the spread of the venom (Brown 1954; Quisumbing 1951) and it very do so because of its rubefacient action. The root bark (containing 0.105% alkaloids), especially moringinine, is pulverized and mixed with black peppercorns and the combination taken as an abortifacient in India, often with fatal subsequences (Chopra *et al.* 1965). Roots are bitter, act as a tonic to the body, lungs, emmenagogue, expectorant, mild diuretic and stimulant in paralytic afflictions, epilepsy and hysteria.

16.5. Root bark and stem bark

In India, stem and root bark are taken as appetizers and digestives. In Senegal, a decoction of root bark, roots, leaves and flowers is used to treat epilepsy, hysteria and intestinal spasms. In India, a decoction of the root bark is used as a fermentation to relieve intestinal spasm and is considered useful in calculous affections (mineral buildup/kidney stones). Stem bark is used to cure eye diseases. In India, stem and root bark are believed to be aphrodisiacs and anthelmintic. In India, root bark is said to prevent enlargement of the spleen and formation of tuberculous glands of the neck, to destroy tumors and to heal ulcers. Juice from root bark is put into

the ear to relieve earaches and also placed in a toothache cavity as a pain killer.

Bark is used as a rubefacient and as a vesicant. In India, bark is sometimes mixed with peppercorns and used as an abortifacient (although often with fatal consequences). The fresh trunk bark contains ß- sitosterol and moringine (benzylamine) and traces of alkaloids (Watt and Breyer - Brandwiki 1962). It is steeped in alcohol and prescribed as a counter-irritant on headache and other pains. Internally the bark alone acts as an emmenagogue and in stronger doses, as an abortifacient (Burkill 1935; Kirtikar 1983). Shukla *et al.* (1988) showed that the root and bark of *M. pterygosperma* and the root of *M. concanensis*, prevented implantation when given orally by intragastric tube after 7 days of pregnancy. There was no variation in the activity of *M. pterygosperma* root regardless of season or location of collection. The root contains also spichin, a bacterioside, which affects the heart and has a paralyzing effect on the nerves (Dastur (1952). In the Philippines, the not decoction has been given to delirious patients (Brown 1954; Quisumbing 1951).

16.6. Gum

Gum, mixed with sesame oil, is used to relieve headaches. This is also poured into ears for the relief of earache. In Java, gum is given for intestinal complaints. In India, gum is used for dental caries. Gum is considered to be diuretic. In India and in Senegal, gum is considered useful in treating fevers, dysentery and asthma. Gum is used as an astringent and rubefacient (skin tonics). In India, gum is sometimes used as an abortifacient. In India, gum is used to treat syphilis and rheumatism.

16.7. Seeds

Seeds are used against fevers. Flowers, leaves and roots used as remedies for various tumors and the seed for abdominal tumors. In Aruba, a paste of crushed seeds is spread on warts.

16.8. Seed oil

In India, seed oil is applied externally to relieve pain and swelling in case of gout or rheumatism, and to treat skin diseases. Oil is used to treat hysteria and scurvy. Oil is applied to treat prostrate and bladder troubles. Oil is considered to be a tonic and a purgative. Villagers in Oman use moringa oil to treat stomach disorders. They also use it in perfume and hair oil.

16.9. Research on Medicinal value of moringa

Mazumder *et al.* 1999 reported that the methanolic extract of *M. oleifera* roots contained alkaloids (0.2%). The effect of the crude extract (weekly doses of 35, 46 or 70 mg/kg, i.p.) on liver and kidney functions and haematological parameters in mice were studied. In the weekly treatment, the high dose increased white blood cell count and decreased clotting time significantly.

Guevara-*et al.* 1999 found that seven known compounds were isolated from *Moringa oleifera* in Philippines, 4(alpha-L-rhamnosyloxy)-benzyl isothiocyanate, niazimicin, niazirin, beta-sitosterol, glycerol-1-(9-octadecanoate), 3-O-(6'-O-oleoyl-beta-D-glucopyranosyl)-beta-sitosterol, and beta-sitosterol-3-O-beta-D-glucopyranoside. Four of the isolates, which were obtained in relatively good yields, were tested for their potential antitumour-promoting activity using an in vitro assay which tested their inhibitory effects on Epstein-Barr virus-early antigen (EBV-EA) activation in Raji cells induced by the tumour promoter, 12-O-tetradecanoyl-phorbol-13-acetate (TPA). All of the tested compounds showed inhibitory activity against EBV-EA activation, with 3 compounds having very significant activities. Based on the in vitro results, niazimicin was further subjected to an in vivo test and found to have potent antitumour-promoting activity in the 2-stage carcinogenesis test in mouse skin using 7,12-dimethyl-benz(a)anthracene (DMBA) as the initiator and TPA as the tumour promoter. From these results, niazimicin is proposed to be a potent chemo preventive agent in chemical carcinogenesis.

Kurma *et al.*, 1998 found that the powder and different extracts of fruits of *M. pterygosperma* [*M. oleifera*], obtained from a local market in India and traditionally used to treat ascites, rheumatism, and liver and spleen diseases, were screened for their anti inflammatory and hepatoprotective activities in albino rats. The aqueous extract showed significant anti inflammatory activity against carrageenan-induced paw oedema. It also showed significant hepatoprotective activity against CCl4- and paracetamol-induced hepatic damage. The methanolic extract was effective against rifampicin-induced toxicity on the liver.

Studies on the hepatoprotective activity of different extracts of stem bark of *M. pterygosperma* [*M. oleifera*] (obtained from a local market in India) was carried out in albino rats. The total aqueous extract showed hepatoprotective action against carbon tetrachloride- and rifampicin-induced hepatotoxicities. The petroleum ether extract exhibited similar activity against paracetamol-induced hepatotoxicity. Caffeic and fumaric acids, isolated for the first time from the bioactive total aqueous extract, were characterized and assessed for their in vitro hepatoprotective activity. These showed significant hepatoprotective activity against galactosamine- and thioacetamide-induced hepatic cytotoxicities (Kurma *et al.* , 1998).

Udupa *et al.*, 1998 repoted that the aqueous extracts of 4 plant materials used as indigenous drugs (leaves of *Aloe barbadensis* and Tridax procumbens; roots + root bark of *Aegle marmelos* and *Moringa oleifera*) were studied for their effects on both normal and steroid-depressed healing of wounds. The herbals not only promoted healing but also overcame the depression of healing caused by dexamethasone. The increased lysyl oxidase activity induced by these plant preparations could be responsible for their wound-healing activity. Raised levels of nucleic acids indicate that the action may be at the cellular level.

The roots of *M. pterygosperma* [*M. oleifera*], which have many medicinal uses including as a carminative, stomachic, abortifacient, cardiac tonic and in paralytic conditions, rheumatism, liver disease, asthma and

epilepsy, were obtained from a commercial source in Vadodara, India. The roots of *M.pterygosperma* in powder and extract form were studied for their anti inflammatory and anti hepatotoxic activities in rats.The methanolic extract showed significant oedema suppressant activity against carrageenan-induced paw oedema similar to that of indomethacin. The aqueous extract showed significant activity against carbon tetrachloride-induced hepatotoxicity, total aqueous extract against paracetamol-induced hepatotoxicity and methanolic extract against rifampicin-induced hepatotoxicity(Rao and Mishra 1998).

Aqueous and alcoholic extracts of roots and flowers of *M. oleifera*, collected in Trichy, India, were screened for antihepatotoxic activity in paracetamol-treated albino rats. Liver function was assessed based on liver to body weight ratio, serum levels of transaminase, alkaline phosphatase and bilirubin. All extracts were found to have antihepatotoxic activity. The LD50 value of ethanolic extracts of roots and flowers was 1023 and 1047 mg/kg, respectively, and corresponding values for aqueous extracts was 1078 and 1092 mg/kg, respectively (Ruckmani *et al* 1998).

The aqueous extract of the mature flowers of *Moringa oleifera* collected in West Bengal contained the free neutral sugars D-mannose and D-glucose in the ratio 1:5 and 2 unidentified carbohydrate bearing materials along with proteins and ascorbic acid, but no polysaccharide. In contrast, the aqueous extract of pre-mature flowers was composed of the above materials (with varying proportions) and a polysaccharide (PS) which on hydrolysis gave D-glucose, D-Galactose and D-glucuronic acid in a molar ratio of 1.0:1.9:0.9. Using methylation, periodate oxidation and partial hydrolysis studies, a plausible structure was been assigned to the repeating unit of the PS (Amar - Pramanik *et al.* 1998).

16.10. Nutritive value of Moringa

Moringa trees have been used to combat malnutrition, especially among infants and nursing mothers. Three non-governmental organizations in particular-Trees for Life, Church World Service and Educational Concerns

for Hunger Organization-have advocated moringa as "natural nutrition for the tropics." Leaves can be eaten fresh, cooked, or stored as dried powder for many months without refrigeration, and reportedly without loss of nutritional value. Moringa is especially promising as a food source in the tropics because the tree is in full leaf at the end of the dry season when other foods are typically scarce.

A large number of reports on the nutritional qualities of moringa now exist in both the scientific and the popular literature. In fact, the nutritional properties of moringa are now so well known that there seems to be little doubt of the substantial health benefit to be realized by consumption of moringa leaf powder in situations where starvation is imminent. Nonetheless, the outcomes of well controlled and well documented clinical studies are still clearly of great value. Even small amounts of the leaves could protect thousands of people from suffering and death. People in several countries have found that Moringa leaves are quite acceptable to taste, especially when added to common foods.

The leaves of the *Moringa oleifera* tree are very nutritious. They can be consumed fresh, cooked or dried. Since dried moringa leaves retain their nutrient content, it is possible to convert them into leaf powder. When there is an abundance of leaves, this leaf powder can be made and stored easily. Moringa Leaf Powder is an excellent nutritional supplement and can be added to any dish. According to Dr. Lowell Fuglie, the West Africa representative of the Church World Service who used the Moringa tree as a base for a nutrition program, "for a child aged 1-3, a 100 g serving of fresh cooked leaves would provide all his daily requirements of calcium, about 75% of his iron and half his protein needs, as well as important amounts of potassium, B vitamins, copper and all the essential amino acids. As little as 20 grams of leaves would provide a child with all the vitamins A and C he needs."

For pregnant and breast-feeding women, Moringa leaves and pods can do much to preserve the mother's health and pass on strength to the

fetus or nursing child. One 100 g portion of leaves could provide a woman with over a third of her daily need of calcium and give her important quantities of iron, protein, copper, sulfur and B-vitamins.

One rounded tablespoon (8 g) of leaf powder will satisfy about 14% of the protein, 40% of the calcium, and 23% of the iron and nearly all the vitamin A needs for a child aged 1-3. Six rounded spoonfuls of leaf powder will satisfy nearly all of a woman's daily iron and calcium needs during pregnancy and breast-feeding.

Moringa has enormous potential for benefiting humanity. It could:

- Improve human health
- Increase livestock's weight gain and milk production
- Enhance plant growth and crop yields

Most sources seem to agree on the excellent nutritional benefits of moringa. Because the tree produces leaves during the dry season and during times of drought, it is an excellent source of green vegetable when little other food is available (Folkard and Sutherland, 1996). The leaves provide many necessary vitamins and minerals and can be eaten cooked or dried. The foliage has been compared to spinach in both its appearance and nutritional quality. According to Optima of Africa, Ltd., a group that has been working with the tree in Tanzania, "25 grams daily of Moringa Leaf Powder will give a child" the following recommended daily allowances. Protein 42%, Calcium 125%, Magnesium 61%, Potassium 41%, Iron 71%, Vitamin A 272%, Vitamin C 22%

- There are over 46 Antioxidants & 36 Anti-Inflammatory compounds in the moringa plant. The more antioxidants in the body the less aging and disease. Almost all diseases, especially age-related diseases, start with chronic inflammation. If the inflammation can be corrected many of the infirmities of aging can be prevented or reversed.
- Moringa leaves contain all 8 essential amino acids and 18 amino acids in all.

- Moringa is rich in Omega 3, Omega 6, and Omega 9 oils. The moringa plant is the highest source of chlorophyll in the plant kingdom! Chlorophyll is very important in helping the body reach a balanced pH level.
- Moringa has no known impurities or adverse reactions so it's safe to take with most medications.

People taking moringa report the following: Extra energy, better sleep, wrinkles disappearing, smoother healthier looking skin, lower cholesterol & triglycerides, relief from muscle and joint pain from conditions such as arthritis, fibromyalgia and carpal tunnel syndrome, decreased appetite, balanced blood sugar levels, improved mental clarity, weight loss, less anxiety, normalization of blood pressure, allergy relief, strengthening of the immune system, relief from sinus conditions; heartburn, & digestive disorders. People with lupus, asthma, diabetes, anemia, cancerous tumors and auto-immune disorders have also reported positive results from ingesting Moringa Tree Leaf powder capsules.

- Plant pigments (flavonoids) such as rutin and quercetin, and other beneficial phytochemicals (lutein, caffeoylquinic acids) to name just a few are present in moringa. These substances act as antioxidant, anti-aging or protect various tissues (retina, liver, blood vessels) from age-related damage and disease.

These results are impressive, especially when considering this nutrition is available when food sources may be scarce. The leaves and branches may also be used for fodder when nothing else is useable and the high nutrient content of the leaves would make it a prime candidate to incorporate into a mulching system. This is assuming, however, that the leaves are in abundance and not required as a human food source. In addition to the leaves, the pods, or drumsticks are a great commercial product. In India, they are canned and exported all over the world.

Parenchyma cells contain oil drops, aleurone grains and sometimes cluster crystals. The inner cells of the cotyledons are stellate (Vaughan, 1970; Ochse, 1977).

Table1. Composition of leaves and Fruits (per 100g of edible portion)

Sl. No	Leaves	Pods	
1.	Edible portion (%)	75	83
2.	Moisture (%)	75.0	86.9
3.	Protein(g)	6.7	2.5
4.	Fat (g)	1.7	0.1
5.	Carbohydrate (g)	13.4	3.7
6.	Minerals (g)	2.3	2.0
7.	Fibre (g)	0.9	4.8
8.	Calories	92	26
9.	Calcium (mg)	440	30
10.	Magnesium (mg)	24	24
11.	Oxalic acid (mg)	101	101
12.	Phosphorus (mg)	70	110
13.	Potassium (mg)	259	259
14.	Copper (mg/g)	1.1	3.1
15.	Iron (mg)	7	5.3
16.	Sulphur (mg)	137	137
17.	VitaminA (I.U)	11,300	184
18.	Choline (mg)	423	423
19.	Thiamine (mg)	0.06	0.05
20.	Riboflavin (mg)	0.05	0.07
21.	Nicotinic acid (mg)	0.8	0.2
22.	Vitamin C (mg)	220	120

Seeds are consumed after frying; they taste like peanuts. Sometimes the leaves and twigs are used as fodded (Burkill, 1935; Parker, 1918).

Moringa Leaves are full of essential disease-preventing nutrients:

- Vitamin A, which acts as a shield against eye disease, skin disease, heart ailments, diarrhea, and many other diseases.
- Vitamin C, fighting a host of illnesses including colds and flu.
- Calcium, which builds strong bones and teeth, and helps prevent osteoporosis.
- Potassium, essential for the functioning of the brain and nerves.
- Proteins, the basic building blocks of all our body cells.

16.11. Moringa leaf powder

These qualities have made the *Moringa oleifera* tree a candidate in the fight against malnutrition. A group of health workers from the Church World Service have been utilizing this highly nutritious and fast growing tree as a means to cure and prevent malnutrition in infants, pregnant and lactating women as an alternative to the classic and expensive condiments usually used such as whole milk powder, sugar, vegetable oil, and sometimes peanut butter. It takes around ten days to see an improvement in malnourished infants when Moringa leaves are used whereas it takes months for recovery with conventional methods.

Under intensive cultivation, moringa is direct-seeded or transplanted at close spacings into a fertile garden bed and then regularly trimmed. This intensive method produces the maximum quantity of leaves possible in a small plot. Studies in Nicaragua determined that optimum spacing for maximum production in intensive plots was 10cm x 10cm (4in x 4in). Disadvantages of this method are that it does not allow for seed production and it requires increased maintenance for irrigation, fertilization, and pest control.

16.12. Phytochemistry

Phytochemicals are, in the strictest sense of the word, chemicals produced by plants. Commonly, though, the word refers to only those chemicals which may have an impact on health or on flavor, texture, smell or color of the plants, but are not required by humans as essential nutrients. An examination of the phytochemicals of moringa species affords the opportunity to examine a range of fairly unique compounds. In particular, this plant family is rich in compounds containing the simple sugar, rhamnose and it is rich in a fairly unique group of compounds called glucosinolates and isothiocyanates (Bennett *et.al.*, 2003). For example, specific components of moringa preparations that have been reported to have hypo-tensive, anticancer, and antibacterial activity include 4-(4'-O-acetyl-a-L-rhamnopyranosyloxy) benzyl isothiocy-anate, 4-(a-L-rhamnopyran osyloxy) benzyl isothiocy-anate, niazimicin, pterygospermin, benzyl

isothiocyanate and 4-(a-L-rhamno pyranosyloxy) benzyl glucosinolate. While these compounds are relatively unique to the moringa family, it is also rich in a number of vitamins and minerals as well as other more commonly recognized phytochemicals such as the carotenoids (including a-carotene or pro-vitamin A).

16.13. Disease Treatment and Prevention

The benefits for the treatment or prevention of disease or infection that may accrue from either dietary or topical administration of moringa preparations (e.g. extracts, decoctions, poultices, creams, oils, emollients, salves, powders, porridges) are not quite so well known. A plethora of traditional medicine references attest to its curative power and scientific validation of these popular uses is developing to preparations have been cited in the scientific literature as having antibiotic, antitrypanosomal, hypotensive, antispasmodic, antiulcer, anti-inflammatory, hypo-cholesterolemic, and hypoglycemic activities, as well as having considerable efficacy in water purification by flocculation, sedimentation, antibiosis and even reduction of schistosome cercariae titer .

Unfortunately, many of these reports of efficacy in human beings are not supported by randomized clinical trials, nor have they been published in high visibility journals. For example, on the surface a report published almost 25 years ago appears to establish moringa as a powerful cure for urinary tract infection, but it provides the reader with no source of comparison (no control subjects). Thus, to the extent to which this is antithetical to Western medicine, moringa has not yet been and will not be embraced by Western-trained medical practitioners for either its medicinal or nutritional properties.

In many cases, published *in vitro* (cultured cells) and in-vivo (animal) trials do provide a degree of mechanistic support for some of the claims that have sprung from the traditional medicine lore. For example, numerous studies now point to the elevation of a variety of detoxication and antioxidant enzymes and biomarkers as a result of treatment with moringa or with phytochemicals isolated from moringa.

16.13.1. Antibiotic Activity

This is clearly the area in which the preponderance of evidence-both classical scientific and extensive anecdotal evidence-is overwhelming. The scientific evidence has now been available for over 50 years, although much of it is completely unknown to western scientists. In the late 1940's and early 1950's a team from the University of Bombay (BR Das), Travancore University (PA Kurup), and the Department of Biochemistry at the Indian Institute of Science in Bangalore (PLN Rao), identified a compound they called pterygospermin a compound which they reported readily dissociated into two molecules of benzyl isothiocyanate . Benzyl isothiocyanate was already understood at that time to have antimicrobial properties. This group not only identified pterygospermin, but performed extensive and elegant characterization of its mode of antimicrobial action in the mid 1950's.

Although others were to show that pterygospermin and extracts of the moringa plants from which it was isolated were antibacterial against a variety of microbes, the identity of pterygospermin has since been challenged as an artifact of isolation or structural determination. Bennie Badgett, identified a number of glyosylated derivatives of benzyl isothiocyanate (e.g. compounds containing the 6-carbon simple sugar, rhamnose) . The identity of these compounds was not available in the refereed scientific literature until "re-discovered" 15 years later by Kjaer and co-workers. Seminal reports on the antibiotic activity of the primary rhamnosylated compound then followed, from U Eilert and colleagues in Braunschweig, Germany (33,34). They re-isolated and confirmed the identity of 4-(a-L-rhamnopy-ranosyloxy)benzyl glucosinolate and its cognate isothiocyanate and verified the activity of the latter compound against a wide range of bacteria and fungi.

Extensive field reports and ecological studies forming part of a rich traditional medicine history, claim efficacy of leaf, seed, root, bark, and flowers against a variety of dermal and internal infections. Unfortunately, many of the reports of antibiotic efficacy in humans are not supported by

placebo controlled, randomized clinical trials. Again, in keeping with Western medical prejudices, practitioners may not be expected to embrace moringa for its antibiotic properties. In this case, however, the *in vitro* (bacterial cultures) and observational studies provide a very plausible mechanistic underpinning for the plethora of efficacy claims that have accumulated over the years.

16.13.2. Cancer Prevention

Since moringa species have long been recognized by folk medicine practitioners as having value in tumor therapy , scientist examined compounds 4-(4'-O-acetyl-a-L-rhamnopyranosy loxy)benzyl isothiocy-anate and 4-(a-L-rhamnopyranosyloxy)benzyl isothiocy-anate for their cancer preventive potential. Recently, 4-(4'-O-acetyl-a-L-rhamnopyranosyloxy)benzyl isothiocy-anate and the related compound niazimicin were shown to be potent inhibitors of phorbol ester (TPA)-induced Epstein-Barr virus early antigen activation in lymphoblastoid (Burkitt's lymphoma) cells. In one of these studies, niazimicin also inhibited tumor promotion in a mouse two-stage DMBA-TPA tumor model. In this mouse model, which included appropriate positive and negative controls, a dramatic reduction in skin papillomas was demonstrated. Moringa leaves could practically wipe out malnutrition on our planet.

Phytochemical constituents isolated from *Moringa oleifera* Lam.

Parts	Phytochemical constituents
Roots	4-(α-L-rhamnopyranosyloxy) - be nzylgluc osinolate and benzylglucosinola te
Stem	4-hydroxymellein, vanillin, β-sitosterone, oc ta cosanic ac id and β-sitosterol
Bark	4-(α-L-rhamnopyranosyloxy)-benz ylglucosinolate
Whole gum exudates	L -arabinose, D-galac tose, D-glucuronic acid, L-rhamnose, D-mannose, D-xylose a nd leucoa nthocyanin
Lea ves	Glycoside niazirin, niazirinin and three mustard oil glycosides, 4-[4'-O-acetyl-α-L-rha mnosyloxy) be nzyl] isothiocya nate, niaz iminin A and B
Mature flowers	D-mannose, D-gluc ose, protein, ascorbic acid, polysacc haride
Whole pods	Nitrile s, isothiocyanate, thiocarbana te s, 0-[2'-hydroxy-3'-(2''-heptenyloxy)]-propylundeca noa te, 0-ethyl-4-[(α-1-rhamnosyloxy)-benzyl] carbama te , methyl-p-hydroxybenz oate and β-sitosterol
Mature seeds	Crude prote in, Crude fat, ca rbohydrate, methionine, cysteine, 4-(α-L-rhamnopyranosyloxy)-benzylglucosinola te , benz ylglucosinolate, moringyne, mono-palmitic a nd di-ole ic triglyceride
Seed oil	Vita min A, beta carotene, precursor of Vitamin A

Traditional uses of *Moringa oleifera* Lam.

Parts and its form	Pharmacological activities
Crude ethanolic extract of dried seeds, Hot water infusion of flowers, leaves, roots, seeds and bark, Crude methanolic extract of the roots	Antiinflammatory
Oil from dried seeds, Methanol and ethanol extract of free dried leaves	Antioxidant
Defatted and shell free seeds, Fresh leaves juice, Roots and bark	Antimicribial
Aqueous extract of stem bark, ethanolic extract of leaves, Ethanolic and aqueous extracts of whole pod and their parts, namely, coat, pulp and seed	Cardiovascular
Leaves and fruits	Antihyperlipidemic
Methanolic extract of roots	CNS depressant
Aqueous or ethanolic extract of bark and roots	Antifertility
Paste of leaves, Ethanolic extract of seeds	Anticancer
Aqueous and ethanolic extract of roots and flower, Ethanolic extract of leaves	Antihepatotoxic
Methanolic extract of leaves and flower buds	Antiulcer
Hot water infusion of flowers, leaves, roots, seeds and stalks of bark Seed infusion Carotene of *M. olifera* Extract of *M. olifera*	Miscellaneous Antispasmodic Diuretic Produces Vitamin A Rises blood Hemoglobin level Increases blood glucose level Regulate hyperthyroidism

16.14. Summary

Moringa leaves, flowers and pods contains several nutrients which can be used to cure many diseases. Several reports high light the importance of moringa in preventing diseases like cancer, diabetics, AIDS etc., hence consuming moringa leaves, flowers will solve most of the problems encountered by rural and urban people.

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17. VALUE ADDITION IN MORINGA

Moringa oleifera belonging to the monogeneric family, Moringaceae is well known for its nutritive value in leaves, pods, and seeds. It contains high protein content in the leaves, twigs, stems and seeds. They are an exceptionally good source of provitamin A, vitamins B and C, minerals (particularly Iron) and sulphur containing amino acids methionine and cysteine. It is commonly said that moringa leaves contain more Vitamin A than carrots, more calcium than milk, more iron than spinach, more Vitamin C than oranges, and more potassium than bananas," and that the protein quality of Moringa leaves rivals that of milk and eggs. However, the leaves and stem of *M. oleifera* are known to have large amounts of their calcium bound in calcium oxalate crystals.

17.1. Commercial processed products of moringa

17.1.1 Moringa Pickle

Ingredients

Moringa Pods	-	1 kg
Salt	-	150 g
Chilly powder	-	200 g
Oil	-	300 ml
Mustard Seeds	-	10 g.
Turmeric Powder	-	15 g.
Fenugreek Powder	-	5g
Asafetida Powder	-	5g.
Vinegar	-	20 ml

Method:

Select Matured, tender moringa pods, washed, surface dried and cut in to 2 cm length small pieces. Blanched the moringa pieces for 2 min. Added salt and turmeric powder to the small moringa pods mix it well and kept for 24 hr. Heat the oil in a frying pan, season with mustard seed and add the moringa pods and cook for 1 min. Add the other spices such as chili powder, fenugreek powder and asafetida powder and mixed will. Cool the mixture and add the vinegar as require and store in sterile glass bottles.

Flow Chart for Moringa Pod Pickle

Mature, tender moringa pods

↓

Washed & cut in to 2 cm. Length small pieces.

↓

Blanched for 2 min.

↓

Add the salt and turmeric powder

↓

Mixed well & kept for 24 hrs.

↓

Heat the oil in a pan

↓

Season with mustard seeds

↓

Add the moringa pods to the oil and cooked for 1 minute

↓

Added other spices

(Chili powder 200 g., fenugreek powder 5g. Asafetida 5g.)

↓

Mixed well & cool

↓

Add vinegar

↓

Stare in sterile glass bottles

17.1.2 Dehydrated moringa pods

Method:

Select the matured moringa pods, washed thoroughly, surface dried. Cut the long moringa pods in to 2 cm. Length small pieces. Blanched it 2 min and spread in trays to dry. Dry the pods in cabinet drier at the temperature 55º c. for hrs.

Note: The dehydrated moringa pods can be rehydrated and use in the preparation of curries and sambar.

17.1.3. Moringa pulp powder

Select the matured moringa pods, washed, surface dried and cut in to 3 cm. Length of small pieces. Blanched for 3 min. and cool. Scoop the pulp and pretreated with 0.5% KMS for 10 min. drained and spread in trays. Dry the pulp in cabinet drier at the temperature 55 c. for 6 hrs. Then the pulp is ground in a mixer in to fine powder. Sieved in to fine smooth powder and packed in 200-gauze polyethylene pack and store at ambient temperature.

For maximum utilization of available nutrients in moringa, value added products are prepared from different parts, which are as follows.

Receipes

Moringa Haako

Ingredients required

3 1/3 c. Moringa
leaves 1/4 c. ground
peanuts 3 dried fi sh
2 medium onions, minced
2 medium tomatoes, chopped
2 cloves garlic,
minced Salt
Pepper

Red Pepper

Dried oysters (optional)

Boil leaves for 10 minutes, then remove leaves from water and set aside. Reheat water to boiling and stir in the other ingredients. Boil for 15 minutes, then reduce heat, add leaves again and simmer for ten minutes. Serve over a simple grain (millet couscous, rice, etc.) or eat as soup.

17.1.4. Moringa Porridge

Ingredients required

1½ c. water

1 ½ c. milk

1/2 c. millet fl our

1/4 c. ground roasted cowpeas

3 T. ground peanuts

2 T. Moringa powder

2 T. sugar

1 pinch iodized salt

Butter or cream (if you're lucky enough to live near Pulaars)

Boil water and mix dry ingredients. Add these to the water and stir vigorously. Reduce heat and add milk. Cook for 10 minutes while stirring constantly to prevent scorching. Serve with butter or cream.

17.2. Leaf preparations

17.2.1. Moringa leaf powder

The leaves after harvest should be stripped off the stems, washed and dried in shade (sunlight can destroy vitamin A). The dried leaves are made into fine powder which can be stored in a air-tight containers. Vitamin A retention is enhanced if the leaves are blanched before drying. (Subadra *et al.*, 1997). As a nutritional additive, 2 or 3 spoonful of the powder can be added to soups or sauces. Moringa leaf powder can be stored for up to 6 months when protected from light and humidity.

17.2.2. Moringa juice

Fresh leaves are crushed and pounded in a mortar with a small amount of water. For larger production, hammer mill is used to pound young moringa shoots (not more than 40 days old) together with little water (about one liter per 10 kg fresh material).Then it is filtered and diluted with water and sugar is added for taste. Alternatively, spoonful of more moringa leaf powder can be added to a litre of water. Then it is stirred together, strained and sugar is added. Juice or juice concentrate is stored in a refrigerator.

17.2.3. Moringa leaf sauce

Two cups of fresh leaves are steamed for a few minutes in one cup of water. Chopped onions, salt, butter and any other seasonings are according to taste (Meitzner and Price, 1996).

17.3. Preparations from flowers

The flowers are a good source of calcium and potassium and should be cooked and consumed. Fried alone or with a batter they have a taste reminiscent of mushrooms. Moringa flowers can be mixed with any leaf recipes or steamed and eaten as a salad.

17.4. Preparations from pods

The entire young and pliable pod is cooked and eaten or used in the preparation of curries. In older pods which develop tough exterior, the pulp and immature seeds remain edible just before ripening begins. A dish is made by slicing pods into 5 cm lengths and boiled in water along with lentils. The flesh inside the pod sections is eaten.

Alternatively, pods can be opened and the flesh and young immature seeds scraped out pods are boiled in water for a few minutes. The seeds of edible pods should be white in color. The seeds should be scraped out with the winged shells intact and as much of the soft white flesh as possible. It is rinsed with water to remove the sticky, bitter film. It is mixed with rice or roasted or fried in oil to give a taste like sweet groundnuts. The flesh

can be cut into strips and steamed or fried, used to make a soup or be added to other sauces.

Salads are also prepared from moringa pods. Very young moringa pods (should be less than 1 cm thick and snap easily) are selected and they are cut into 3 cm lengths. It should be steamed for 10 minutes and then marinaded in a mixture of oil, vinegar, salt, pepper, garlic and parsley.

A recipe called moringa beans is prepared using very young moringa pods (should be less than 1 cm thick and snap easily). The pods are sliced into pieces of any length and steamed or boiled until tender.

17.5. Preparations from seeds

The seeds can be boiled for few minutes to remove the fine transparent hull and the water should be drained. Seeds should be eaten green before they change colour to yellow. The dry seeds can be ground to a powder and used for seasoning sauces.

17.6. Root preparations

The moringa tree has been called the "horseradish tree" because a similar-tasting condiment can be made with from its pungent roots. Even when the plant is only 60 cm tall, it can be pulled up and the roots harvested. The roots from young plants can also be dried and ground for use as a hot seasoning base with a flavour similar to horse radish. A tasty hot sauce from the roots can also be prepared by cooking them in vinegar. The root bark (which contains two alkaloids as well as the toxic moringinine) must be scraped off. The interior flesh is pounded, then mixed with salt and vinegar.

However, it can be dangerous to consume the roots too often or in large amounts. Even when toxic root bark is removed, the flesh has been found to contain the alkaloid spirochin, a nerve paralyzant (Morton, 1991).

17.7. Moringa oil

Moringa oil or Ben oil is obtained by pressing the seeds. The oil content of de-hulled seed (kernel) is approximately 42 %, which is brilliant yellow coloured. It is used as a lubricant for fine machinery such as timepieces

because it has little tendency to deteriorate and become rancid and sticky (Ferrao and Ferrao, 1970; Ramachandran et al., 1980). It is also useful as a vegetable cooking oil. The free fatty acid content varies from 0.5 to 3 %. Indian Ayurveda claims that moringa oil also possess antitumor, antipyretic, antiepileptic, anti-inflammatory, antiulcer, antispasmodic, diuretic, antihypertensive, cholesterol lowering, antioxidant, antibacterial and antifungal activities, and are being employed for the treatment of different ailments in the indigenous system of medicine, particularly in South Asia.

17.7.1. Cosmetic products

Moringa oil has tremendous cosmetic value and is used in body and hair care. Moringa oil has been used in skin preparations and ointments. It has nourishing and emollient properties, making it an excellent massage oil due to the presence of palmitoleic, oleic and linoleic acids, vitamins A and C and unsaturated fatty acid.

This moringa oil is in demand because it is so stable and resistant to rancidity and it has long been valued for its enfleurage property by the perfume industry. It is useful in the manufacture of perfume and hairdressings. The oil is known for its capacity to absorb and retain volatile substances and is therefore valuable in the perfume industry for stabilizing scents and the oil has been used in skin preparations and ointments since Egyptian times.

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18. BIOTECHNOLOGICAL APPLICATIONS IN MORINGA

While Green Revolution technologies were being adopted on farms around the world, scientists were working to understand the biochemical and molecular basis for life. Their insights gave rise to new techniques for making highly specific changes in the properties of plants in ways not possible with traditional breeding methods. This area of research is often referred to as "modern biotechnology." However, the field of biotechnology (which encompasses any application of living systems to develop new products and processes) is hardly new. Indeed, what we consider the emerging field of agricultural biotechnology is actually part of a continuum of breakthroughs in both science and agriculture that has unfolded since the earliest human civilizations. Modern biotechnology has its origins in several important breakthroughs in the basic biological sciences. Building on Mendel's discovery that traits are passed from parents to offspring in the form of "factors" or genes, scientists of the early twentieth century connected this hereditary function with a long, negatively-charged molecule known as DNA. Found in every cell, DNA contains the genes that direct an organism's development. The discovery of genes and the mechanisms that enable their function laid the foundation for scientists to alter the activity of one or a few genes or transfer genes from one species to another in a highly specific manner. The term agricultural biotechnology refers to the application of these advances in the modern biological sciences to improve on products and processes in agriculture.

18.1. Economic, Agronomic, and Societal Importance of Moringa

The Hindustan centre of crop origin is the ordale of many economically important vegetable crops. Ash gourd (*Benincasa hispida*), bitter gourd

(*Momardica charantia*), Kundru (*Cocccinia indica*), pointed gourd (*Trichosanthus dioica*), snake gourd (*Trichosanthes anguina*), egg plant (*Solanum melangena*), hyacianth bean *(Dolichos lablab*), sword bean (*Canavalia* sp) and many other plants originated in this part of the world. There is another vitamin rich, mineral packed and nutritious vegetable of this tropical and sub tropical centre of crop origin grown by the Dravidians and later by the aryans in each and every home yard and presently disappearing from cultivation called variously as Drum stick, Horse radish tree, Radish tree and West Indian Ben.

Moringa is fast growing, drought tolerant and easily adapted to varied ecosystems and farming systems, it occupies a unique and consistent position in the Indian vegetable industry. Because of its many different uses, its free flowering nature and the ease with which it can be cultivated, the area required for it is on increase, as is demand for its product.

The cultivation of moringa in India occurs mainly in the southern states of Tamil Nadu, Karnataka, Kerala and Andhra Pradesh. Principally perennial types have been known about for cultivation for a very long time. However perennial types are best with many production constraints, such as a relatively long pre-fruit bearing period, non-availability of planting materials, requirement of a greater number of rainy days in regions where water is scarce and vulnerability to pests and diseases.

India is the largest producer of Moringa with an annual production of 1.1 to 1.3 million tones of tender fruits from an area of 38,000 ha. Among the states Andhra Pradesh leads in both area and production (15,665 ha) followed by Karnataka (10,250 ha) and Tamil Nadu (7,408 ha). In other states, it occupies an area of 4,613 ha. Tamil Nadu is the pioneering state is so much as it has varied genotypes from diversified geographical areas, as well as introductions from Sri Lanka.

There are only a few named varieties of Moringa. One type, named Jaffna grown in various parts of Southern India, produces fruits of 60-90 cm in length with soft, tasty flesh. It is presumed to have been introduced

from Sri Lanka, where however, three more varieties are distinguished based on the colour and length of their pods. Another type introduced from Sri Lanka is chavakacheri Murungai producing fruits 90-120 cm long. Another regional type is chemmurungai (red tipped fruits) which is said to flower throughout the year and yield heavy crops. Kadumurungai is wild type producing small inferior quality pods. Smoother less popular types includes Palmurungai and puna Murungai with thick pulp and a bitter taste and kodikkal Murungai from betel vine growing areas of Tamil Nadu.

18.2. Biotechnological applications in moringa

18.2.1. *In vitro* studies

Limited information on biotechnological research work are available in this crop. Recently, due importance has been stressed in micropropagation. A technique was described by Kantharajah and Dodd (1991) for in vitro propagation of *M. oleifera* using nodal segments collected from a mature field grown tree. An average of 22.1 shoots/plant were developed in the woody plant medium containing sucrose 2%, solidified with agar and supplemented with 1 mg BA/l. root formation was readily achieved using MS basal medium with 0.5 mg NAA/l. the resulting plantlets were transferred to soil and successfully grown in the greenhouse. Tissues from seedlings were found to be less useful as sources of explants for micropropagation than those from mature nodal segments from older trees.

Stem segments from 10 day old seedlings were transferred on to MS medium supplemented with various combinations and concentrations of auxin (NAA) and cytokinin (kinetin and BAP). Regeneration of plantlets of 100 % (with profuse rooting) was obtained after 3 weeks on MS medium supplemented with NAA (0.2 mg/l) + kinetin (0.2mg/l) (Mughal *et al.*, 1999). Direct somatic embryogenesis was obtained in immature zygotic embryos of Moringa cultured in continuous light in media with GA3, BA and activated charcoal (Iyer and Gopinath, 1999). Long term, fast growing callus cultures were established from rapidly elongationg epicotyls in in vitro plantlets of Moringa in media with 2,4-D, NAA and coconut milk (Iyer and Gopinath, 1999).

Moringa is an Old-World dry tropical plant genus with great food, horticultural, industrial, and pharmaceutical potential. Although many of the thirteen known Moringa species are in danger of extinction, one species, *M. oleifera* Lam., is now widely cultivated. *M. oleifera* was therefore utilized to develop micropropagation techniques that may be applicable to the more endangered members of this genus (Katherine *et al.*, 2004). Immature seeds were the most responsive tissue source, and greatest success was achieved using membrane rafts and a liquid growth medium. The success rate was 73%, but the multiplication rate averaged only 4.7 shoots per culture. Most vigorous plantlet development through the transplant stage was achieved using a commercial plant preservative formulation of isothiazolones following shoot proliferation. Although there was no evidence of contamination, treatment with this microbiocide prevented early tissue senescence and it increased culture survivability.

Chaves *et al.* (2005) evaluate the effects of K^+ rates on the initial growth as well as on the partition and accumulation of this element in roots, stems and leaves of moringa (*Moringa oleifera* Lam.) plants. A pot (0.5 dm3) experiment was carried out under greenhouse conditions using river sand as substrate irrigated with nutrient solution twice every day. The experiment that was a completely randomized design had six treatments and three replicates. The treatments consisted of nutrient solution free of K^+ (control) or supplied with 2, 4, 6, 8 and 12 mM of K^+ as KCl salt. After germination and the period necessary for the plants to stabilize in conditions of the experiment they had been irrigated with K^+- nutrient solution treatments during 30 days. The experiment was harvested 80 days from transplanting. K^+ , Ca^{2+} and Mg^{2+} contents in roots, stems and leaves were determined. Through the growth analysis the leaf mass ratio, the efficiency of K^+ translocation and use were calculated. The results have showed that *Moringa oleifera* was not responsive to the K^+ external concentration above 2 mM. The K^+ accumulation in stems was higher than in roots and leaves. The treatments had not influenced on the translocation efficiency of K^+ throughout the plants. Finally, the plants showed to be more efficient

to use K^+ under conditions of a lower concentration of this ion in the nutrient solution.

18.2.2. Vegetative micro-cloning to sustain biodiversity of threatened Moringa species

The Moringaceae comprises 13 tropical and sub-tropical trees species. *M. oleifera* is the sole species from the Moringaceae for which cultivation practices are being developed (Veeraragava Thatham 1998; Sánchez *et al.* 2006). In absence of cultivation practices of other species, and growing demands by local populations, wild-harvest and over-browsing is decimating natural tree resources. Genetic diversity of *Moringa arborea*, *Moringa borziana*, *Moringa longituba*, *Moringa rivae* , *Moringa ruspoliana*, and *Moringa stenopetala* is endangered. *M. peregrina* is a rare species with a low rate of regeneration following herbivorous animal browsing (Hakham and Ritte 1993), *M. arborea* is listed in the 2006 IUCN Red List of Threatened Species (World Conservation Monitoring Centre 1998), and *Moringa hildebrandtii* is extinct in the wild (Olson and Razafimandimbison 2000; Hammer and Khoshbakht 2005).

Plant tissue culture technologies support endeavors to alleviate extinction threats (Fay 1994; Sarasan *et al.* 2006), yet *Moringa* spp. have received little attention. Multiplication of *M. oleifera* from immature embryo-, seedling-, and mature tree-derived explants was reported (Mohan *et al*. 1995; Islam *et al.* 2005), but Stephenson and Fahey (2004) encountered difficulties to repeat such an accomplishment. Achievement of plant regeneration and multiplication *in vitro* of any other *Moringa* species have not been reported.

The inception of an *in vitro* micro-cloning approach for endangered plants may differ from a micropropagation approach developed for cultivated crop plants in several respects:

(a) the intent is initiation and establishment of small vegetative clones that will serve subsequent vegetative and reproductive propagation. The aim is not mass micropropagation on the scales employed in horticulture or forestry;

(b) the method should maintain biodiversity found in a plant or seed population;

(c) due to paucity of specimens, inconsistent year-to-year seed production or seed availability, inconsistent seed germination, or due to the dynamics of current events requiring swift plant rescue, the amount of plant material available for experimenting and formulating proper culture conditions could be limited.

Numerous studies demonstrate that very often plant growth regulator (PGR) regimes in culture media must be defined for each genotype to succeed in plant regeneration and micropropagation, which means that valuable plants may be sacrificed for this purpose. Moreover, due to genotype-specific PGR requirements, formulation of a uniform culture protocol valid for a genetically heterogeneous wild or non-cultivated plant population is often impossible.

18.2.3. Molecular markers

Molecular data can be used to define conservation strategies, both *ex situ* (e.g. collecting strategies) and *in situ*. Molecular technologies may help promote germplasm use by providing exact data about the genotypic attributes of plants, including crops. Germplasm characterization offers information about individual genomic composition and, as such, allows breeders to select promising material based on genotype, as well as on phenotype. The construction of molecular linkage maps have opened up the possibility of locating important agronomic traits in crop genomes and, consequently, of selecting germplasm based on the presence of a particular gene of interest. Introgression of genes from 'donor' germplasm can thus be followed in subsequent generations, using so-called marker assisted selection, thus facilitating and accelerating traditional selection trials.

Molecular marker technologies are also used to detect somaclonal variation which may be useful for breeding-that sometimes occurs after regeneration through tissue culture. They can also help in the routine

housekeeping activities of a breeding program, such as keeping track of progenies through pedigree analysis, identifying off-types in seed lots and confirming or disproving hybrid purity. The latest tools for molecular genetics will, hopefully, speed up breeding procedures through such activities as permitting the quick discovery of useful genes in germplasm collections or correlating genotype with phenotype.

Molecular markers have proved to be powerful tools in the assessment of genetic variation both within and between plant populations by analyzing large fragments of loci distributed throughout genome (Powell *et al.,* 2000). In order to facilitate reasoned scientific decisions on its management and conservation and prepare for selection breeding programme, genetic analysis of seven populations was performed using AFLP markers by Muluvi *et al* (1999). The four pairs of AFLP primers (psI/MseI) generated a total of 236 amplification products of which 157 (66.5%) were polymorphic between or within populations. Analysis of molecular variance revealed significant difference between regions and populations, even though outcrossing perennial plants are expected to maintain most variations within populations.

The mating system in plant populations is influenced by genetic and environmental factors. Proper estimates of the outcrossing rates are often needed for planning breeding programmes, conservation and management of tropical trees. The majority of outcrossing angiosperms have bisexual flowers, a condition from which self-pollination can evolve directly through thermodification of self-incompatibility or other floral traits that prevent self-pollination. In addition to the role of the variable floral architectures in determining mating systems of the plant populations, the mating system may be sensitive to plant density and population size, type of pollination vector and abundance, flower colour, size of floral display and anther-stigma separation. Temporal changes in quality or quantity of pollinator service or variation in the timing of flowering can lead to seasonal changes in the mating patterns and composition of the outcross pollen pool. As such it is reasonable to expect that outcrossing rates could vary extensively

both spatially within and between populations, and temporally within a single population.

Traditional methods used for the measurement of mating systems have been based on the analysis of floral morphology, greenhouse crossing experiments, and (where appropriate) the observation of pollinator behaviour (Clegg, 1980). The practical use of phenotypic markers in trees is limited by a number of factors such as long time required for progeny to reach maturity for the markers to be scored and lack of consistency between phenotypic markers and outcrossing.

The development and application of isozymes provided numerous genetic markers which can be used to measure mating systems in plant populations (Brown and Allard, 1970; Holtsford and Ellstrand, 1990; Cottrell and White, 1995; Premoli, 1996; Schoen *et al.,* 1997). In recent years DNA based methods such as RAPDs (Gjuric and Smith, 1996) and AFLPs (Gaiotto *et al.,* 1997) have been used to estimate outcrossing rates. However, due to their dominance behaviour, RAPD and AFLP markers provide less information per locus than codominant markers (Gaiotto *et al.,* 1997). This is particularly relevant for applications that require genotype discrimination, as in the case of outcrossing-rate estimation (Gaiotto *et al.,* 1997). However, Ritland and Jain (1981) demonstrated that this limitation could be readily overcome by multilocus estimation of outcrossing with dominant markers having intermediate gene frequencies.

M. oleifera is adapted to selfing (geitonogamy) and outcrossing (xenogamy) with larger fruit set, seed set and fecundity in the latter mode (Jyoth *et al.,* 1990). The flowers produce both pollen and nectar with bees as the main pollinators (Puri, 1941, Jyoth *et al.,* 1990, Chand *et al.,* 1994). However, the proportion of selfing in *M. oleifera* has not been previously estimated. Raja and Bagle (2008) test the utility of dominant AFLP markers in estimating outcrossing rates in *M. oleifera* and then use them (AFLP markers) to obtain estimates of outcrossing rates in an *M. oleifera* seed orchard from Mbololo, Kenya.

There are two essential developments needed in moringa, genomics and functional genomics today; first, the development of significant sequence-based resources, second, the use of these sequence resources to integrate moringa research into the substantial informational and physical resources that already exist in other species. A few decades ago, crop researchers worked in their own species with limited reference to what was happening elsewhere. Bioinformatics, genomics and functional genomics have developed to the point where most researchers today will at the very least use information from other species as a guide to work in the crop of interest, if not as a surrogate. For moringa, this could mitigate the difficulties of working in this species, while still allowing the particular strengths of moringa to be exploited.

18.3.The future thrust areas for moringa include,

- Strengthening of germplasm collection and characterization of different traits for utilization in breeding programmes
- Cryopreservation of germplasm and development of molecular markers for marker assisted selection (MAS) in breeding programmes
- Development of regeneration protocol
- Development of theoretical ideotype for focused crop improvement
- Understanding the abiotic stress tolerance and screening germplasm for tolerance to different stresses
- Physiological and biochemical characterization for productivity potential
- Development of integrated eco friendly crop protection
- Development of databases for moringa.

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19. AN ANALYSIS OF PRESENT MARKETING STRATEGIES FOR PROMOTION OF LOCAL AND EXPORT MARKET

India is the prevalent producer of Moringa with an annual production of 1.3 million tonnes of tender fruits from an area of 38,000 ha. Among the states, Andhra Pradesh leads in both area and production (15,665 ha) followed by Karnataka (10,280 ha) and Tamil Nadu (7,408 ha). In other states, it occupies an area of 4,613 ha. Tamil Nadu is the pioneering state insomuch as it has varied genotypes from diversified geographical areas, as well as introductions from Sir Lanka.

Tamil Nadu, moringa was cultivated as sole trees in homesteads, round cattle sheds, on farm boundaries, and as isolated plants in fences and as groups of trees on village waste lands. In the early 1990s in southern Tamil Nadu people started growing perennial types - Moolanoor as an intercrop on field scale and their allies were cropped with vegetables and Sorghum. This system evolved as moringa offered some protection to alley crops from drying winds during summer and moringa provided some additional income. With the migration of people from south to north India, the demand for moringa picked up.

Farmers found that growing moringa crops during this season was remunerative. Thus, moringa gained a foothold as a summer vegetable. Its unique flavour and aroma became popular. In South India any meal without moringa and pulses is considered incomplete. The demand for the moringa pod also increased due to increased urban settlements and migration of people to urban colonies. With taste and flavour as deep seated customs, ethnic Indians settled elsewhere in the world, predominantly in the Far East and Gulf countries, and longed for moringa in their diet. All these

simultaneous developments led to the focus on commercial moringa cultivation and organised market networking.

With the demand for bulk quantities of moringa, farmers started increasing the number of trees by taking branch cuttings of perennial types in the late 1980s.The limb cuttings failed to sprout when cut during improper seasons. The delicate buds which are located on the very surface of the bark were damaged during collection and transportation. The productivity of these trees was erratic and in most cases, these trees were not fertilised or properly maintained. Even at this stage commercial cultivation was not thought of. The perennial ecotypes that were cultivated are Jaffna, Moolanur, and Savahacherry etc. Attempts to seed propagate these ecotypes also met with failure as the seedlings took several years to flower and fruit. These were not true - to - type as their pods had varied characters.

Based on the significance of Moringa this study might be more viable with the specific objectives of to assessing the marketing strategies for promotion of local and export market of PKM annual moringa in Tamil Nadu.

19.1. PKM 1 Moringa

During this period, Tamil Nadu Agricultural University (TNAU) undertook systematic research on Moringa. The variety PKM - 1 was released with the following traits.

- Seed propagated
- Annual in habit and bushy in growth.
- Precocious bearing - within eight months
- High productivity (250 - 350 fruits / tree / year)
- Spread harvest (4 months) - Better prices
- Pods green and fleshy and non - bitter.
- Uniform fruit length (1mt) - Easy packing.

- Pods non - fibrous and seeds soft even in late harvests.
- Seeds non - bitter unlike perennial types.
- Long shelf life (10 - 12 days) at room temperature.
- Minimal pod damage in transit due to rubbery texture.
- Amenable for intercropping in young orchards
- Suitable for alley cropping (vegetables and pulses)
- Amenable for ratooning twice.
- Low cost of production.
- Free from hairy caterpillar and gumming.
- Soil enrichment through leaf litter - Better successive crops.
- Suitable for oil extraction (30 - 35%).
- Preferred for curry powder making.
- Better consumer preference - low fibre, good storage quality, non - bitter.

In fact the acceptance of the PKM 1 variety by all sections *viz.* consumers, farmers and curry powder industry made commercial moringa cultivation a viable proposition for small, medium and large farmers alike. Even the corporate sector found the moringa to be an ideal intercrop to generate income from horticultural estates in the very first year of planting, while perennial fruit trees generate income only after 5 - 6 years. The escalating demand leading to extended cultivation of the PKM 1 variety contributed to successful commercialisation of this crop.

19.1.1 Characteristics of PKM 2 Annual Moringa

- Hybrid derivative developed by a cross between MP 31x MP 28.
- Medium tall stature.
- Can easily be propagated by seeds to cover extensive area within a limited time.
- Pods are 125 cm long with 8.3 cm girth weighting 280g.
- Less seeded, fleshier.

- Suitable for growing in tropical plains of India.
- It can be grown as an intermediate crop in coconut and tropical fruit orchards at pre - fruit - bearing stage.
- Suitable for home garden.
- Average fruit numbers 240 / tree with an estimated yield of 98 tonnes / ha.

19.2. Marketing Channel of Moringa

Farmer / Producer
↓
Wholesaler - I, II & III
↓
Retailer
↓
Consumer

19.3. Marketing Cost

Based on farm survey at Ethakoil, Andipatti Taluk, Theni district from the farmers Th. Samuthiram & Th. Chinnan Moringa farms. Moringa farmers are incurring higher marketing cost while middleman plays major role.

- Labour cost for Male: Rs. 200/- and Female : Rs. 70/-
- Packaging materials like gunny bag about Rs.10 - 13/-
- Transport cost of 50 kg and 100 kg gunny bags about Rs.15/- and Rs. 20/- respectively.
- Pesticide spraying cost of about Rs. 20/- for 12litres tank.
- The price of the produce about Rs.5 to 7/ kg only in the intense production season.
- While the least production season i.e. Karthiagai and Markali (October, November and December) of about Rs.80 - 90/-

19.3.1. Benefit - Cost Ratio

Based on the farm survey at Kullapuram village, Andipatty Taluk, Theni district farmer Th. Sethuram Ponnusamy, Mobile Number: 99445 51825. He

is cultivating annual moringa of about one acre past 5 years with very profitable manner.

- Total cost of the production : Rs. 25,000 / acre
- Seed cost : Rs. 750/ kg
- Field preparation : Rs. 1500/-
- Labour cost : Rs. 3000/-
- Fertilizers & Pesticides cost : Rs. 10000/-
- Weeding cost : Rs. 4000/-
- Irrigation , Harvesting & Marketing cost : Rs. 5750/-
- Yield : 9 tonnes / acre x Rs. 7/- kg of price
- Profit : Rs. 63,000/-
- Benefit - Cost Ratio : Rs. 63,000/- /Rs.25,000= 1: 2.52

Hence, the moringa farms incurred the expenditure of one rupee could get the profit of about rupee 2.52 being an economic viable one.

19.4. Marketing Strategy for Local Market for Moringa

High Quality Drumsticks of Export Quality are available with farmers of Tamil Nadu in large quantity. The Moringa growers are generally smaller in size holding (less than one hectare). They need their produce price very soonly to meet out the other commitments. Since, they are selling their produce very nearest market with - middle man (whole saler) with the lowest price. Major local markets play as Andipatti, Themmarasanayakkanur and Koyempedu.

- Moringa growers might be produce in the need based of consumer's demand and preference.
- Pods and leaves are suited for local markets.
- Collective systems of marketing to be followed.
- Moringa farms might be directly involving to the sale their produce.

- More cautious about the different other nearest market price of produce.
- Avoid the mind set knowledge about their position.
- An important new potential market includes ethnic groups not traditionally using the crop, restaurants and health food stores.

19.5. Export Marketing Strategy of Moringa

Commercial production of immature pods for processing is a large industry in India with about 1.2 million MT produced annually on 38,000 ha. Most of the Moringa are exported to southern parts of Tamil Nadu like

- Dindugul → Oddanchatram, Vedachanthur & Bangaloru Market
- Erode → Moolanur Moringa Market
- Karur → Bangaloru Market & Mumbai Market
- Theni → Andipatti
- Madurai → Palamedu Moringa - Usilampatti - Koyempedu Market
- Cochin Market & Valayapatti Moringa
- Tirunelveli → Jaffna Moringa by Shipment to Gulf countries like Dubai.
- Trichy → Kodikal Moringa Market

There is ample market for moringa in metro cities like Hyderabad, Mumbai, Pune, Nashik, Surat and others. Moringa have more demand in Rajasthan also. In addition, moringa have highest demand in Singapore. Since the moringa has antibiotic such as Penicillin it has much more demand in countries like England, Japan, Canada, Bagkok, Doha, Dubai, Baharen, Musket and Daman etc.,

- Government might be formulating procurement centres of moringa farms.
- Leaves, medicinal and value - added products have potential shipment to North America and Asia.
- Provide the timely market information need based.

- Moringa is relatively to grow organically and organic certification may increase consumer appeal.
- Based on super food trends, producers of processed juices and smoothes may also be a potential high - value market for moringa growers.
- Construct the formal quality standards for moringa products, including oil.
- Food safety certification may be required by some wholesale and retail venues for fresh leaf and pod sales.
- Expanding the awareness and appreciation of moringa tree beyond existing cultural boundaries as a sustainable, local food source will enhance the nutrition and food security of island community.
- As for almost any versatile crop, new product markets can be developed.
- Strong potential for internet sales exists, oils and supplements because of product stability and established or emerging markets.

19.6. Conclusions

Community education about moringa's valuable products should be carried out, especially for import replacement (e.g., leafy greens and oil). Annual moringa should be planted in April, May because drumstick fetches higher price in the months of November, December and January. There is ample market for moringa in local and international level. Government should make an arrangement for procurement centres of moringa at grass - root might be a more advisable to the small and marginal farmers with profitable one.

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20. SOCIO-ECONOMIC STATUS OF PKM RELEASED MORINGA

Moringa is a multipurpose crop as all parts of the moringa tree are used for food, oil, fiber, and/or medicine. Since moringa is fast growing, drought tolerant and easily adapted to varied ecosystems and farming systems, it occupies a unique and consistent position in the Indian vegetable industry. In India, the most important products are pods and leaves. Leaf has the some of the required nutrients in very high quantities.

20.1. Nutritional Value of Leaves

The following nutrients are present in 100 gm of fresh moringa leaves

Moisture (%)	75.0
Calories	92
Protein (g)	6.7
Fat (g)	1.7
Carbohydrate (g)	13.4
Fiber (g)	0.9
Minerals (g)	2.3
Ca (mg)	440
Mg (mg)	24
P (mg)	70
K (mg)	259
Cu (mg)	1.1
Fe (mg)	7
S (mg)	137
Oxalic acid (mg)	101

Vitamin A B carotene (mg)	6.8
Vitamin B choline (mg)	423
Vitamin B1 thiamin (mg)	0.21
Vitamin B2 riboflavin (mg)	0.05
Vitamin B3 nicotinic acid (mg)	0.8
Vitamin C ascorbic acid (mg)	220
Arginine (g/16g N)	6.0
Histidine (g/16g N)	2.1
Lysine (g/16g N)	4.3
Tryptophan (g/16g N)	1.9
Phenylanaline (g/16g N)	6.4
Methionine (g/16g N)	2.0
Threonine (g/16g N)	4.9
Leucine (g/16g N)	9.3
Isoleucine (g/16g N)	6.3
Valine (g/16g N)	7.1

The leaves contain hormones, bioflavanoid, arachidic acid, oleic acid and linoleic acid[1].

20.2. Uses of Moringa green

Moringa as a green is considered a very healthy food in India. The juice from leaves is believed to have a stablizing effect on blood pressure, control blood glucose level and treats anxiety2. Mixed with honey and followed by a drink of coconut milk 2 or 3 times a day, leaves are used as a remedy for diarrhea, dysentry and inflammation of the colon. Leaf juice, at times added with carrot juice used to increase urine flow. Eating leaves is recommended in cases of gonorrhea on account of the increasing of urine flow. Leaf juice at times is used as a skin antiseptic. Leaves are used to treat fevers, bronchitis, eye and ear infections. Eating leaves is believed to

increase a woman's milk production and prescribed for anemia. Moringa leaf is shadow dried and used in pharmaceutical and food industries.

Two moringa varieties namely PKM 1 and PKM 2 are released from Horticultural College and Research Institute, Periyakulam. This short report is prepared based on the discussion with the farmers growing moringa in Andipatti taluk. We visited the Andipatti market to meet the producers as well as the buyers (wholesalers & retailers) of moringa in the market. Consumers' preference towards moringa was also captured during the discussion with consumers at retail vegetable market. Later we visited the moringa farms in Kurumpapatti and Rangasamudiram. Based on the interaction in the market and field, we present the facts under three different headings as follows.

20.3. Socio-Economic Status of Farmers:

Moringa is suitable for small & marginal farmers and they opined that three ac is the optimum area for growing and managing the crop effectively. Moringa can be grown even where water resources are scarce and it is one of the remunerative crops if input application and other cultural operations are done timely. Generally, farmers allotted part of their land (apart from raising moringa) for raising fodder and pulse crops. Farmers' economic conditions are slightly improved after adopting the moringa cultivation in a scientific manner. The cost of production varies (around Rs. 28,000 - 30,000 per ac) from place to place while it reduces over years.

20.3.1. The advantages of Moringa cultivation for small farmers are

- Moringa requires minimum irrigation facilities.
- It does not require much labour and family members can deal with the various operations as time requires.
- Because small farmers cultivate less than one hectare of moringa they can transport their produce themselves to the local market.
- Pruned materials can be effectively recycled for supplying pulp and paper industries, which is an additional advantage for small farmers.

- According to Rajangam *et al.*, (2010) the conditions for large scale moringa farming are as follows

20.3.2. Factors governing profitability of large scale production

- Selection of high yielding varieties with suitable marketable quality.
- Sowing in a proper season, in compliance with the latest agro techniques.
- Management of ratoon crops
- Adoption of post harvest management.

20.3.3. Constraints and limitations of large scale cultivation

- The crop is highly heterozygous because it is highly cross pollinated in nature and there is a wide variability in yield and components. As a result, the maintenance of genetic purity represents the limitation.
- The sowing period must be strictly adhered to, (During Aug Sep).
- The commercial crop requires irrigation during summer and windy seasons when the water table is always at its lowest. Extension as a commercial crop in water-scarce areas is limited.

20.4. Preference towards PKM Released Moringa Greens

20.4.1. Farmers' Choice andAdoption

Awareness on PKM released moringa varieties (by name) is very low. After listing out the characteristic features of the PKM released moringa varieties to the farmers, they did not show any interest on cultivation varieties / selection, which are not preferred largely by the marketing agency and consumers. Farmers adopted high yielding moringa types (Ottu Murungai - Hybrid) but they are not aware of their pedigree and name. They adopted from their neighbour farmers or through relatives and the planting materials were brought from Cholavandhan region. Cost of planting material has been increasing as its demand is tremendously increasing. Cost of a moringa cutting had raised to Rs. 25 in recent times, which was only Rs. 3 before four years.

Farmers in Ottanchatram and Cauvery delta districts prefer the PKM released moringa. However, the other varieties grown in Andipatti region are also transported to the above markets. Moringa is scarcely grown for green commercially. Farmers focus is on the moringa pod as a main product. The reason for this situation is that moringa green is considered mainly as a by-product in moringa cultivation. Moreover, it is labour intensive in harvesting, transporting and bulky. The profit rendered by its sale is minimal. Frequent pesticides application and its residue in the greens pose as major constraint for consumption of green. Hence, moringa cultivation for green purpose is not to be found at the commercial level.

20.4.2. Consumers' Preference

Consumer preference is the most important for the successful adoption of a particular technology. Though moringa is liked by the consumer, it is not a part of daily diet. People prefer medium sized moringa to the lengthier ones. This is because of constraints in handling, transportation (without damage) and the small family size. Moringa can be frozen but the consumer preference to frozen and refrigerated foods is still not in the crease. The consumers prefer to buy the pod when they are slightly elastic and not so hardy. Consumers hold the pod in their hands and twist in opposite sides, which should not result any breakage or development of crack in the pod and it should restore its original shape (elastic nature).

As far as moringa green is concerned, the marketing is very poor. Moringa green is not preferred when compared to Amaranthus group of greens. Rural consumers prefer greens from their own locality. They identify trees within their friends and relatives and get the leaf as and when required. The trees which bear less pods and those that are not bitter after cooking are mostly selected for green purpose.

Though the attitude to consume moringa green among urban dwellers is positive, its laborious cleaning procedure makes it a less preferred green.

20.5. Strategies to improve adoption of PKM moringa varieties for green purpose

The following strategies are to be adopted to increase the use of PKM varieties for Greens.

- The seeds should be made available at all leading places with good quality especially in semi-urban areas.
- Development of machinery for harvesting and pruning.
- Increasing the cultivation of moringa for leaf powder. Moringa leaf powder is gaining momentum in national and international markets. The markets for such value added products should be identified and farmers can group themselves to process and export the leaf powder from their own locality.
- Develop standard procedures for production and pruning of moringa as greens.

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IPM Modules

Kharif 2006 – *Gitona digestime* (Meigen)

Suggestive Module 1 (SM 1)

Soil application of thiamethoxam 25 WG @ 200 g ai per hectare on 150, 180 and 210 days after sowing, use of fermented tomato in a trap, collection and destruction of fruit fly damaged fruits at weekly interval and foliar spray of spinosad 45 sc @ g a.i. per hectare and profenofos 50 EC @ 250 g a.i. per hectare on 165 and 195 DAS found to be the best module in minimizing fruit damage and purpose in the soil and increasing fruit yield and cost benefit ratio.

Fruit damage by Fruit fly

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