Advanced Agricultural Research & Technology Journal ▪ Vol. III ▪ Issue 1 ▪ JANUARY 2019 ISSN: 2581-3749 (online)

IMC-2018 Special

Mango (*Mangifera indica*) Cultivation in North-Eastern Region of India

S. C. Das[1], M. Datta[1], P. Ray[2], S. K. Singh[3], R. K. Jena[2], B. Das[2] and S. K. Ray[2*]

[1]College of Agriculture, Tripura, Lembucherra, West Tripura (India) 799 210

[2]ICAR-National Bureau of Soil Survey & Land Use Planning, Regional Centre, Jorhat, (India) 785 004

[3]ICAR-National Bureau of Soil Survey & Land Use Planning, Amravati Road, Nagpur (India) 440 033

Abstract

In the North Eastern Region (NER) of India, mango is mainly cultivated in sub-tropical plain / mid hill region of Assam, Manipur, Tripura, Mizoram and Meghalaya. Cultivation of mango is believed to have originated in South East Asia. Mango is being cultivated in southern Asia for nearly six thousand years. The Mango fruit is very popular due to its wide range of adaptability, high nutritive value, richness in variety, delicious taste and excellent flavour. It is a rich source of vitamin A and C. The fruit is consumed raw or ripe. Good mango varieties contain 20% of total soluble sugars. The acid content of ripe desert fruit varies from 0.2 to 0.5 % and protein content is about 1%. Raw fruits of local varieties of mango trees are used for preparing various traditional products like raw slices in brine, amchur, pickle, murabba, chutney, panhe (sharabat) etc. Presently, the raw fruit of local varieties of mango are used for preparing pickle and raw slices in brine on commercial scale. The wood is used as timber, and dried twigs are used for religious purposes. The mango kernel also contains about 8-10 % good quality fat which can be used for saponification. Its starch is used in confectionery industry. Mango also has medicinal uses. The ripe fruit has fattening, diuretic and laxative properties. It helps to increase digestive capacity. Mango is well adapted to tropical and sub-tropical climates. It thrives well in almost all the regions of the country but cannot be grown commercially in areas above 600 m. It cannot stand severe frost, especially when the tree is young. High temperature by itself is not so injurious to mango, but in combination with low humidity and high winds, it affects the tree adversely. Mango varieties usually thrive well in places with rainfall in the range of 75-375 cm annum^{-1} and dry season. The distribution of rainfall is more important than its amount. Dry weather before blossoming is conducive to profuse flowering. Rain during flowering is detrimental to the crop as it interferes with pollination. However, rain during fruit development is good but heavy rains cause damage to ripening fruits. Strong winds and cyclones during fruiting season can play havoc as they cause excessive fruit drop. Loamy, alluvial, well drained, aerated and deep soils rich in organic matter with a pH range of 5.5 to 7.5 are ideal for mango cultivation. India has 1000 mango varieties and few are commercially cultivated in India. Mango can be propagated from seed and vegetative parts. Plants are generally propagated vegetatively by using several techniques like veneer grafting, inarching and epicotyl grafting etc. Planting is usually done in the month of July-August in rainfed areas and during February-March in irrigated areas. In case of heavy rainfall zones, planting is taken up at the end of rainy season. Fertilizers may be applied in two split doses, one half immediately after the harvesting of fruits in June/July and the other half in October, in both young and old orchards followed by irrigation if there are no rains. The frequency and amount of irrigation depends on the type of soil, prevailing climatic conditions, rainfall and its distribution and the age of the trees. No irrigation is required during the monsoon months unless there are long spells of drought. Frequent irrigation during 2-3 months prior to the flowering season is not advisable as it is likely to promote vegetative growth at the expense of flowering. Irrigation should be given at 50% field capacity. Generally inter-crops are grown during the early years of plantation and hence frequency and method of irrigation has to be adjusted accordingly. The method usually followed for irrigating mango plants is basin irrigation. However, use of drip irrigation will not only reduce the water requirements but also help in fertigation in root zones of the plants. The frequency and the time of inter-culture operations vary with age of the orchards and

Corresponding author: headnbssjorhat@gmail.com

Received Date: 17/04/2018; Accepted Date: 25/12/2018

existence of inter-crops. The weed problem may not exist immediately after planting the mango crop but it is advisable to break the crust with hand hoe each time after 10-15 irrigations are applied. In case of mono-cropping, the area between the basins should be ploughed at least three times in a year i.e. during the pre-monsoon, post-monsoon period and in the last week of November. Intercropping can be taken up till the mango trees attain suitable height and develop canopy (at 5-6 years of age). Leguminous crops like green gram, black gram, gram etc., cereals like wheat, oilseeds like mustard, sesame and groundnut, vegetable crops such as cabbage, cauliflower, tomato, potato, brinjal, cucumber, pumpkin, bitter gourd, tinda, lady's finger etc. and spices like chilli can be grown as intercrops. The partial shade loving crops like pineapple, ginger, turmeric etc. can be cultivated in fully grown orchards. In addition to field crops, some short duration, less exhaustive and dwarf type inter- fillers like papaya, guava, peach, plum etc. can be grown till these do not interfere with the main mango crop. It is advisable to take vegetable crops as inter crops for better returns. Proper cultural practices like addition of fertilizers and control of diseases and insect pests may be adopted to regulate growth and bearing. The North Eastern Region (NER) of India needs a special attention for promoting the cultivation of Mango particularly in the area suitable for its cultivation and wild varieties may also be brought under consideration for further investigation and its subsequent use in mango development programme through further research.

Key words: NE Region, mango hybrids, polyembronic varieties, plant protection

Introduction

Fruits, vegetables and plantation crops make the major component of horticultural crops. Besides these, flowers and nuts are also important. Among all fruits, mango has the prominent place in terms of area, production and significance. Mango, the king of fruits is believed to have its origin in South-East Asia, most probably in northeast India, north western Myanmar, and Bangladesh. From these mentioned gene centres the fruit crop later spread all around the Asia and the world by natural means and with the help of humans. Taxonomic and molecular evidences also support an evolution of mango within a larger area including northwestern Myanmar, Bangladesh and northeastern India. Some authors have considered India as the centre of origin due to the high degree of mango diversity observed in the country. Mango is grown in more than 90 countries of the world in different agro-climatic conditions and is the most important commercially grown fruit crop in India. Mango is the national fruit of India and also of Pakistan and Philippines and national tree of Bangladesh. India has the richest collection of mango varieties. Mango has been known in India since very early times. It is referred in Sanskrit literature as 'Amra' and has been cultivated by man for over 4000 years. 'Ain-n-Akbari' (1590 A.D.) contains a good account of the mangoes regarding its quality and varietal characteristics.

Mango belongs to the family Anacardiaceae and the genus *Mangifera* which includes 69 species with edible fruits. *Mangifera indica* is the only species, which is commercially grown among all species. Only three species are found in India, namely; *Mangifera indica*, *Mangifera sylvatica* and *Mangifera coloneura*. Mango is rightly and widely known as the king of fruits in our country. Three important varieties and hybrids like Amarapali, Himsagar and Mallika and local types are grown in different parts of Tripura. However, area under Amarapali cultivation (80 %) is higher than the Himsagar and Mallika. There are many wild species and wild types of mangos naturally growing in the state. Since the hybrid Amrapali is suitable for the region because of its dwarfness, having less canopy and is a regular bearer and very easy to cultivate in the agro-climatic condition of Tripura. Raw fruits are used for making chutney, pickles and drinks and many other traditional dishes prepared by many euthenics group of the state. The ripe ones are used for preparing several products like squashes, syrups, nectars, jams and jellies. There is a high potential for increasing production and value added products. During April to July the state usually receives high rainfall accompanied by high relative humidity and high temperature which rapidly deteriorate the keeping quality. Insect pests and diseases are the major problems for mango grower and reduce quality and consequently prices.

Mango is cultivated in about 4.72 million hectares around the world with a production of approximately 34.89 million tonnes per annum. India shares about 56% of total mango production in the world. Its production has been increasing since independence, contributing 39.5% of the total fruit production of India. India is the single largest producer of Mangoes and occupies about 49.6 per cent of the total area of world-wide cultivation,

producing about 49.1 per cent of world production. But the productivity of Mango is highest in Brazil, at 15.6 tonnes per hectare followed by Indonesia, Mexico and Pakistan. In India, the productivity is only seven tonnes per hectare. Andhra Pradesh tops in total production, whereas Uttar Pradesh tops area-wise. Andhra Pradesh, Uttar Pradesh, Bihar, Karnataka, Maharashtra, West Bengal and Gujarat together contribute for about 82% of the total production in India. However, in Uttar Pradesh the productivity is about 13 tonnes per hectare. Mango in NE India is cultivated in tropical area of Assam, Tripura, Manipur, foot hills of Mizoram and Meghalaya. No of varieties grown in NE India are 25 along with some wild varieties. Some native *Mangifera* species are found in Tripura, Manipur, Mizoram and South Assam. Wild form of *M. indica* and its allied species *M. sylvetica* occur in Arunachal Pradesh, whereas *M. khasiana* and *M. pentandra occur* in Assam.

History of Mango

Mango is a very popular fruit among the millions of people in India where it is considered to be the choicest of all indigenous fruits. It occupies relatively the same position in the tropics as it enjoyed by the apple in temperate America or in Europe. In fact it will be no exaggeration to say that because of its excellent flavour, attractive fragrance, beautiful shades of colour, delicious taste and healthful value, mango is now recognize as one of the best fruits in the world market. At present it is being cultivated commercially in more than 91 countries in the world, nowhere does it achieve the same premier position as in the subcontinent of India; it thrives throughout the length and breadth of the country. Heritage and culture of the country is associated with mango, which is often referred as the king of the fruits.

Ancient Hindus valued mango so highly not merely because of sentimental or even or religious consideration, but because they fully realize its importance in the economics and cultural life of the society. The very word "aam" (amra) implies that it is the fruits of the masses. Mango leads itself to a variety of uses, every part of this valuable trees, right from root to top, is utilized by mankind in one form or another. The fruits itself in all its stages of development is used by man. In its premature stage raw fruit is used for extraction of tennis and other astringent products, for delightful chutneys, curries, cold drinks, pickles etc. Ripe fruits are a delicacy all the world over, even the unremarkable surplus can be utilized for squashes syrup, marmalades, jams, jelly, and candies. The stones are mostly use to rise seedlings which judiciously planted not only provide rest and shade for travelers, peasants and herdsman in the blazing tropical sun but also play an effective role in binding the soil and protecting it from the erosion. Besides stones of some of the varieties provides fibre which are soft and pliable, and can be utilized after treatment for the manufacturing of the fine brushes. They also make a good stock feed for pigs. The inside kernel of the stone is rich in carbohydrate, calcium and fats, thus it can be used as a source of food and the starch can be used for industry purpose. Goats and cattle's are fed on mango leaves in time of fodder scarcity, while dead and decay branches are utilized as fuel, it also provide good timber for heavy furniture and for doors and windows. Its bark is a good source of important organic compound such as tannin and gums.

Historical Prospective

Looking at the age old association of mango with Hindu mythology and ritual, there should be no doubt in mind regarding its antiquity in India. It can safely be said that here mango cultivation is nearly as old as the Indian civilization. The life like representation of mango trees on the Buddhist stupas, including the famous Barhut Stupa of 110 BC bear testimony to its antiquity. Mention is made of this tree is the CHARAKA Samihita, a great medico scientific treatise. It is also said that Alexander the great (327 BC) spotted a pleasant mango garden in the Indus valley and probably this was the first occasion when a foreigner saw the tree. Later Huien Tsang (632-45 AD) and Ibn Hankal (902-68 AD) who came to India from beyond its frontiers mentioned this fruit in their notes under the *an-mo-Io* and *ambag*, respectively. Huien Tsang is possibly the first writer who brought this fruit to the notice of the people beyond India. Huien Tsang also observed Catterpillar disease of mango during Kumar Bhaskar Barman's time in Assam which led to its poor yield. This visit was followed by that of Ibn Batuta (1325-49 AD), who describe mango as closely resembling an orange tree accept that it was larger and more leafy. Jordanus (1930) called the mango amba in his memorial notes known as *Mirabilis Descriupta*. Its praise reached its climax when a Turkoman saint and poet, Amir Khusroo (1330) composted and exquisite lyric in Persian on mango.

In sixteenth century when Mughal rule was established in India mango was honoured with royal patronage. Babar (1526) described it as an excellent fruit. Akbar the Great (1556-1605) was so much in love with this fruit that he planted the famous Lakhi Bagh (orchard of 1 lakh mango trees), near Darbhanga which also attests to the importance and the esteem that this fruit had won

at a time when large orchard of fruit trees were not even heard of, perhaps this period also marks the beginning of selection of superior varieties and their plantation in formal orchards. In the great work Ain-e-Akbari it is mentioned that a number of mango varieties were cultivated in India during that perod (Abul Fazal, 1590). Particular mention was made of a splendid orchard owned by one Husain during the reign of Akbar or Jahangir. Kairnah was considered to be the most famous variety of mango in Delhi in those days. Charles Maries who visited India nearly three hundred years after the plantation of Lakhi Bagh, found some trees still in vigorous condition, but only as a relic of the old glory. In fact, the mango was greatly patronized by the Mughal rulers and chieftains, and even today a large number of mango varieties are known by Muslim names, such as Humayuddin, Allampur Baneshan, Kudaratulla and Safdar Pasand.

Origin of Mango

The Mango is said to have originated in the Indo-Burma region as cited by De Candolle in 1904. Basing their findings on the maximum number of allied species growing' in Malaya, some workers are led to believe that the Malaya region is the original home of mango, where as many as twenty species are found to grow. However, the number of other species growing at a particular place can only be clue to the origin of a plant and can in no case mean that the plant actually originated there. Moreover, the introduction of the mango into certain islands of the Asiatic Archipelago has been proved to have been made only in recent centuries as described by Rumphius (1741), whereas, it has been undoubtedly under cultivation for more than four thousand years in eastern India and Burma according to De Candolle, 1904. Besides, the history of the mango genus, the occurrence of numerous wild and cultivated varieties, philological, archaeological and other literary evidence, the number of ancient names (particularly sanskrit ones), phytogeographical distribution, phylogenetic taxonomy of all the species and its relation to climatology and geology and its abundance, in the gardens of Bengal and Deccan since ancient times, all go to prove that the mango originated in the Indo-Burma region, and should leave no room for any doubt.

This fruit which has been grown in India for more than 4000 years or even for six thousand years forms now an important commercial fruit crop of number of other countries of the world, particularly those lying in the orbits of south-east Asia, the Philippines, Indonesia, Java, Thailand, Burma, Malaya and Ceylon. It is also quite popular in Egypt, south-east Africa, South Africa, Hawaii, and the West Indies. Considerable efforts are afoot to develop it as a potential market crop in Florida, Israel, and tropical Australia. It is also being popularized in Brazil and Mexico. In India, mango growing area of more than 2.2 million acres out of total acreage of 3.16 million acres is under orchard.

Mango an integral part of Indian culture and heritage

Mango in Sanskrit literature

Though there are reference of several trees in sanskrit literature but mango tree are considered most perfect tree according to Sanskrit poet as it bears fragrant flower, sweet fruits, and provide thick shade to the visitors. Only limiting point of mango is that it has hard and ugly stone. Several Sanskrit literature viz., Valmiki Ramayana, Vyas Mahabharat, Hindu Puran, Kamasutra, Bhasa's plays, Bharavi's Kiratarjuniyam, Banabhatta's Kadambari and Harshcharitam, Harsha's Ratnavali, Bhavabhuti's Malati Madhavam, Sudraka act V and VI, Damodara Gupta's Kuttanimatam, Kalidas creations viz., Abhijanasakuntalam, Ritusambhavam, Kumarsambhavam, Meghdutam, Malbikagnimitram, Bikramorbasiyam and Subhasitas have made reference mango in their text. Sanskrit Literature has mention four types of mango i.e. Amra, Chuta, Rasala and Sahakara.

Mango in Ramayana

The mango has found its place in the epics of Ramayana. There are numbers of reference of mango in Valmiki's Ramayana, which is an ancient Hindu holy book. The varieties enumerated by Sage are Amra, Chuta, Sahkara. Amra is a common cultivated mango. The Chuta is a sucking variety found in village and the Rasala is a fragrant, perhaps a grafted variety. There is no mention Sahakara variety. This Sahakara variety use to flower and fruit together, that means it is baramasi throughout the year type variety. Ayodhya was the heart of mango belt of India. Mention of mango is made in Aranya, Kanda, Ayodhya Kanda, Kishkindha Kanda, Sundera Kanda etc. Loard rama who was accompanied by his brother Lakshmana saw innumerable trees of mangoin full bloom, while proceeding towards the lake Pampa. He had a holy dip in the lake and rested under the shade of mango tree. Valmiki described that mangoes were in full bloom with nice fragrance and peacock used to dance. There is also mention of mango in the Panchavati. Loard Rama stayed in Panchavati. The flora of panchavati is described by Valmiki in Aranya Kanda.

Sri Ram saw the beautiful forests attached to the Sahaya and Malaya Mountain with mango trees on his way to

Lanka to recover Sita from the demon king Ravana. The monkey brigade, which accompanied him, destroyed Chuta (Mango) and other trees on the mountain. Monkeys uprooted Chuta (Mango) and other trees through them into sea. Valmikis description of Lanka in Sundra Kanda of his epic contains a number of references to the mango. Ravana seems to have been found of the luscious ripe mango fruits, which grew abundantly in his island kingdom.

Mango in Purana

Almost all puranas have made reference to the mango in one context or other. The agni purana has stated that the branches of mangos are in religious ceremonies. The Vayu Purana says the mango tree in Brahmasaras was in the shape of the Brahma and he who waters mango trees lead to pitrus to salvation. The same Purana consider the mango as the progeny of Kasyap. There are several references to the mango in Vayu Purana. Mastsya Purana has a reference of Bhadramala, where w3as abundance of mango in the country, where the Inavati river had its sources.

Mango in Ram Charit Manas

In Ram Charit Manas written by Goswami Tulsi Das during the 17th century AD is not in Sanskrit but in Awadhi. Mango is described to grow in many places in Ram Charit Manas during the time of lord Ram. In Aranyakand beauty of pampa saravar is described very beautifully. After looking such a beautiful pond and feeling extremely pleasant atmosphere, Loard Ram took a bath and rested in the shade of mango with his brother Laxman and told the storey of mango. In Ayodhya, Loard Ram with his brothers and Hanuman used to enjoy and relax in mango orchards. After the period of lord Ram Mango was grown at a higher elevations of Himalayas, as describe in Uttarakand. Existance of those trees is described by God Mahadev to Mata Parvati and he also told her about the religious utility of those trees to Kag Bhusundji.

Climate and Soil

Mango can be grown on a wide variety of soils under varied climatic conditions. It can be grown from alluvial to lateritic soils except in black cotton soil having poor drainage. It grows well in soils with slightly acidic pH. It does not perform well in soils having pH beyond 7.5. Soils having good drainage are ideal for mango. Mango is a tropical fruit, but it can be grown up to 1,100 M above mean sea level. However, the crop cannot be grown commercially in areas above 600 M. Therefore, the parts of the North Eastern Region having elevation more than 600 M above the mean sea level are not potentially suitable for commercial cultivation of mango (Fig. 1). Further, there should not be high humidity, rain or frost during flowering. The temperature between 24 and 27°C is ideal for its cultivation. Higher temperature during fruit development and maturity gives better-quality fruits. The areas experiencing frequent showers and high humidity are prone to many pests and diseases. Thus it can be grown best in regions with a rainfall between 25cm and 250cm. Regions having bright sunny days and moderate humidity during flowering are ideal for mango cultivation. The soils of the North Eastern Region (NER) can broadly be classified in five orders *viz.* Inceptisols, Entisols, Alfisols, Ultisols and Mollisols. However, the soil map of potentially suitable areas for mango cultivation in the NER indicates the presence of Inceptisols, Entisols, Alfisols and Ultisols in the potential areas (Fig. 2). The heterogeneity in soil characteristics in NE region is due to the interacting effects of various factors such as climate, parent material, topography, vegetation and living organisms. Presence of diverse group of soils in this region provides wider opportunity for mango cultivation.

Status of mango cultivation in North East India

Systematic information on the area, production and productivity of various horticultural crops in the NER is not available. However, the available data on the area, production and productivity of mango in Tripura is presented in Table 1. The data indicate the decline in the area, production and productivity of mango in Tripura over the years since 1995-96.

India is the home of about 1,000 mango varieties. However, only a few varieties are commercially cultivated throughout India. The mango varieties cultivated commercially in the NER are given in Table 2.

Commercial mango varieties grown in the NER

Amarapali

The variety is evolved from a cross between Dashehari x Neelum. It is a dwarf and regular bearing variety with medium sized fruit. The variety can be grown under high density planting. Amarapali is suitable for the region because of its dwarfness, less canopy and regular bearing with good flavour, test, aroma, texture and acceptability. Its fruits are very sweet and have no fibers. Flowering starts in the first week of February and matures in the first week of June. Fruits are small to medium sized. Total soluble solids (TSS) in the fruits range from 23-

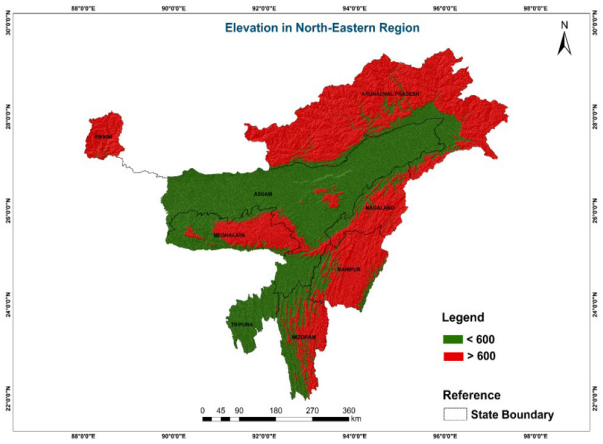

Fig. 1. Elevation map of the North Eastern Region (NER)

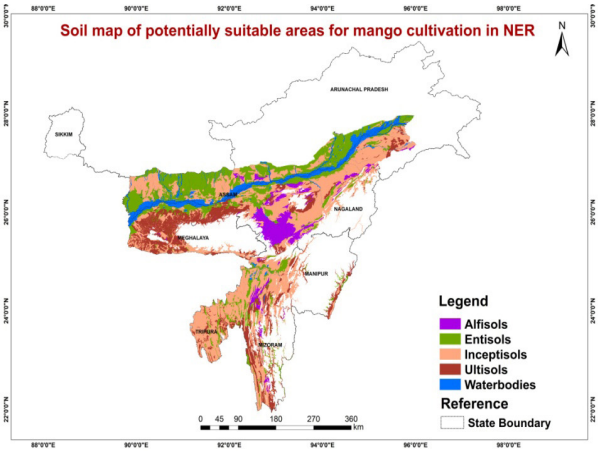

Fig. 2. Soil map of potentially suitable areas for mango cultivation in NER

24^0 Brix and acidity 0.17 %. The shelf life of the fruits is 4-5 days under room temperature.

Himsagar

It is an excellent commercial variety of Tripura. Flower starts in January and matures during the second week of May. The fruits are medium to large averaging 2-3 kg. Fruits are oval in shape with green color and ripen with rough skin. The fruit pulp is very sweet with good flavor, taste, aroma, texture and acceptability but susceptible to mango stone weevil infestation. The TSS is 22-23^0 Brix and acidity 0.22 %. Shelf life of the fruit is very short, only 3-4 days under room temperature.

Mallika

It is a cross between Neelum x Dashehari. It is semi-vigorous, regular bearer. Fruits have very good taste, flavour, texture, aroma and acceptability. It is mid season hybrid. It starts flowering in the first week of February and matures at end of May and first week of June. TSS ranges from 23-24^0 Brix and acidity 0.22%. Shelf life is of 6-7 days under room temperature.

Langra

It is an important commercial mango variety of the

Table 1: Area (ha), Production (mt) and productivity (mt ha^{-1}) of mango in subtropical humid climate of Tripura.

Year	Mango		
	Area (ha)	Production (t)	Productivity t ha^{-1}
1995-96	5036	41270	8.2
1996-97	5036	41270	8.2
1997-98	5022	23100	4.6
1998-99	5030	23145	4.6
1999-00	5000	22300	4.5
2000-01	3075	4500	1.5
2001-02	3150	8500	2.7
2002-03	3175	4600	1.5
2003-04	3460	6121	1.8
2004-05	3623	9360	2.6
2005-06	3868	12340	3.2
2006-07	3700	11358	2.9
2007-08	3981	11924	3.00
2008-09	4190	12706	3.03
2009-10	4254	13170	3.09

Table 2: Commercial mango varieties grown in different states of the NER.

State	Varieties
Tripura	Amarapali, Mallika, Himsagar and wild local types
Nagaland	Amarapali and wild local types
Manipur	Amarapali and wild local types
Assam	Amarapali, langra and wild local types
Arunachal Pradesh	Amarapali and wild local types
Mizoram	Amarapali and wild local types

region. It is biennial-bearer and a mid-season variety, with good quality fruits. Flesh is firm, lemon-yellow in colour and scarcely fibrous. It has characteristic turpentine flavour. Keeping quality of fruit is medium.

The performance of some of the commercial mango varieties was evaluated under subtropical humid climatic condition of Tripura (Table 3). The hybrid Mallika had the highest fruit weight of 737 g followed by Bangalora 570 g per fruit. The hybrid Amarapali recorded highest TSS at 23.53^{0}Brix followed by Mallika (23.20^{0}Brix). The lowest acidity was observed in Amarapali hybrid (0.17%), followed by Alphanso (0.21%). The hybrid Amarapali recorded highest carotenoids (15795 µg 100g^{-1} pulp) followed by Pusa Arunima (14065µg100g^{-1} pulp). The highest ascorbic acid was recorded in Mallika hybrid (47.0 mg 100g^{-1}) followed by Himsagar (41.8 mg 100g^{-1}). Among the varieties and hybrids studied under subtropical humid climatic condition of Tripura, Amarapali had good performance across the state in respect of size, shape, quality, taste, aroma, texture, overall acceptability and adaptability.

Propagation techniques of Mango

Mango is a highly heterozygous and cross-pollinated crop. Polyembryonic varieties are propagated through seeds. However, the varieties grown in the NER are monoembryonic and propagated vegetatively.

Vegetative propagation of mango

Selection of planting materials

Mango is propagated by grafting. Mango is propagated on mango rootstock. For raising rootstock, the seeds of mango are sown within 4-5 weeks after extraction otherwise they lose their viability. For sowing the seeds, raised beds are prepared with a mixture of farmyard manure, soil and sand. In some places, seeds are sown directly in polythene bags. After germination, the leaves turn green in 2-4 weeks. These seedlings are transplanted to polythene covers containing soil, sand and farmyard manure. Addition of nitrogenous fertilizer to polythene covers after the establishment of plants helps in quick growth of seedlings. The seedlings thus raised should be used for grafting at different ages.

Raising of rootstock

The seeds (stones) are extracted from full ripe fruits within a week. The viability of seeds varies from 90-100 days. The seeds are sown directly in poly bags or raised beds with a mixture of farm yard manure, soil and sand. The seeds are sown flat and germination occurs within 10-15 days. One year old seedlings are used for grafting.

Scion selection

- Should be of pencil thickness
- Selected from healthy terminal shoots of 3-4 months age
- The scion should be defoliated 8-10 days before grafting. This is called precuring

Table 3. Evaluation of varieties and hybrids of mangos under subtropical humid climatic condition of Tripura.

Varieties and Hybrids	Fruit weight (g)	TSS (%)	Acidity (%)	Carotenoids (µg 100g^{-1} pulp)	Vitamin C (mg 100g^{-1} pulp)	Shelf life* (Days)
Alphonso	249	19.5	0.21	11216	37.0	5.42
Amarapali	238	23.5	0.17	15795	37.9	4.97
Bangalora (Totapuri)	570	13.2	0.30	7293	39.4	4.53
Chausa	228	22.6	0.20	8090	36.0	4.67
Himsagar	246	22.9	0.22	7870	41.8	3.84
Lal Sundari	257	15.9	0.23	8374	33.1	4.81
Mallika	737	23.2	0.22	9306	47.0	6.42
Pusa Arunima	225	20.3	0.25	14065	34.3	12.0
Pusa Surya	240	20.5	0.25	12657	33.3	11.8
Ratna	235	20.5	0.24	12140	40.0	7.17
SE.m	12.2	00.3	0.002	2.98122	0.04	0.17
C.D @ 5%	36.4	1.11	0.01	8.8577	0.146	0.50

* at room temperature

Old mango trees ready for top working

Root stock prepared for wedge grafting

Old Trees top worked with new scions

New flushes emerging from the grafted shoots

Successfully top worked mango tree

Fig. 3. Top working of old mango trees for rejuvenation.

Types of grafting

Softwood grafting

The top of rootstock are beheaded where the wood is soft and green with the help of a sharp knife and a slit of 5 cm deep is made to accommodate the precured scion. The lower portion of the scion is made to a wedge shape with equal faces on both sides to a length of 5 cm. After inserting the scion into the root stock, the union is tied with polythene strip. Scions are covered

with a polythene bag of 100 gauge thickness and tied with a thread to keep the scions fresh till the union is completed. When the scions are sprouting (20-30 days after grafting), the polythene cover is removed. When the leaves on the graft are fully matured, the bandage is removed to prevent girdling of the graft.

Inarching

Nine months to one year old rootstock is grafted with the scion which remains attached to the mother plant. In the rootstock, 20 cm above the ground level, 5 cm long slice of bark with wood is removed and corresponding cut is made in the scion so as to attach the cut surfaces firmly with jute thread. The tied portion is covered with cowdung mud paste. The graft is separated from the mother plant after 70-80 days of grafting.

Epicotyl /stone grafting

Grafting is done in 10-15 days old rootstocks by beheading the seedlings about 5 cm above the stone and insert the wedge shaped scions in the vertical split made in the beheaded rootstock. Polythene tape of 200 gauge thickness is used for tying the union of grafts.

Veneer and side grafting

These can be utilized for preparing a grafted plant material or for in-situ grafting i.e. for the rootstocks which are already planted.

Cultivation technique
Planting

As Mango is a perennial fruit crop, care should be taken while planting of Mango garden. The criteria like site selection, proper planting material selection, varieties selection, spacing, layout system are require for proper commercial garden. Different systems of planting like square, rectangular and hexagonal are followed at different places. However, square and rectangular systems are also popular. The spacing depends on the vigour of the variety and the cropping system. The planting season varies from May to September in South India and North- Eastern India and during February – March in North India. The main field is brought to fine tilth. Pits of 1m x 1mx 1m size are dug in advance and exposed to sun for about 30 days. Before planting, pits are filled with well-rotten farmyard manure. The top and sub-soil are taken out separately while digging the pits. The grafts should be planted during pre monsoon and rainy season. In the in-situ grafting, rootstocks are planted in the main field. Then they are raised for 6 months to 1 year. The scions of the variety to be grown are taken and grafted. This is usually done when humidity is high in the atmosphere. While planting in main field graft union should be kept above soil and staking is done to protect the newly planted graft from loadging and breaking.

The traditional system follows the spacing of 8 to 8 m or 8 to 10m or 10 to 10m, by which 100 to 150 trees can be accommodated in a hectare. The concept of high-density planting helps increase the yield/unit area. The dwarf mango Amarapali developed by IARI and is found amenable for high-density planting with a spacing of 2.5m x 2.5m accommodating 1600 plants per hectare.

Training

Rootstock sprouts and low-lying branches have to be removed in the initial years of establishment. Besides training is done to provide a good frame work for the future so that branches are spaced properly and these do not break with the crop load at the bearing stage. Thereafter, overlapping, intercrossed, diseased, dried and weak branches are removed after the harvest season is over.

Pruning

Mango normally does not require any pruning, but when the trees become very old, the bearing capacity decreases. This is due to imbalance in hormonal status, which might be due to excess vegetative growth and self-shading of most of the lower branches. The productivity of old trees can be revived by judicial pruning.

Pruning is done during the month of August to September. In the heading back process, the hefty criss-cross branches are beheaded so that the centre is opened up. All the dead and dried branches are completely removed. By this, there will be abundant penetration of sunlight as well as aeration. The dormant buds in the old woods get activated. This should be practiced normally once in five years. In the thinning out process, the excessive terminal shoots all over the surfaces of the canopy are thinned out by retaining only one or two shoots for each previous season growth. This directs the nutrient and hormonal flow to restricted number of shoots, so that the terminal buds is converted into a reproductive bud. Thus the old unproductive trees can be made to bear a good crop.

Irrigation

The young plants up to 2-year-old should be watered regularly. The newly-planted grafts need about 30 litres of water every week. Irrigation during pre-flowering phase increases flowering. Irrigating trees after fruit set

at 10-day interval increases the yield.

Manuring and fertilization

The nutritional requirement of mango varies with the region, soil type and age. Mature mango tree grow at a normal rate even without any application of manures and fertilizers, but for obtaining good yields proper nutrition should be given based on soil and leaf analysis. Application of judicious macro and micronutrients schedule is important for getting good yield and quality of fruits. For proper growth and development, mango tree requires nitrogen, phosphorous, potassium, calcium, magnesium, sulphur and micronutrients like zinc, iron, manganese, copper and boron. The NPK dose depending on the age of mango plant is given in Table 4. The NPK should be applied in 2 split doses during June-July and September-October. Spraying of zinc sulphate (0.3%) during February, March and May is recommended to correct the zinc deficiency. Spraying of Borax (0.5%) after fruit set twice at monthly intervals and 0.5% manganese sulphate after blooming corrects boron and manganese deficiencies, respectively. Organic manures and phosphatic fertilizers should be applied immediately after harvest, whereas ammonium sulphate should be given before flowering.

Intercropping in mango orchard

In mango, intercropping helps check weed growth and reduces nutrient losses. Tuber crops viz., Cassava, sweet potato, yams (lesser yam, greater yam and African yam), aroids (elephant foot yam, taro, and tannia), Chinese potato and arrowroot can be grown for getting additional benefits. Even initial five to six years, many vegetable crops are also grown along with Mango as main crops. The major vegetables like cabbage, cauliflowers, brinjal etc. and spices like coriander, turmeric and zinger are also grown as intercrops (Fig. 3).

Induction of flowering and fruiting

Spraying of naphthaleneacetic acid (NAA) @ 20 ppm at flowering results in the increase in fruit retention. During February, 0.5% Urea (5g lit^{-1}) or 1% Potassium Nitrate (10g lit^{-1}) may be sprayed to induce flowering, if trees do not flower by that time.

Application of paclobutrazol @ 10 g a.i. in full bearing tree during first fortnight of September results maximum number of fruits and yield during off years.

Rejuvenation / top working of old mango trees

Top working of old mango trees can be done by cleft grafting, budding or bark grafting. Scion should be of 15 cm length with 5 to 6 buds. Scion or bud wood can be taken from any desired improved varieties. After top working the trees should be irrigated once in a week. To avoid the adverse effect of high sunlight intensity, temporary shade can be erected (Fig. 3).

Disorders in mango

Alternate bearing

Alternate bearing has been one of the major problems. Most of the varieties grown in the NER are alternate-bearer. Paclobutrazol is a promising chemical for flower induction in mango. Soil drenching with paclobutrazol (5-10g $tree^{-1}$) results in minimum outbreak of vegetative flushes during September and October. This gives an early and profuse flowering and more annual yield without affecting fruit size and quality.

Mango malformation

It is one of the most important disorders, causing huge losses. Vegetative malformation is more common in nursery seedlings and young plants. Floral malformation affects trees at the bearing stage. In vegetative malformation or bunchy top, compact leaves are formed in a bunch at the apex of shoot or in the leaf axil and growth of shootlet is arrested. Floral malformation directly affects the productivity. The incidence of disorder varies from variety to variety. Deblossoming alone or coupled with a spray of 200ppm NAA lowers the number of malformed panicles significantly.

Black tip

The distal-end of the affected fruits turns black and becomes hard. These fruits ripen prematurely and

Table 4: Year wise fertilizer requirement in mango (per plant)

Age	Organic fertilizer (kg)	Nitrogen (N) (g)	Phosphorus (P_2O_5) (g)	Potash (K_2O) (g)
1	10	70	40	80
2	20	140	80	160
3	30	210	120	240
4	40	280	160	320
5	50	350	200	400
6	60	420	240	480
7	70	490	280	560
8	80	560	320	680
9	90	630	360	720
>10	100	700	400	800

become unmarketable. This disorder is caused by the smoke of brick-kilns located within a distance of 600m. Gases like carbon monoxide and carbon dioxide, sulphur dioxide and acetylene cause these symptoms. It can be controlled by raising the height of the chimney of the brick-kilns. Spraying borax (0.6%) at 10-14 days intervals starting from fruit set also controls it.

Clustering (Jhumka)

This is characterized by a cluster of fruitlets at the tip of the panicle giving an appearance of bunch tip called *jhumka.* These fruitlets are dark green with a deeper curve in the sinus beak region compared with normally developing fruitlets. These fruitlets grow to marble size after which their growth ceases. One of the main reasons for clustering is the adverse climate during February-March, particularly the low temperature. Most of the fruits are aborted with shrivelled embryos and do not develop further.

Common insects and pests

***Mango hopper* (*Amaritodus atkinsoni*)**

This is the most damaging insect during the flowering season. Until February, the hoppers remain hiding under the bark and become active during flowering period. Both adults and the nymphs suck the sap from tender shoots and panicles. The panicles wither away and the fruit set is adversely affected. Injury caused by oviposition further aggravates the situation. They give out honey dew which develops sooty mould on the leaves and panicles. Spraying of phosalone @ 0.05% or carbaryl 2g lit^{-1} or phosphamidon 1 m1 $litre^{-1}$ is effective in controlling the insect.

***Stone weevil* (*Cryptorrhynchus mangiferae* and *C.gravis*)**

This pest is specific to sweet cultivars. Stone weevil damages both the pulp and cotyledons of the stone. The eggs are laid in partly developed fruits. The grub travel through the pulp, enter the seed and pupates inside. Adults come out, piercing through the stone and the pulp. General cleanliness in the orchard, destroying the adults in the bark crevices and holes and spraying of Fenthion at the rate 0.1% are useful in controlling the pest.

***Stem borer* (*Batocera rufomaculata*)**

This pest, tunnel through the main trunk or its branches and weakens the plant, and in extreme cases the plant may die. Its presence can be identified by dry hard balls (small-sized) of excreta, emerging from the tunneled portion. Grub is linear and fleshy. Adults are stout, grayish beetle with two pink spots and lateral spine on the thorax. To control the pest, cleaning of tunnels with a hard wire, pouring kerosene oil or creosote or petrol or crude oil or formalin and subsequently closing of the entrance of the tunnel with mud are effective.

***Fruit fly* (*Dacus spp*)**

This is a serious pest. Affected fruits become unfit for consumption due to feeding by maggots. The fruitfly lays its eggs in a cluster of 150-200 under the skin of fruits just before ripening. The affected fruits begin to rot and drop down. Ploughing of inter spaces to expose pupae in soil, monitor with methyl eugenol traps and removal of the fallen fruits followed by burying them deep into soil are useful.

Control measures of some common diseases

***Powdery mildew* (*Oidium mangiferae*)**Application of sulphur dust (350 mesh) in the early morning to protect new flush or spraying of wettable sulphur at the rate of 0.2% or tridemorph at the rate of 0.05% are effective in controlling powdery mildew.

***Anthracnose and stalk and end rot* (*Collectotrichum gloesporioides*)**

Spraying of mancozeb at the rate of 0.2% (1kg ha^{-1}) or Carbendezim @ 0.1% at 15 days interval is effective.

***Sooty mould* (*Capnodium sp*)**

Spraying of Dimecron @0.03% + *maida* **@ 5% (1kg** *maida* **or starch boiled with one litre of water and diluted to 20 litre) is useful.**

Harvesting of mango

Mangoes should be harvested with pedicel. Injury to the fruits during harvesting brings down their quality and also makes them prone to fungal attack. An average mango tree yields 8 tonnes /ha. The number of fruits per tree depending on bearing age generally various from 1000 to 2000 fruits.

Major problems/constraints of mango cultivation in the North Eastern Region

Edaphic factors

The soils of the NER are in general acidic in reaction. Extremely and strongly acidic soils (pH < 5.5) are not suitable for mango cultivation. Cultivation of mango in such soils of this region needs appropriate management intervention, e.g. liming. Besides, effective soil depth is another constraint for cultivation of mango in some parts of the North Eastern hill region with shallow soil depth.

Since mango is a deep rooted perennial crop, effective soil depth less than 75 cm is not suitable for mango cultivation (Naidu *et al*., 2006).

Climatic factors

Climatic factors play a vital role in mango cultivation. Systematic cultivation of mango is not yet followed in the region. Mostly farmers cultivate in the homestead. High rainfall (1500-2500 mm) during April to September affects the growth and development of mango. Quality also decline in the month of December and January due to the existing temperature ranging from 8-15^{0}C. This affects adversely the growth and development of flowers and fruiting. Besides, natural calamity like heavy cyclone and frost affect the flowering and fruiting of mango.

Abiotic and biotic stress

Heavy rain during April to October causes severe soil erosion and nutrient depletion in soil, which ultimately affects the growth of mango in this region. Humid condition also favours the infestation of many insect-pests and diseases, including weeds. Among the severe diseases, powdery mildew, sooty mold and anthracnose adversely affect the quality of mango. Cultural operation is very difficult due to continuous heavy rainfall. During November to March long dry spells lead to severe moisture stress, which lead to poor quality fruits and fruit drop.

Lack of desirable cultivars or hybrids and planting material

Disease free planting material is absolutely lacking. Screening of varieties or hybrids before its distribution is of utmost importance. The dwarf type Amarapali has been identified in this region for commercial cultivation along with Mallika and Himsagar.

Remoteness of the region

This is one of the major problems in the North Eastern region of India. Lack of communication and infrastructure facility hinders the dissemination and adoption of modern techniques of mango cultivation among farmers.

Poor cultivation practices

General neglect and non-adoption of scientific cultivation practices are major constraints. It results in the production of mango in this region far below the national average.

Lack of marketing facilities

Due to lack of organized marketing structure in the NER, farmers are getting low return compared to the other parts of India, whereas the middleman gets the profit at their expenses.

Scarcity of trained manpower and extension support

Dearth of trained manpower and low priority to mango in the development plans of the north eastern states are some of the factors responsible for ineffective extension programme.

Problems of processing

The processing industry can help in sorting out the problem of proper disposal of perishable commodities. Lack of cold storage facilities as well as food processing industries are also important factors for low production of mango in this region.

Less expenditure on mango research

Poor investments for research on mango have results in poor technological support.

Future Strategies

Collection, characterization and conservation of germplasms

There is a need for extensive survey and collection of all the local germplasm in the region. These germplasm should be utilized in strategic breeding programme involving high yielding national varieties.

Identification of specific areas suitable for cultivars and hybrids

There is need to identify suitable area based on soil-site suitability assessment for cultivation of high yielding cultivars and hybrids in the region.

Hi-technology

Hi-technology has to be deployed, which is less environment dependent but capital intensive and has the capacity to improve productivity and quality of mango. Hi-technology includes micro propagation, micro irrigation, fertigation, protected cultivation (greenhouse/ polyhouse cultivation), organic farming, mechanization and use of remote sensing.

Infrastructure facility

The basic infrastructure facilities like packing and grading shed, short and long term cold storage facilities, refrigerated containers, phytosanitary facilities are the

need of the hour.

Post harvest management and processing

Emphasis on post harvest handling, packaging, transportation, value addition needs to be given for promoting agro-based industries in this region.

Emphasis on organic farming

There is need for research on standardization of doses of different organic fertilizers like FYM, green manure, vermicompost, neem cake, biofertilizers, etc. for the production of high quality mango in this region.

Conclusion

Systematic cultivation of mango is urgently required in the North Eastern region for improving the socio-economical status, livelihood generation and creating employment. Mango cultivation has the potential to provide food, nutrition, health security and livelihood opportunity in the region. Soils at an elevation lower than 600 msl and those soils with a moderate acidity are suitable for mango. Inspite of this fact, the North Eastern Region provides enough scope for the fruit crop to flourish due to climatic and other aesthetic reasons. Development of proper infrastructure facilities coupled with technical support is the need of the hour for promoting mango cultivation in the North East. Among the cultivars and hybrids, Amarapali and Mallika are the most promising in this region and further research is needed for evolution of better genotypes suitable for this region.

References

Naidu, L.G.K., Ramamurthy, V., Challa, O., Hegde, R. and Krishnan, P. (2006) Manual Soil-Site Suitability Criteria for Major Crops. NBSS Pub. No.129, NBSS&LUP, Nagpur, 118 pp.