Chapter - 5

AGRO-CLIMATIC BACKGROUND OF KARNATAKA
Coconut is unique in all respects among horticultural crops grown in the country as a source of food drink, shelter. Its raw materials are also used for industrial purposes. This crop assumes considerable importance in the national economy in view of the income and employment potential for rural population (Namashivayam, N. and Richard Pual, 2004).

In the domestic economy of the inhabitants of the tropical countries, every part of the coconut tree is utilized in some manner or other. The coconut palm (*Cocos nucifera* Linn.), the tree of heaven, belongs to the family Arecaceae. It is monocotyledons palm without top root and the stem is unbranched. It is a monotypic species with partropical distribution.

Coconut palms are successfully grown in the tropical climes and are referred to as “King of the Tropical Palms”. According to Mayuranathan the Arabs who were trading with India, called it an Indian fruit from very early times and they further vedic times depicted in Mahabharata, Ramayana and other Puranas and Sri Lanka in about 300 B.C. There was a popular belief Kerala which literally means the land of ‘coconuts’. However, neither India nor Sri Lanka can be considered the original town of coconut. The spread of coconut to regions of the world might have been affected through the agency of man and sea (Mandal, R.C., 1998).

Coconut stands out as the foremost amongst the palms that human kind has discovered for its multifarious uses to sustain and support of life. The outstanding range of its use includes the utility of coconut and its products as food and medicine. According to some versions, coconut was one of the five trees that emerged during the charming of the milky ocean. Tradition has placed coconut as a tree that has descended from the heaven. A tree that can remove disease, promote health and improve the quality of life (Rammonohar, P., 2005).
Coconut area in the state could be broadly classified into three categories; i. The coastal tract: Extending from Northern tip of Kerala state in the south to the border of Goa in the north covering coastal districts Dakshina Kannada and Uttara Kannada. This region has distinct humid and warm climate with annual rainfall of 200-300 cm. ii. Dry tract: This is the vast area extending from 200 kms from sea almost confined to south central districts of the state comprising low lying valleys of Tumkur, Hassan, Chitradurga and Chikmagalur districts covering 60 percent of the state. iii. Irrigated tracks: Large number of gardens is developed where tank, canal and lift irrigation water was available. There are large jointly owned compact coconut gardens ranging from 20-25 hectare in Bangalore district alone (Prasanna, K.P.R., 1989).

Climate and soil

Karnataka State, which has been in the fore-front in respect of agricultural and horticultural production, is blessed with an ideal agro-climatic condition (ten zones) and enterprising farming community. The State has a salubrious and moderate climate, which accounts for an enormous area under horticulture and also it is receiving an active support from the State as well as Central Government (Hanumaiah, L., 2004-05).

The coconut palm is not very fastidious in its climatic requirements in fact it is highly adaptable to a variety of environmental conditions but is considered essentially a tropical plant. It likes a climate characterized by warm and humid conditions. Coconuts are grown in Karnataka either in the gardens irrigated by tank water, in wide shallow valleys or on river banks for satisfactory yield. On land areas, palm requires soil that permits root penetration and good aeration with adequate moisture, as its roots cannot withstand stagnation of water. The light textured soils with good depth and good drainage conditions are for superior to rich fertile soils with impeded drainage (Kumar, D.K., 2002).
Karnataka is bestowed with a variety of soils and climate in its different regions which are congenial for the development of most of the temperature, tropical and sub-tropical fruits vegetables, flowers, spices and plantation as well as tuber crops. Physiographically, the State divided into four regions viz., the coastal region, the malnad region and central region. In coastal region, the soils are alluvial and the annual rainfall is 2540 mm. The main horticultural crops are coconut, arecanut, potato, mango, lemon and pineapple and spices quantities. The hilly region includes the Western Ghats region, the soils are mostly laterite and the rainfall varies from 1,524 to 6,350 mm. The crops grown in the region are coconut, arecanut, pineapple, mango, jack, banana, sapota and potato and vegetables which are reddish and medium black. The rainfall varies from 1,016 to 1,524 mm. Different fruits, vegetables and spices are grown in these regions. The dry central northern and south-eastern region has mostly black cotton laterite, sandy loam and mixed soils. These tracts are dry receiving about 262 to 382 mm rainfall annually. The important fruit crops are grapes, guava, sapota, mango, jack, coconut, arecanut, beteleaf, cashewnut, chillies, onion and vegetables (Puttaswamaiah, K., 1983).

The coconut palm is found to grow under varying climate and soil conditions. It is mainly a tropical plant, growing between 20°N and 20°S latitudes. The coconut palm requires a warm climate without too great diurnal variation of temperature. The ideal annual temperature is usually put at around 27°C (18° F) and the average diurnal variation between 5°C and 7°C (9°F and 12°F). Various authors quote figures of a degree or two either side of 27°C for the optimum. The palm does not flourish in climates with mean temperatures below 20°C (68°F) that of Florida (the place farthest from the equator at which coconuts are successfully grown) is 25°C. The mean temperature of the coldest month, January, being 20°C and of the warmest, August 28°C. Occasional short
spells of low temperatures, provided they do not reach freezing point. Frequent, even short periods of temperature below 15° C result in abnormalities of the fruit such as bicarpelate nuts.

Higher temperature than the optimum are tolerated and are only harmful when they coincide with low humidity, possibly aggravated by hot dry winds, causing a rate of transpiration from the leaves insufficiently compensated by water supply through the roots.

The palm grows best under a rainfall between 1,300 and 2,300 mm well distributed throughout the year. Much higher precipitation, even upto 3,800 mm are tolerated provided that soil drainage is good. They may however have some disadvantage in that sunshine is less during wet weather and excessive heavy falls may cause soil erosion and leading.

There are districts where coconuts are successfully grown which have annual rainfall much lower than 1,300 mm. These are coastal districts or lands at the base of inland foot hills, which receive a constant supply of seepage water from higher ground. Where such favourable soil water conditions do not occur and the rainfall is likely to fall below 1,300 mm, coconut palm can only be grown under irrigation or under conditions amounting to natural irrigation. Near the equator, productivity of coconut plantations can be established upto an elevation of about 1,000 mm per year and well distributed throughout, is the best for proper grow and maxim yield (Reginald Child, 1985).

The gardens in Karnataka located about 150 miles to 200 miles inland are some of the best gardens in India. The largest area under the coconut is located on the red laterite soils goods yields are obtained in black clay soils also. The best soils for the coconut are rich alluvial soils with sufficient quantity of sound so as provide good drainage (Patel, J.S., 1996).
In Karnataka, major portion of the coconut gardens is located in the coastal areas and the rest is distributed in the interior maidan regions. This is an undulating open area with an annual rainfall of 60-70 cm and devoid of dense forests. This area helped to find out the physiographical, morphological, chemical and mineralogical variations.

In the central and southern parts of Karnataka are located between 12-30° to 13-45°N and 76-77°E and distributed in Channapatna, Ramanagaram, Turuvekere, Chikkanayakanahalli, Tiptur, Arsikere and Channarayapatna taluks of Bangalore, Tumkur and Hassan districts. In general, the area has a semiarid, subtropical climate with an average annual rainfall of 60-70 cm. The maximum precipitation occurs during June to September. The mean maximum temperature is 35-40°C and mean minimum temperature 10-15°C geologically, the area dates back to Archean era. The dominant rock types are grants and genite gneisses with intrusions of dolerites and diorites. Quartzizites and schistore rocks are common in Tumkur and Hassan districts.

The general topography of the area is ridge and valley type. The coconut gardens in these areas occupy valley, bottom, stream and river banks. A glance at the area in parts of Tumkur and Hassan districts clearly indicates the distribution of coconut gardens in all the valley areas, while it is more concentrated along the major drainage line in Bangalore district (Murthy, R.S.).

The coconut is also grown on hills slopes but terracing has to be resorted so as to prevent erosion and to facilitate cultural operations. The stem bleeding disease is common in places where the drainage is bad. It is equally true that soils lacking in water holding capacity and where no underground supply of water is available are useless for growing the palm. Hard rocky pan near the surface of the soil is undesirable, because during the rainy seasons the trees suffer from water logging. Palms standing on the bunds of rice fields yield very
well as under these conditions sufficient aeration of the roots, adequate supply of water to the plant and good amount of light to the leaves are assured. The red laterite soils which support the majority of the palms are deficient in available phosphate, potash and lime. The chemical analysis of the typical soils on which, the coconut is largely grown in Tamil Nadu and South India.

The soils of the coastal tracts are well drained vary from fine sand to sandy loam and are ferruginous. The soils of the deltaic regions are heavy alluminium and poorly drained. The water table has been rising on the coastal tracts and it is hoped that this will benefit the coconut industry on the coast (Patel, J.S., 1996).

Coconut is one of the major traditional plantation crops in Karnataka. The coconut is being grown in the 13 main districts of the State, but the major coconut growing areas comprise Kadur, Arasikere, Tiptur, Channarayapatna taluks and Brahmavara and coastal regions. Climatic and rainfall conditions were found to be suitable for coconut plantations in these five taluks of Karnataka. In addition to climate and rainfall conditions, soil suitability is also very important. Soil is a basic and non-renewable resource and dynamic medium for plant growth.

Coconut is the most important garden crop in Karnataka. The coconut palm flourishes well in highly red soils, sandy loams, light alluvial soils, rock debris and low-lying areas and tanks beds. It requires equitable climate, bright sunshine and well distributed rainfall. It cannot withstand heavy drought and as such, it is irrigated during dry season. Coconut trees are usually propagated from nuts which have not been begin to bear fruit after three to twelve years, depending upon the variety and the nature of the soil and continue to yield till they are about fifty to eighty years (Karnataka Gazetteer, 1983).
Cultivars and hybrids

Of the varieties of coconut available in India, the West Coast, which is also known as the ordinary or common tall variety, is the one is extensively cultivated in all the important coconut tracts in the country and is great commercial importance. It is found to grow well in littoral sand as well as in the interior and up an attitude of about 3000 feet above sea level. It has been cultivated in India from very ancient times and may therefore, be considered as indigenous to the country.

The west coast variety is a long-lived, hardy, multi-purpose palm, yielding nuts, copra oil and fibre of good quality. The tree also yields, on tapping good quantity and quality of coconut juice or today which can be fermented or converted into jaggery or sugar. In this variety, growers recognized different sub-varieties or forms based mostly on the colour and shape of nuts or bearing capacity. The nuts are generally of medium size, varying in shape from spheroid to linear with colour varying from green, yellow and yellow orange to shades of brown. Some of the forms show variation in the thickness of husk and the thickness of meat or kernel.

Trees yielding a large number of medium sizes round nuts in almost every leaf-axil without any tendency for bunch to buckle or droop are considered the best for planting on a large scale. Under favourable conditions, the variety commences yielding nuts in about six to eight year after planting. The time of first bearing is prolonged to 8-10 years or ever if conditions are favourable.

The yield varies according to the ecotypes selected for cultivations and the conditions under which they are grown. The average yield of copra per nut is about 5.02 with oil content of about seventy two per cent.

The dwarf or short variety, which has three distinct forms, i.e., producing green orange and yellow nuts, respectively is liked by some planters for its
earliness in bearing, short stature and attractive colour of the nuts. The palms are commonly known as Nicobar or Andaman dwarf and also by different local names. They begin to yield nuts in about three to three and half years after planting and throw out bunches with fairly large number of nuts. They are, however irregular in bearing.

The bunch with attractive coloured nuts is generally used for decorative purposes. The nuts are small in size and avoid or round in shape. They are often harvested in the tender nut stage for the sweet water which provides a cool and refreshing drink. The copra obtained from the nut weight about 3.02. It is leathery and is not much commercial importance. The variety is found to be very susceptible to diseases and pests. For these reasons, it has to be considered as an economic variety.

**New Guinea**

This is a robust palm with tall and stout trunk. The nuts are large, spheroid or ellipord in shape and with colour varying from green to brown. They contain plenty of sweet water in the tender nut stage. The quality of the copra is not as good as that of the west coast variety. In the gravelly soil of the west coast, the palm yields, on an average, about sixty five nuts per tree per year.

**Cochin China**

This is a robust palm giving nuts which are large sized, spheroid in shape and with colour ranging from green to shades of brown. The water in the tender nut is sweet and plentiful. The variety yields about eighty six nuts per tree per year.
Java

This is a tall variety with fairly stout trunk. The nuts are medium to large in size and round or some what elongated in shape. It yields about 95 nuts per tree per year.

Siam

This is a fairly robust palm. The nuts are green in colour and medium to large in size and ellipsoid in shape. The water in the tender nuts is sweet. The variety yields about 50 nuts per tree per year.

Laccadive ordinary

This variety resembles the ordinary west coast variety. The nuts are medium sized. The yield per tree per annum is about 124 nuts.

Laccadive small

The palm resembles the ordinary west coast variety in stature, but the nuts are small in size and spheroid or linear in shape. Large number of nuts is produced in a bunch and the copra is of good quality. The palm is however, an alternate bearer and produces not less than 150 nuts per tree per year (Agriculture and Animal Husbandry in India).

Coconut palms are broadly classified into two groups: the tall and dwarfs. The tall cultivars are the common type that occurs throughout the world. The tall cultivars largely grown in India are the west coast tall and east coast tall. The dwarf varieties are shorter in stature and life span as compared to talls. They start bearing earlier compared to talls. The size of the nut and the quality of copra are inferior to talls. The dwarf cultivars occur with 3 nut colour of nuts like green, yellow and orange. The common dwarfs available in India are chawghat orange dwarf, chawghat green dwarf, Malayan green dwarf, Malayan yellow dwarf, ganga-bondom, etc.
The hybrids between tall and dwarf forms show hybrid vigour for growth and yield. The hybrids are produced using tall and dwarfs. When the tall is used as female and dwarf as male they are called (TxD) while the reciprocal is known as (DxT). Lakshaganga (LOxGB) is a (TxD) hybrid while Chandra Sankara (CODxWCT) is a (DxT) hybrid. Lakshaganga, Chandrasankara, Chandralaksha (LOxCOD) are superior hybrids and yield over 19-24% over other combinations and their parents. Tamil Nadu Agricultural University is a (TxD) hybrid between east coast Tall x Malayan, yellow dwarfs, which has given about 26 per cent more nut yield (Coconut Gardens, 2005).

Elite coconut seed farm was established in Bangalore district in 150 acres, where TxT elite coconut seedlings would be produced. Production and distribution of TxD hybrid seedling of coconut by controlled hand pollination was taken up at Krishnarajasagar Research Centre with a view of supply of TxD coconut seedling annually (Mandal, R.C., 1991).

Based on the available information on the performance, the following tall cultivars are found suitable in the states noted against each.

1. **West Coast Tall**
   
   Kerala, Karnataka, Gujarat, Bihar, Orissa, Assam, Tripura, Tamil Nadu, Madhya Pradesh.

2. **Chandrakalpa (Lo)**
   
   For all the states.

3. **Andaman ordinary**
   
   Andaman, Andhra Pradesh, Bihar, Orissa, Assam, Kerala, Tripura, Tamil Nadu, West Bengal, Pondicherry.
4. East Coast Tall
   Tamil Nadu, Orissa, Andhra Pradesh, Bihar, Madhya Pradesh, Pondicherry, Andaman, West Bengal.

5. Tiptur and Arsikere Tall
   Karnataka.

6. Benaulim
   Maharashtra and Goa.

7. Chawghat Orange Dwarf
   For all States.

8. Philippines Common Dwarfs
   Kerala, Tamil Nadu, Andhra Pradesh.

9. Anandaganga (DOTxGTGD)
   Kerala.

10. Chandralaksha (LCD - COD)
    Karnataka, Kerala.

11. Chandrasankara (LODxWCT)
    Kerala, Karnataka, Tamil Nadu.

12. Kera Ganga (WCTxGBGD)
    Kerala.

13. Kera Sankara (WCTxCOD)
    Kerala, Karnataka.

14. Kera Sowbhagya (WCTxSS Apricant)
    Kerala.

15. Kerashree
    Kerala.
16. Laksha Ganga (LCTxGBGD)  
   Kerala.

17. VHC - ECTxCGD  
   Tamil Nadu.

18. VHC-2, ECTxMYD  
   Tamil Nadu.

19. VHC-3, ECTxMYD  
   Tamil Nadu (Chadha, 2005).

**Planting materials**

Being a monocot, the coconut palm is propagated only through seeds. As the palm is usually cross-pollinated in nature, the following steps are required to be taken for the production of quality planting materials.

Selection of seed nuts and seedlings is of utmost importance in coconut as the performance of the new progeny cannot be evaluated only several years after planting. If the seed nuts and seedlings are of poor quality, then the new plantation will prove to be uneconomic, causing considerable loss to the grower. Since coconut is a cross fertilized palm, the selection of seedlings in the nursery is difficult. By means of a series of selections made at different stages, it is possible to eliminate poor quality seed nuts and seedlings.

For collection of seed nuts in a large scale certain ideal centres are to be located in each country, according to the yield and quality of nuts produced there. Based on the past records of consistently high yields with good quality nuts and proportionately a good number of heavy bearers, exist such guards should be selected for collection of nuts. Care should be taking that such plantations and the adjoining areas are free from the incidence of major pests and diseases.
Selection of high yielding mother palms has proved to increase the productivity. In India, it is reported that 15 per cent more yield can be achieved by selection of mother palm; while in Sri Lanka, 50 per cent efficiency has been reported. In selected seed gardens which have relatively higher mean yield, mother palm should be carefully marred out for seed nut collection, based on certain visible phenotypic and easily discernible characters. The middle aged palms should be preferred as mother palms so as to make sure their yielding ability. In a perennial or long duration crop like coconut palm, which also exhibits considerable genetic variation, the selection of right type and use of quality planting material are of utmost importance (Mandal, R.C., 1991).

Establishing Plantation

Selection of site

Coconut thrives well in lands reclaimed by heaping alternate layers of sand and clay. Proper supply of moisture either through well distributed rainfall or irrigation and sufficient drainage are essential for coconut (Prasanna, K.P.R., 1989).

Coconut is being grown in a variety of soils in Karnataka state starting from pure sand in the coastal area to black cotton soils in northern Karnataka. Deep red loams of dry tract are rich in plant nutrients and have good water holding capacity, whereas the coastal laterite soils are deficit in plant nutrients and need plenty of manuring and irrigation for raising a good crop. Gardens developed on shallow soils with a gravel base suffer very much. Although they exhibit good vegetative growth, the yields are very poor. Similarly, the low lying areas with high water table and inadequate drainage with planting exhibit poor growth, leaf yellowing followed by leaf spotting and rooting symptoms, are also commonly seen. In some gardens in Tumkur district Ganoderma disease is also observed. Prolonged water logging results in the death of young seedlings (Mangala Hegde, 2000).
Preparation of land and planting

Preparation of land for planting seedling size of pit for planting depends on soils type and water table. In soils with low water level take pit size of 1x1x1 m. In sandy soils, take pit size of 0.075x0.75x0.75. Follow two layer of husk burial for water conservation. Bury husk in layer with concave surface facing upwards.

Preparation of land for planting coconut depends to a large extent on soil type and environmental factors. If the land is uneven and fall of shrubs, then the shrubs have to cleared and land, leveled before taking pits. The depth of pits will depend upon type of soil. In laterrite soil with rocky substratum deeper and wider pits (1.2x1.2x1.2) dug and filled up with lose soil. Powdered cow dung and ash upto a depth of 60 cm must be filled before planting. In loamy soil with low water table planting in (1.0x1.0x1.0 m) pits filled upto fifty cm depth is recommended.

Arrange two years of coconut husk at the bottom of the pit before filling up the soil with concave surface facing up, this will help in conserving the moisture. In the laterrite soil, addition of two kg of common salt will help in loosing the soil (Mandal, R.C., 1998).

Spacing

The main garden being coconut plantation, the square method of planting in respect of tall varieties will be adopted 9mts x 9mts (30 ftx30 ft) distance will be provided in order to give room for sunshine. Dwarf varieties will be planted as double row method at 6.5 mts in triangular system, leaving (30 ft) 10mts in between two rows. The other crops will be as mixed / inter crop giving proper spacing in the garden, limiting to the maximum numbers.
The coconut palm is a light longing plant and hence founds of adjustment palms should not over tap cut off the light. Seventy three per cent of the roots of coconut palms is concentrated within a radius of two meters around the palm occupying an area of 12.5 sq. m. around each palm. Out of a total of 57sq. m. (when palms are planted (7.5x7.5m), 45.5sq. m. are left around each palm available for cultivating inter crops. This will be available for cultivating inter crops. This will accommodate 177 to 124 palms per hectare under the square system of planting. If the triangular system is adopted giving a spacing of 5.0 to 5.5 m along the rows and 9 to 10 m between the rows (Prasanna, K.P.R., 1989).

The recommended spacing for coconut in the state Karnataka is 7.5 to 8 m for tall varieties and seven meter for dwarf and hybrid varieties. However, close spacing of six to seven meter is also common in coastal districts and a wider spacing of eight to ten meter is adopted in dry tract. The yields are always low in closely planted gardens. Square method is the most popular methods followed and border planting around gardens is also restored to where seasonal crops are grown. Both surfaces planting and deep planting are followed by farmers. In low lying areas and paddy fields, planting is done on mounds raised to ten to fifteen cm which are later joined to form a continuous bund (Prasanna, K.P.R., 1989).

Time and planting

In well-drained soils where water stagnation is not a problem, seedling can be transplanted with the beginning of south-west monsoon. If irrigation facilities are available, it is advisable to take up planting at least a month before the monsoon sets in so that the seedlings get well established before the onset of heavy rains. Planting can also be taken up before the north-east monsoon. The best period for seed nut collection would be from January to April on the West Coast and February to May-June on the East Coast of India, as those nuts are big
in size with maximum copra-content and give a high percentage of early germination and good vigour of seedlings. The season of harvest varies from tract to tract according to local climatic conditions (Mandal, R.C., 1991).

The most common practice is to plant 12-18 months old seedlings supplied through Government nurseries. However, in the dry tract farms plant two to three years old secondary seedlings raised their own yards. These seedlings are moved from the nursery with a ball of earth for planting to reduce seedling mortality, withstand prolonged dryness and to protect from cattle damage (Prasanna, K.P.R., 1989).

Cares of young palms

Sufficient attention will have to be paid to the young palms in the early years of growth. The transplanted seedlings should be shaped and irrigated properly during the summer months. Irrigation with forty five litres of water once in four days has been found to be satisfactory in sandy soils. The pits should be cleared of weeds periodically and widened every year before the application of manure. The palms should be frequently examined for any fungus or insect attack and necessary remedial measures should be taken up promptly.

Manuring

It is general practice in India to bury coconut trees. Most growers use organic manure regularly consisting of about twenty five to fifty five kg cow dung, green leaves, ash compost, fish manure and bonemeal per tree. In addition, upto four kg of biofertilizer, 8:8:16 chemical fertilizers are used. Small farmers use proportionally more organic fertilizer, resulting from home composting than larger farmers. Large holding receive more cultivation that small lots do. Coconut husks are rich in potash, if forms 15 per cent of the dried husks and 30-
35 per cent of husk ash. Two kilograms of such ash is equivalent to one tonne (0.9 tonne) of muriate of potash.

An application of 500 gm N, 320 gm P₂O₅ and 1200 gm K₂O per palm is recommended for adult plantations. Fertilizer-like urea, rock, phosphate, sulphate, muriate of potash etc., used to supply the required quantity of nutrients. Fertilizer applied in two split doses. After the receipt of summer shower one third of the recommended dose of fertilizer spread around the palms with a radius of 1.8 m and forked in circular basins of 1.8 m radius and 25 m depth dug in August-September and green leaf or compost at 50 kg per palm is spread in the pits.

Regular manuring from the first year of planting is essential to ensure good vegetative growth early flowering and bearing and high yields. The first application of fertilizer should be done three months after planting, when the south-west monsoon ends on the west coast, if seedling is planted before the rains in May-June. In addition to fertilizer, 1.0 kg dolomite or 1.0 kg of lime plus 0.5 kg of magnesium sulphate per palm per year applied in acidic soils. Dolomite or lime is broadcast in April-May in the basins and should not be applied with other fertilizer management. Sulphate can be applied along with other fertilizer in the basins is September.

In Karnataka, application of farmyard manure/cattle manure, compost and green leaves are common practices to improve soil fertility and water holding capacity of soil which also help to utilize the fertilizers applied, more effectively. Practices like application of neem cake, fishmeal, common salt, poultry manure, bonemeal spreading red earth, tank silt and sheep parking are also adopted. Green manure crops, particularly, horse gram, is grown and incorporated into the soil. In the coastal districts fertilizer are applied at the end of heavy rains in September-October in irrigated area applied twice before and after monsoon. However, in gardens with assured irrigation and better management,
bio-fertilizers are applied along with manures four to six times in a year in split doses.

**Irrigation and soil moisture conservation**

The coconut palm corresponds to summer irrigation. Under west coast conditions two cm irrigation once in a five days during December-February and once in four days March-May, has been found to be beneficial in sandy loam soils in increasing yields. Where basin irrigation is practiced 200 litre per palm once in a four days will be beneficial. In areas where water is scarce drip irrigation system can be adopted. Addition of coconut pith or coir blust as a mulch at twenty five kg per palm basin or mulching with husk with the convex side upwards will help in conserving soil moisture (Mandal, R.C., 1991).

Majority of the area under coconut, both in coastal and dry tract is rainfed. Good gardens are developed under irrigation using lift irrigation wells and tanks. Basin irrigation is the most common method adopted. However, in canal areas where water is adequate flood irrigation is preferred. In some parts of coastal area, perforated posts are buried at the base of the trees to supply moisture to the palms. Drip irrigation is gaining popularity in the state. A good number of small, medium and large coconut holdings are being brought under drip irrigation. Coconut gardens in the coastal area large basins around the palms and are opened two to three times a year (Prasanna, K.P.R., 1989).

**Inter-cultivation**

Regular inter-cultivation and adequate manuring are very essential to set up and maintain the production at a high level. Tillage operation like digging the garden with spade, ploughing, forming small and mounds in August-September and spreading them in December-January and making shallow basins with a radius of about two meter at the beginning of monsoon are beneficial to the trees.
Methods of inter-cultivation will depend upon local conditions, availability of labours size of holdings soil type, topography and distribution of rainfall.

A good number of intercrops and mixed crops are being grown in coconut gardens at various stages depending on the planting distance and irrigation facilities.

Cover cropping

Cover cropping is recommended where inter and mixed cropping is followed to prevent solid erosion is coconut gardens and this adds organic matter to the soil. Leguminous crops like Mimocainuisa, Stylosenethese gracilies and Calopogonium, munenoides are generally recommended.

Inter and mixed cropping

Cultivation of two or more crops on the same tract/piece of land is an age old practice in India’s agriculture. The importance of cropping systems can be considered in a wider perspective as combination of activities leading to diversification or specialization in agriculture. It has importance both from the point of view of individual farm and nation as a whole. In the former case, it is a question of combination of crops to be grown on limited farm or land area and with the given quantities of labour, capital and management resources (Mangala Hegde, 2000).

A good number of intercrops and mixed crops are being grown in coconut gardens at various stages depending on the planting distance and irrigation facilities. In coastal districts mixed crops like cocoa, pepper, banana, pineapple, nutmeg, clove and cinnamon are being grown. In irrigated areas vegetables crops like beans, brinjal, cabbage, cauliflower, potato etc are grown. Commercial crops like sugarcane, cotton, ginger, turmeric, mulberry, groundnut, sunflower etc are grown. Flower crops like jasmine, marigold, artery etc., and fruit crops like
guava, lime, pomegranate, banana, papaya, watermelon etc., are grown during the few years. Later only such crops which can tolerate partial shade like coffee, banana and pepper could be grown profitably. In rainfed areas ragi, jowar, teiild beans, green gram, black gram, horse gram, groundnut, ginger etc., are grown in Karnataka (Prasanna, K.P.R., 1989).

In recent years many coconut farmers have suffered economic difficulties due to unstable copra and nuts prices in world and local markets and occurrence of pest and diseases. Being a small holder crops in India, coconut does not provide adequate income and gainful employment to the dependent families. In a situation where the coconut industry is threatened with recurring uncertainties, the need for a farm practice that augments the coconut farm income becomes clear and urgent (Maheshwarappa, H.P. and Anitha Kumari, 2002).

Inter-cropping is one of the agronomic strategies for efficient resource use and to have higher farm productivity. Intercropping have several advantages over sole cropping. Food crops such as tubers, cereals, legumes and fruits; species and condiments such as arecanut, betel vine, chillies, ginger and turmeric; cash crops like black pepper, cocoa, cinnamon, cloves, coffee and nutmeg; cut flowers like anthurium and orchids and pasture crops are grown under coconut trees. Intercropping with medicinal and aromatic crops has been found remunerative. Coconut yam inter-cropping is available agro-technique to improve the farm productivity (Surendran Kumar, P.S. et al., 2002).

Inter-cropping refers to the cultivation of annuals or biennials in the inter-space of coconut garden. Tuber crops, fruit crops, rhizomes, cereals, pulses and vegetables are grown well in coconut garden. Suitable crop combination can be selected depending on the agro-climatic condition, soil type and marketability. Banana, pineapples are the most popular fruit crops grown as intercrops in coconut gardens in Indian condition. Papaya also can be intercropped in a coconut garden. The economic feasibility of raising short and long season annual crops like elephant, food yam, turmeric, ginger, sweet potato and
colocasia in a middle aged coconut garden was investigated at one of the research station.

Profitability of growing vegetables also has been proved beyond doubt. Resign of chillies, potato and French beans is found to be a profitable practice in Malnad areas of Karnataka. The experiments conducted in Kasaragod have shown that the vegetables like snakeguard, bottleguard, coccinia, brinjal and bitter-guard are compatible intercrops in coconut gardens. Ginger and turmeric are the two important rhizome spice crops commonly intercropped in coconut gardens.

Leguminous pulse crops help in enriching the soil with nitrogen. Among the pulse crops cowpea, black gram, green gram, Bengal gram, short duration red gram and soybean give satisfactory yield in the Malnad areas of Karnataka. Soybean is also highly promising as inter crop in coconut gardens. Oil seeds crop like groundnut and sunflower are remunerative intercrops in coconut garden, which enriches the soil. In Karnataka, intercropping with groundnut is a common practice in young and old coconut plantations orchids. Anthuriums and other cut flower and ornamentals can be successfully grown as intercropping coconut garden.

In the state like Andhra Pradesh and Karnataka floriculture is a common enterprise adopted in coconut plantations. Presently, there is high demand for natural herbs used in the preparation of ayurvedic medicines. Crops such as lemon grass, kacholam, dioscorea, arrow root, sida, thippali (long pepper), Aalaarmari and adapthiyan are suitable as inter crops in Indian condition in coconut gardens. In Maidan tracts of Karnataka, inter-cropping with eleven crops in coconut plantation.
Mixed cropping

Growing of perennial crops with coconut is termed as mixed cropping. Crops like cocoa, pepper, nutmeg, cinnamon, coffee, betel, vanilla and mulberry have been proved to be highly remunerative. Cocoa is an ideal crop for coconut garden. Clove is also grown as a mixed crop in coconut gardens. In fertile well drained soils with assured irrigation in the west coast as well as evaluated areas of Karnataka. It is planted at the centre of four coconut palms. Cinnamon crop can be planted in the double hedge system at spacing of three meter between plants.

Multi-storied cropping

Coconut gardens above twenty years old are suitable for multi-storied cropping where in crops having different morphological characteristics are planted in the interspaces as to intercept sun light at different levels and to draw nutrients from different soils depts. This system has four crops consisting of coconut black pepper trained on coconut, cocoa and pineapple. Several crop combinations were tested in a multi-storied cropping experiment in order to identify the most remunerative crop combinations. Of the several combinations of perennial crops tested, the most productive and remunerative combination was coconut + pepper + cocoa + pineapple. Under the crop combination of coconut + cinnamon + pineapple + pepper; the annual per palm yield was 69 to 70 nuts whereas it was 92 to 98 nuts under coconut + cocoa + pineapple + pepper.

High density multi-species cropping system

High-density multi-species cropping system involves growing a large number of crops to meet the diverse needs of the farmer such as food, fuel, timber, fodder and cash. This is ideally suited for smaller holdings and aims at maximum production per unit area of land and time simultaneously ensuring sustainability. This system includes annuals, biennials and perennial. The crops
selected include cash crops, food crops and fodder crops. The biomass, other than the economic part is recycled within the system. The annual crops are moved as the canopy size of perennial crops increases. In maidan areas of Karnataka state where coconut palms are planted at a wider spacing of 8x8, more and more growing of mulberry as a mixed crop and silkworm is popular. Through integrating sericulture with coconut cultivation sustainable increase in the net income and employment potential is achieved under all India coordinated research project on palms, the coconut based high density cropping systems applicable to different agro climatic regions were evaluated at Ambajipet, Arasikere, Kahikachi, Rathagire and Veppakulum to identify the most compatible component crops which would generate maximum, economic returns. The crop combinations were elevated and profitability assessed at various centres, Arasikere-clove, nutmeg, pepper, pineapple, mango, banana and coffee; Kachikuchi-pepper, betelvine, citrus, pineapple and banana; Veppankulam-subabul, guava banana, topicocoa, sweet potato, tumeric and soybean (Rathinam, P., 2001).

Coconut based mixed farming system

Milk is scarce in areas where coconut is extensively grown mainly due to non-availability of fodder. Mixed farming by raising fodder grasses such as hybrid napier or guinegrass along with leguminous food crops such as *Stylosanthes gracilis* in coconut garden has been found to be profitable raising the above crops in one hectare of coconut garden can support four to five dairy animals.

The inter-gradations of animal enterprises like dairying, poultry, bee keeping, sericulture, pisciculture etc., in a coconut garden along with compatible crops including fodder crop is termed as coconut based mixed farming systems. This system helps in maintaining soil health and ecological balance. In the mixed
farming system involving cultivation of shade fodder crops in the interspaces of coconut and integrating animal enterprises like dairy, poultry etc., the income evaluates manifold.

Adoption of any cropping system by the farming community will ultimately be decided by its economic advantages in Karnataka. Coconut based cropping systems enables maximum utilization of interspaces and solar energy leading to higher income from a unit holding. Coconut based farming system will have positive influence on soil health and would stimulate the natural resistance of the palm against disease causing pathogens and soil borne factor. This system ensures substantiability in coconut farming. Growing of crop combinations would be conducive for supplying slough ages and root exudates in the soil. These activities will lead to the multiplication of soil microflora and thereby increasing soil fertility which would ultimately result in the increased farm outputs at sustainable basis without creating any disturbance to the ecology. Deleterious effects of surfaced run of and soil erosion will also be reduced in this system. The fallen leaves, dead roots etc., have a salutary effect on the properties of soil through their degradation process and related activities undergoing in the soil. The beneficial effects of changes in the physico-chemical and biological properties of soil become apparent from the yield increase obtained under different cropping systems and increase in soil fertility status. The vermiculture facilities organic recycling and helps in maintaining soil fertility (Rathinam, P., 2001).

**Plant protection**

The coconut palm (*Cocos nucifera* L.) of India was reported to be affected by many pests. Coconut palm is affected by a number of diseases in different countries. Of these, some are lethal, while, other is of debilitating nature adversely affecting the production (Padmanaban, B. and Sukumaran, A.S., 1998).
The major insects pests of the coconut palm are the Rhinoceros, Leaf eating caterpillar, Opisina arenosella, Red palm weevil, root eating cock-chafers, deucapholis conesphora, eriophyidmite, the Asian palm weevil, coconut root grubs in Karnataka.

a. **Rhinoceros beetle**

The coconut *Rhinoceros beetle* commonly known as coconut black beetle viz., *Oryctes rhinoceros* L. is one of the major pest of coconut found attacking palms in all the countries where coconut is grown. The adult beetle cause damage brows and remains between leaf sheath near the crown and thus cuts the leaf in folded stage. It also attacks the unopened spatches and can cause 10 per cent annual reduction in yield. Frequent infestation results in leaf reduction, stunting of trees and death of growing points. The death is not common in grown up palms but the beetle may cause mortality of young seedlings (Padmanaban, B. and Sukumaran, A.S., 1998).

This is most serious pest. The adult beetle bores through into the unopened fronds and slather. The beetle breeds in a variety of materials such as decaying organic debris, farm yard manure and compost. The total duration of life cycle of this part is about 6 months. *Rhinoceror beetle* is a profit breeder and it can multiply whenever there are accumulations of decaying organic debris. As such, maintenance of sanitation in coconut gardens by producer disposal of decaying organic delibris is a important step in the management of Rhinoceros beetle. Mechanical method of central is possible by extracting the beetles with beetle hooks, without causing any further injury to the growing point of the palm. Filling the inner most three to four leaf axils of palms with a mixture of 5% B.H.C. dust and sand in equal proportions is effective prophylactic measure.

Integrated pest management is essentially a system of management of pest population, utilizing all suitable techniques harmoniously and blending them
in a compatible manner so as to minimize the pest (Padmanaban, B. and Sukumaran, A.S., 1998). Integrated pest management for Rhinoceros includes the following.

**Sanitation method**

Crown cleaning: Once in a year crown has to be cleaned to avoid the colonization of insects. Extraction of adult beetles with beetle hook and filling boreholes with mancozeb + sand mixture (3 kg + 1 kg). Treatment of breeding sites with 0.01 per cent carbaryl 50 wp (dissolve sevin 50 wp 1 hg in 5 litre water).

**Prophylactic method**

After crown cleaning, treat the crown with carbaryl: r-HCH 8g (sevidol 4:4g) + sand mixture at 1:8 ratio. This can be applied during pure and post-monsoon period at 45 days interval.

**Biological method**

Application of green Muscardine fungus, Metarhizium anisopliae 5x10⁶ spores/M³ in the breeding sites for biological suppression of all stages. Pheromone traps, pheromone traps/ha can be placed. The dispenser hanged in a plastic bucket having 2 litre of insecticide solution (1.5 ml endosulfon 35 EC+2 liter water) once in a week trapped beetles can be disposed off (Veeresh, G.K., 1982).

**b. Leaf eating caterpillar**

The leaf eating caterpillar is a serious pest of the coconut palm in India, Sri Lanka and Myanmar. It is distributed in the coastal and backwater area. The pest out break occurs during summer months. The caterpillar lives in galleries made of silken threads and their faecal matter on the lower surface of the leaflets. The life cycle is completed in two months, continuous feeding on the green
tissues results in the leaves dry up giving a burnt-up appearance. Infestation results in reduced yield.

The caterpillar live on the under surface of leaflets inside silken galleries and feed voraciously on the chlorophyll containing functional tissues. This affects the health of the palm adversely and results in the reduction of yield. With the onset of south-west monsoon the pest population begins to decline. Spraying of infested palms on the lower surface of leaves is essential.

Integrated management of this pest includes;

**Mechanical method:** Cutting and burning the heavily affected outermost 2 to 3 leaves.

**Biological method**

Release of larval parasitoids such as gonious niphantidis mues, Braconhebetor say and pre-pupal parasitoids like *Elasmusnosatio haber* at fixed norms.

The dose is to be fixed based on the target stages of the pest present at the time of observation. The norms fixed for the release are 20.5 per cent, 49.4 per cent and 31.9 per cent respectively for larval, prepupal and pupal stages. If all the three states of pest is noticed 40% of larval, prepupal and pupal parasitoids are to be released to have a good biological suppression of the pest.

**Chemical method**

Spraying with dichlorvor 0.22 per cent (1 ml in 2 liter water), malathion 0.05 per cent (1 ml / liter water) / endosulfan 0.5 per cent (1.5 ml / liter water), phosalone (Zolone) (1.5 ml / liter water).
Root feeding of monocrotophos: select a fresh and live root, cut sharply an angle to get maximum surface area and insert the root in the monocrotophos solution in a polythene bag. This is recommended for coastal areas.

Stem infection of ten ml monocrotophos, thirty six EC for maidan areas (method as described under red palm weevil). As indicated earlier, before root feeding and stem infection of pesticide, harvest the nuts and a waiting period of 45 days must be observed for harvest.

c. Red palm weevil

In recent years, red palm weevil has become a major concern to coconut plantations in India as compared to the other pests of coconut. This “hidden enemy that strikes to kill from within” is the most dreadful because once the palm is attacked it succumbs within six to eight months if timely control measures are not adopted. Of late, this pest has assumed serious proportion in all major coconut growing tracts of India as it is found throughout the year taking a very heavy toll on the coconut crop.

Symptoms of infestation

Generally, this pest enjoys wide host range, the pest infestation goes unnoticed and by the time the farmer recognizes the problem, the growing point or cabbage of palm might have been damaged. Infestation by red palm weevil is broadly of two types, through the crown and through the different parts of the stem, including the leaf-axil the hole. Red palm weevil in many cases, wilting or yellowing of inner leaves is invariably observed in such types of crown entries. This is the most dangerous type of infestation as the growing point of the palm is damaged much earlier than in other types of infestations. This type, unless identified early can never be successfully treated. As leaf-axils offer soft and protected areas they provide congenial sites for oviposition by the female weevils.
In leaf-axil entries, the green leaves may easily come off when pulled as the basal portions. Such leaves have been eaten up by the tissue borer. Such leaves, when dry up and fall, the presence of small round holes about 2 cm in diameter can be located on the stem. Usually from these holes exudation of a thick brownish viscous fluid and extrusion of chewed up and discarded fibres are sent. The bases of attacked leaves sometimes split and extrusion of fiber sis seen are from these cracks. The total number of leaves on an infested palm decreases due to the early drying of the bottom whorls and delayed emergence of fresh ones. Presence of cocoons and weevils or chewed up fibres in leaf axils or at the bottom of the palm on the ground provides indication for the presence of the pest. The graming and nibbling sound produced by the grubs during feeding is audible early in many cases. Injuries or cuts on the stem and bole portions happening through the cultural operations and implementations can also pave way for the weevil entry through these parts. The important control measures to be adopted against this pest are below.

Sanitation / cultural

The crown of the palms should be kept clean and tidy. Palms showing rhinoceror beetle damage and but rot and leaf rot diseases should be properly treated. The practice of making steps on the stem should be discouraged. Whenever leaves are cut from the palm, they should be cut leaving behind a length of 120 cm from the base. This is to ensure that even if the cut petiole attracts the weevils from oviposition, the emerging grubs would not reach the main stem as the petioles will dry up and fall within two months.

Coconut palms or any other host plant destroyed the pest should be cut and spit into small pieces. So as to expose and destroy the various stages of the pest inside the palm. The discarded plant parts are to be burnt along with the dried rubbish collected from the plantations. It has often been observed in many
gardens that the dead palm trunks are retained as such or only the crown position is removed.

In many cases farmers burn the dead palm trunks in their standing position without cutting / splitting. Often what happens in such cases is that the burning affects only the peripheral tissues of the trunk and the various stages of the pest lodged inside the palm are not killed and they act as breeding grounds and further dissemination sites. Care should be taken to see that uninfected palms especially those between the age group of five and 30 years that are cut for different purposes should be properly disposed off because these fallen and cut stems facilitate the spread of the weevil. Tapping and killing adult weevils help to reduce weevil population in all area.

**Prophylactic**

A prophylactic treatment of filling leaf axils of young palms with a mixture of twenty five gm senidol, eight gm granules and 200 gm of fine sand thrice a year during April, August and December will give protection to the palms against both rhinoceror beetle and red palm weevil infestation.

**Curative-chemical method**

The weevil-infested palm can be saved by the administration of Endosulfan at 0.1 per cent concentration or carbaryl at one percent concentration to the palms. These two insecticides were found to be highly effective against the pest and as they are contact insecticides they do not leave any residues on the crop. To prepare 0.1 per cent and 1 per cent concentration of the above insecticides, mix 3 ml Endosulfan or 20 gms of carbaryl in 1-1.5 liters of the insecticide suspension is required for treating one palm.
D. Root eating cockchafer

Root eating cockchafer or the soil inhabiting ‘white grubs’ cause damage to the roots of coconut. The leaves of affected palms become sickly pale yellow. In cases infestation, the immature nut will fall as well. *Leuccopholis* and other related species of cockchafer attack roots of coconut and other intercrops adversely affect the vigour of the palm and yield. The grub occurs in sandy and sandy loam soils feeding on the root of coconut resulting in yellowing of the leaves and loss of yield.

Integrated management of this pest includes mechanical method, cutting and burning the heavily affected outermost two to three leaves. In biological method, release of larval parasitoids such as Goniozys nephntidis mues. *Bracon hebetor* say and pre-pupal-parasitoids like Elasmus nosatio, Habu at fixed norms. The dose is to be fixed based on the target stages of the pest present at the time of observation. The norms fixed for the release are 20.5 per cent, 49.4 per cent and 31.9 per cent respectively for larval, prepupal and pupal stages. If all the three stages of the pest noticed 40 per cent of larval, pre-pupal and pupal parasitoids are to be released to have a good biological suppression of the pest. Spraying with dichlorvos 0.02 per cent of 1 ml in 2 liter water / malathion 0.05 per cent (1 ml/liter water), endosulfan 0.05 per cent (1.5 ml / liter water) phosalone (Zolone) 1.5 ml/ liter water). For root feeding of monocrotophos, select a fresh and live root, cut sharplus an angle to get maximum surface area and insert the root in the monocrotophos solution (Monocrotophos 36EC, 10ml water) in a polythene bag. This is recommended for coastal areas.

Stem infection of 10ml Monocrotophos 36EC for maidan areas (method as described under red palm weevil). As indicated earlier, before root feeding and stem injection of pesticide, heaviest the nuts and a waiting period of forty five days must be observed for harvest. On application of heptachlor 1.4 kg / ha
(28 kg of 5 per cent dust) in June or two application of B.H.C. at five kg ai/ha
(100 kg of 5 per cent dust) each in June and September to be applied and raked in
the top fifteen cm soil, would give effective control of the pest. Application of
phorate ten gm (Thiment ten gm) 100 g/palm twice during post monsoon season
is suggested in this method.

f. Coconut root grubs in Karnataka

In recent years, root, grubs belonging to the subfamily Melolonthinae and
Rutelinae of searabacidac (Coleoptera) have become major pests of cultivated
crops in India. Coconut too is attacked by these pests particularly in the young
stages.

Three species of white grubs damage coconuts in Karnataka. While
Leucopholis coneophora, Bur meister and L. pepidophora balanchard confine
themselves to heavy rainfall areas of coastal Karnataka and malnad, Hotorichain
Serrata fabricius is endemic to the plains.

Both the Leucopholis spp. occur together in the districts of north and
south Canara, Shimoga and Chickmagalur. They feed on both areca and coconut
roots. They have not been noticed to occur in plains so for ecology and chemical
control of this grub, five soil insecticides including chlordane 20 EC, durshan
200 EC phorate 10 g, counter 5 g and temik 10 g were tried under irrigated and
un-irrigated conditions at two levels each. Durshan 200 EC at 10 ml and counter
5 and phorate 10 g 20 g/palm with irrigation after insecticide treatment gave
good control of grubs (Veeresh, G.K., 1982).

g. Minor pests

The coreid bug (nut crinkler) Paradasynus rostratus has become a serious
problem in many parts of Kerala. It causes damage to the buttons and tender
nats. During summer months, mealy bugs cause damage to spindle leaves, swathes and bunches. The infested leaves turn yellow and finally dry up. The mealy bugs can be controlled with two rounds of spray with 0.1% fenthion or monocrotophos. Termites infest the trunk of palm occasionally. This can be controlled with 0.1% BHC or chordane spray.

h. Mammalian pest

Rats damage tender nuts and cause severe crop losses in many places. They can be controlled by providing mechanical barriers, position baits and traps. Rats can be killed by position batting using either single dose anti-blood coagulants like warfarin or function compounds. Coconut bunches can be protected from the ravages of fragivorous bats by covering bunches with throng twings of the wild plant *Ziziphus* sp. (Mohammed Jalaluddin, S. and Mohanasundaram, M., 1990).

i. Eriophyid mite

Eriophyid mite (*Aceria guerreronal* Keifer) is a serious pest of coconut. Occurrence of this pest in India was first reported from Ernakulam district by Suthiamma *et al.* (1998). The pest has been reported from Tamil Nadu and Andaman and Nicobar islands. Characters such as colour and shape were reported as factors influencing the extent of injury by the pest (Mohammed Jalaluddin, S. and M. Mohanasundaram, 1990).

Recently, the coconut cultivators in many locations in state suffered because of the production of extremely small sized coconuts. These cultivators faced severe loss as these small nuts were disused by the buyers in copra industry and almost 50 per cent of their produce failed to fetch the actual market price.
These mites inhabit the floral bracts and the tender portion of the nut covered by the perianth. They live by sucking the sap from the tender meristematic tissues. They harbour on the immature nuts, usually one to three months old, after pollination unfertilized female flowers did not harbour, these mites nuts upto nine months of age harboured the mite, but the fully mature nuts never contained any stage of the mite.

**Damage symptoms of Eriophyidmite**

The damage initially appears as a triangular patch at the level of the perianth. Colonies the mite live in the white tender portion covered by the inner tracts of the perianth and sucksap from the tender tissues. Feeding injury by large number of mites, result in the brownish patches. As the nut grows, this injury on the nuts leads to watering and longitudinal fissures on the nut surface. Draining of the sap from young batons, results in poor development of the nut reduction in nut size and kernel content and poor quality of husk (Mohammed Jalaluddin, S. and M. Mohanasundaram, 1990).

**Controls**

Efforts to manage the menace caused by the mite have centred on using synthetic and botanical pesticides. These are directly sprayed on the young bunches or administered through the root or stem, but these have not helped the farmers to mitigate the loss caused by the mite. These treatments have to be repeated frequently since the mites rapidly reinvest the treated nuts since the above measures are not being implemented by all farmers. As a long term strategy, an IPM module based on comprehensive management of the garden i.e., providing the required nutrients to the palms, application of neem cake, administering neem based products through a root or spraying neem oil, growing inter crops are being advocated to the farmer. This strategy, which has been found effective in reducing the damage, caused to the nuts and enhancing the nut yield is being popularized in Karnataka, Tamil Nadu, Kerala.
In recent years some farmers in Arsikere, Tiptur, Hassan etc., of Karnataka have adopted a technique of protecting the nuts by force feeding an unlabelled product to the stalk of the bunches. The farmers were satisfied about the effectiveness of the product in reducing the loss caused by the mite. They believed it was a neem based organic product but were not aware of the constituents.

The mite infestation starts when the nuts are $1\frac{1}{2}$-2 months old. The population of the mite increases till the nuts is five months old and declines thereafter. Hence, only the second, third, fourth and fifth bunches were treated during which, the youngest bunch was considered as the first. The spate covering the stalk of younger bunches was pulled aside to expose the stalk. Three to four inches below the first rachis a hole, "1/2 to 3/4" deep, depending on the size of the stalk, was drilled using a three mm steal nail. For convenience, the nail was fixed to a wooden holder (1 cm x 1 cm x 20 cm). The nail was held on the stalk and gently driven in using a wooden mallet (Plate K). After the nail was pulled out the pesticide was poured in, aided by a polyethylene micropette tip inserted into the hole formed by the nail.

The second experiment was conducted to test monocrotophos econeem plus (10,000 ppm azadirachtin), neemazal (10,000 ppm azadirachtin), neem seed, kernel extract (NSKE, 10%), abamectin and milbemectin. Each pesticide was tested on five palms (replicates). The second, third, fourth and fifth bunches were treated. Seven days after treatment nut samples were collected from the fourth bunch.

The third experiment was conducted to find the effective dosage of monocrotophos. Monocrotophos was administered at 0.05, 0.1, 0.2 and 0.4 ml in two ml water per bunch. Five palms (replicates) were treated with each dosage. As in the second experiment and the third, fourth, fifth bunches were treated;
however nut samples were treated and collected from the fourth bunch and observations were recorded as mentioned above.

In the preliminary experiments conducted to short-list the pesticides, it was observed that some were absorbed in just about 10 hrs, while a few like clofentezine were not completely absorbed. On nuts from monocrotophos treated bunches 95-100 per cent mortality in the mites was observed, whereas on nuts from bunches treated with other pesticides the mortality ranged from 1.25-2.93 per cent.

The second experiment was conducted to test monocrotophos, neem based commercial products like Econeem plus (10,000 ppm) and neemazal (10,000 ppm), neem seed kernel extract, abamectin and milbemeeitin. In monocrotophos treated palms the incremental damage on second, third and fourth bunch was 0 per cent, 2.35 per cent and 1.08 per cent nuts, respectively. While in palms treated with other pesticides the progressive damage on the second bunch ranged from 47.78 to 74.29 per cent and was nearing 100 per cent on older bunches, which were not different from those on untreated palms.

All the method of force-feeding coconut bunch stalk may help in completely suppressing the coconut eriophyid mite. In an area if all the palms are treated in a short span of time, with the participation of all the stake holders. At the same time, it is necessary to identify an alternative chemical, as effective as monocrotophos, to safeguard environmental concerns, as also to prevent the development of resistance (Mallik, B. et al., 2005).

j. Termite

Termite is an important pest of coconut seedling and palms in sandy loam soils and on soils other than sandy. This pest appears, to be attracted by the husk of the nut in the nursery. Termite can cause heavy damage to the transplanted
seedling also. Older palms are also attacked. The termites make colonies at the foot of the coconut palm and construct galleries on the stem.

Cultural and chemical methods of termite management it is sent hat spraying with any one of the following viz., Aldrin 0.15 per cent or HCl + 0.25 per cent or chlordane 0.1 per cent or DDT 0.25 per cent on the base and upto two meter height of the trunk of the coconut palm and spraying with aldrin 0.15 per cent or chlordane 0.1 per cent on the painted coconut leaves attack upto five months even when the treated plaited leaves were kept on the bare ground having the continuous occurrence of the termite (Sadakathulla, S. and Ramachandran, T.K., 1990).

Diseases

Coconut palm has survived for centuries in the tropics under neglected conditions, particularly in the pacific islands, thus showing tolerance to diseases. It is the poor palm having deficiency in plant food that suffers most under high humid conditions, due to reduced transpiration. In Karnataka, the coconut palm is affected by a number of diseases; some of them are discussed below.

a. Bud root

This disease is caused by a parasitic fungus, *Phytophthora palmivora*. The earliest symptom is the yellowing of one or two younger leaves surrounding the spindle. The spindle withers and drops down. The tender leaf base and soft tissues of the crown root into a slimy mass of decayed material emitting a foul smell. The disease kills the palm if not controlled at the early stages. Palms of all age are liable to be affected but normally young palms are more susceptible. The disease is more prevalent during the monsoon months when the temperature is low and humidity is high.
Controls

In early stages of the disease, when the spindle leaf starts withering, cut and remove all affected tissues of the crown and apply Bordeaux paste and protect it from rain by providing polythene covering till normal shoot emerges. Burn all disease affected tissues removed from the palm. As a prophylactic measure, spray 1 per cent Bordeaux mixture on spindle leaves and crown of affected palms as well as neighbouring palms before the onset of monsoon. Leaf axil filling with sevidol eight gm, twenty five gm mixed with 200 gm sand is recommended to prevent red palm weevil infestation of affected palms. Dwarf varieties of coconut are sensitive to copper injury. Hence, Bordeaux mixture spraying should not be done; instead, place small perforated sachets containing two to three gm of Indofil M-45 in the top two or there leaf axils to control bud rot disease.

Preparation of 1 per cent Bordeaux mixture: dissolve 1 kg of powdered copper sulphate crystals in fifty liters of water. In another 50 liters of water, prepare milk of lime with one kg of quick lime. Pour the copper sulphate solution into the milk of lime slowly, stirring the mixture all the while. Test the mixture before use for the presence of free copper, which is harmful to the palms, by dipping a polished knife in it. If the blade shows a reddish colour add more lime till the blade is not stained on dipping. Always use plastic cement, earthen or copper vessels for the preparation of Bordeaux mixture.

Bordeaux paste

Dissolve 100 gm of copper sulphate and 100 gm of quick lime each in 500 ml water separately, mix together to make one litre of Bordeaux paste 10 per cent (Maheshwarappa, H.P. and Anitha Kumari, 2002).
b. Root (Wilt) disease

Coconut root (wilt) disease was reported back in 1874 from Eraltupetta of Meenachil taluk in Kottayam district. Buttur called it root rotting disease, probably due to the rotting of roots observed in the affected palms.

The disease occurs in all types of soils found in Kerala and under various ecological conditions, from hilly tracts to coastal plains. The spread of the disease was conspicuous in sandy, sandy loam and clay soils and along banks of rivers and canals. As a general rule, the spread of the disease can be traced along the course of waterbodies like rivers and hence water borne pathogen was believed to be the cause of the disease. In fresh disease pockets near hillocks, initially the incidence is seen at the foot of the hills and subsequently of spreads up the hill. The intensity and spread of the disease was comparatively lower in laterite soils.

Symptomatology

Wilting and dropping of the leaves, flaccidity, ribbing, paling / yellowing and necrosis of the leaflets are the typical foliar symptoms of the diseases. With the progress of disease there is standing of the crown due to reduction in number of leaves and successive leaves become shorter. Flaccidity is the earliest consistent symptom and it is observed in leaves of the central and outer whorls. It is regarded as the most frequent and common of the three foliar symptoms associated with the disease irrespective of the age of the palm or the soil type.

It is believed that this disease has made its appearance after the great floods of 1982. The important visual diagnostic symptoms of the disease are abnormal bending or ribbing of the leaflets, a general yellowing and marginal neurosis of the leaflets. The yield is reduced considerably on coconut of the disease. The nuts are smaller and the kernel is thin. The oil coconut of copra is also reduced. Mycoplasma like organism is the causative agent of the disease.
Since the disease is not lethal but debilitating and no curative control measure is known at present the approach will be to manage the disease in the already infected gardens (John T. Eapen, 1993).

c. **Leaf rot**

Fungal spores enveloped in dewdrops or rain water adhere to the catial of the tender whitish leaflets and germinate within twenty four hours producing tiny spots of various colours and shapes. These water soaked lesions enlarge, coalesce freely leading to extensive rotting. The rotting any advance in the interior of the spindle. When the spindle grows the rotten portion dry up, turn black, break and get blown of the wind. The development of the symptoms and rotting is severe at the distal end of the leaf, especially 1 to 1.50 M in length. On leaflets also the distal ends are more susceptible. Occurrence of intermittent rotting of leaflets and mid ribs on the same leaf is also seen. In many cases, the rotten distal portions of leaflets adhere to each other from top to bottom on both sides thereby giving a fish bone appearance on drying these drops off.

**Disease management**

It is leaf rot which is responsible for the reduction in photosynthetic area, disfiguration of the palm and reduction in yield. Therefore, an easy, effective and economic control for leaf root is the most important factor in root (wilt) disease management. In the management of leaf root the role of the photosynthetic area available in every leaf and its contribution to yield is the most important factor to be considered. The second is the labour requirement for the operation. Difficulty in getting the services of climbers in time of need and the prohibitive cost are the other limiting factors. The fact that the white, soft, chlorophyllus leaflets of single alone are susceptible of fungal attack, suggests that the spindle alone is to be protected. The rhinoceros beetle also attacks only the spear leaf. Through the earlier recommendation of sequential spraying or
Bordeaux mixture 1 per cent dithane M-45, 0.3 per cent and fytolan 0.5 per cent in leaf rot affected palms using rocker sprayer (six labour) and separate application of BHC 10 per cent or sevidol eight gm for the control of rhinoceros beetle three times a year is effective, farmers had not adopted it because of the very high requirement of skilled labours and the cumbersome spraying involved. Therefore, the need for a simpler, environment-friendly and less labour intensive method combining the application of fungicide and insecticide, without the aid of a sprayer was keenly felt (Koshy, P.K., 2000).

d. **Leaf blight or grey leaf spot**

The fungal disease caused by palmarum is common in most of the coconut growing states. The disease symptoms develop in the mature leaves of the outer whorls. Minute yellow spots enriched by grayish white, these spots coalesce into irregular necrotic patches. Removal of the older affected leaves and spraying the foliage with 1 per cent Bordeaux mixture will check the spread of disease.

e. **Mahali or fruit rot and nutfall**

Shedding of female flowers and immature nuts are the symptoms of the disease. Water soaked lesions appear on the young fruit or buttons near the stalk which later develop into a decay of the underlying tissues. The disease is caused by the fungus *Phytophthora* sp. which appears as white webby growth on the surface of the affected part. Spraying the crown with 1 per cent Bordeaux mixture or any other effective copper such as (0.5%) will control the disease.

f. **Stem bleeding**

In general, the typical symptoms of the stem bleeding disease are the exudation of reddish brown liquid through the cracks developing on the trunk. The manifestation of the disease in Goa is generally varied from palm to palm and place to place.
The extent of external lesions bore little relation to the internal decay. Palms which showed only slight discolouration on the outside were found to be extensively decayed on the inside.

The internal decay was characterized by integration of tissues into drop powdery mass. The decayed portion was soft and bleeding was noticed from outside. Affected palms appeared robust and healthy. Otherwise, with a well developed crown and thick trunk, reduction in yield, decrease in the number of leaves, bunches and all appear at about two years or earlier following the appearance of external lesions.

Management of disease

The following three methods to control/check the disease in the disease affected palms just above the bleeding site a hole (10 cm dia) is made on the stem from one and to other. The role is filled with a mixture of ash lime and cow dung. The belief is that, with this treatment the bleeding stops and the disease do not progress further beyond the treated site. The palm affected by the disease is used for tapping. It is again believed that tapping a palm helps in checking the disease. Nailing to the palm just above the budding site is also a remedy. Management trails conducted by them institute have shown that in affected palms root feeding with span/ml of Bavistin calixin thrice a year along with regular dose of fertilizer and 5 kg of neem cake/palm checked the disease which result in increased yields. A systematic approach in controlling this vesed problem affecting the coconut crop in the state will definitely help increase the yields (Koshy, P.K. and Rachel Samuel, 1994).

g. Tanjavur wilt

The disease was first noticed in the coastal areas of Tanjavur district following the cyclones of 1952 and 1955. Tanjavur wilt is a serious problem in Tamil Nadu and in the adjoining the states.
The disease is characterized by the oozing out of a reddish brown viscous fluid from the basal portions of the stem, dropping of leaves and finally the depth of the palm with in 2 to 3 years. Sometimes the palms succumb to the disease even without showing bleeding and will be seen to a height of 15 feet also. The bleeding spot will be soft to touch where the stem portion will be rotten. The colouration of stem portion will also be seen. The affected root portions will be darker in shade and rotten. The number of fresh root will be less.

**Control measures**

Removal of dead palm (along with hole and roots) and palms in the advance stage of the disease burning of the pits, bole and roots bits is essential, along with isolation of diseased palms from healthy palms during irrigation. Regular summer irrigation or coconut husk burial for oil moisture conservation: Addition of fifty kg of green manure leaves / palm / year addition of 200 kg tannsilt / palm / year raising banana as inter crop, wherever irrigation is possible raising sum hemp or kolingin the inter spaces of coconut and ploughing in sites. Application of five kg neem cake / palm / year soil drenching with forty liter of 1 per cent Bordeaux mixture thrice a year palm for one year. Root feeding with two kg of Aure of unginsolt one gm of copper sulphate in 100 ml of water thrice a year at quarterly intervals. Alternatively tridemosph (2 ml / 100 ml) can also be used for root feeding. Fungicide treatments are effective only in the early stages of the disease (Kamala Thirumalaiswamy et al., 1992). If xyleborus attack is seen, smearing the stem with BHC waltable powder (5 per cent) or heptachlor and root feeding with 5 ml of monocrotophos is done.

**h. Tatipaka disease of Andhra**

The disease derives its name from the Tatipaka village of East Godavari district where it made its first appearance following the cyclone of 1949. Development of an abnormally large crown with dark green inner leaves and
higher yield is the precursor of disease incidence. Subsequently, the crown becomes smaller in size, producing progressively shorter leaves. The stem begins to toper. The leaves give a fascinated appearance due to improper unfolding of leaflets. The affected tree process smaller bunches with atrophied barren nuts. The cause of the disease is not known.

i. **Crown choking disease**

This disease is commonly observed in Assam and West Bengal and is characterized by emergence of shorter leaves with fascinated and crinkled leaves. The leaflets show serve tip necrosis and fail to unfurl. In many cases, it gives a choked appearance to the front. Ultimately, the affected palm dies. Application of 50 g of Borax during post-monsoon period in the basins of coconut palms in the early stage of disease helps in controlling it.

**A new disease complex in coconut progressive chlorosis and crown root**

Coconut is one of the most important plantation crops in Karnataka. Of the several problems facing the coconut production in the state the coconut root wilt disease is of utmost concern. The palm is also affected by other number of diseases.

The disease is characterized by yellowing of outer whorls of leaves which latter spread to the inner whorls. Immature nuts and buttons fall down and in advanced case of the whole palm dies with rotting of spindle leaf. In coconut, yellowing of leaves is caused by many reasons viz., deficiency of nutrients, red ring disease, basal stem rot, root wilt and lethal observed in this disease complex differ from the symptoms caused by the above factors.

In progressive chlorosis and crown rot, the disease symptoms develop very fast and the palms die within a short period. There is neither root decay nor any red and of discoloured tissues within the cortex. Root grubs were also not
detected in the soil. The diseased palms did not show any symptoms of stem bleeding. The palms were also not affected by red palm (Govindan, M., 1996).

**Nematode diseases of coconut**

Though many nematode species have been found associated with coconut palms, the nematodes that are considered to be economically important are only two the red ring nematode and the borrowing nematode *Radopholus similis*. The red ring disease has so far never been reported from India as well as from south east Asia. The only important nematode found associated with the coconut palms in India is the *Radopholus similis*. Many of the weeds and intercrops grown in the coconut basins and inter spaces serve as good hots for the multiplication of these nematodes. In India, the burrowing nematode *Radopholus similis* is the only important nematode pest that significantly affects the growth and yield of the palm.

**Symptoms**

Burrowing nematode infested coconut palms exhibit general decline symptoms like stunting, yellowing, reduction in the number and size of leaves and leaflets, delay in flowering, button shedding and reduced yield.

**Control**

Use nematode free coconut seedling and planting materials of other intercrops apply phorate ten kg a i/ha in heavily infested nurseries during September, December and May. Remove all roots external to the husk before planting to reduce the inoculum carried to the planting pit. Use less susceptible / tolerant cultivars or hybrids of coconut and intercrops in infested areas. Avoid use of banana as a shade crop in nurseries. Sanitational methods such as exposing planting pits to summer heat, burning of trash in pits and solarizing nursery beds will help in reducing nematode multiplication. Apply phorate ten gm 1 per cent palm in June/July and in September / October to infested palms in the field.
Grow green manure crops viz., *Corotalaria juncea* or *Peuraria javanica* in coconut basins and interspaces or *Glyricidia maculate* on the borders and incorporate the leaves and tender stem into the soil in September / October. Incorporate effective biocontrol agent viz., bacteria, fungi and the beneficial symbiotic vascular arbuscular mycorrhizal fungi into the nursery beds and planting pits for reducing nematode multiplication for improving plant growth and imparting tolerance / resistance to nematodes. The most important nematode disease of coconut red ring disease caused by the nematode, *Rhadinaphelenchus cocophilus*.

**Symptoms**

Chlorosis that first appears at the tips of the oldest leaves gradually spreads towards the leaf bases. The yellowed leaves later dry up and turn brown. The brown lower leaves may break across the petiole and may hang down. Premature shedding of the nuts is another symptom. About four to six weeks after the appearance of the first symptom, the crown often topples as a result of severe internal damage caused by the palm weevil. Diseased tree acts as the breeding ground for insects and red ring nematodes and attracts all palm weevil including potential vectors. All stages of the insect are able to carry the nematode infestation, either internally or externally for transmission. Weevils trapped from an infested area, showed that about 35-45% of them as carriers of living nematodes with an average of 71 nematodes.

**Controls**

Spraying of the leaf axils of diseased trees with 0.1 per cent Lannate insecticide solution is recommended. Immediately then, the trees should be killed with herbicides. Trees in the advanced stages of the disease should be cut down and the pieces and remaining stumps sprayed thoroughly with at atleast 4.5 liters of 0.1 per cent Lannate solution. Burn off the dried remains after fourteen days.
Traps or guard baskets for attracting and killing the palm weevils can also be used (Koshy, P.K. and Rachel Samuel, 1994).

**Basal stem rot disease of coconut in Arsikere taluk of Karnataka (Anabe Roga)**

Coconut palm is affected by a large number of diseases and the most prevalent disease in Karnataka is basal stem rot caused by Karst. Basal stem root disease of coconut is also known as "Anabe roga" in Karnataka. Thanjavur wilt in Tamil Nadu and Ganoderma wilt in Andhra Pradesh is the most serious disease limiting coconut production in the above states (Ganesha Naik, R., 2000).

It is widely present in the maidan parts, especially in sandy soils of the southern region of the state. This disease seems to affect older palms is neglected gardens more than the young palms. The pathogen has a wide host range (Govindu, H.C. *et al.*, 1982).

The disease first starts in the root system and during the initial period of infection no external disease symptoms are clearly visible. At the beginning, a few roots get infected which start rotting and rotting proceeds towards the whole region. Discolouration and extensive rotting of root system are progressively observed are the characteristics of this disease. In moderately and severely diseased palms, the root decay will be more at 0.30 cm depth, in the crown, leaflets of wilting, later on, one or two outer whorls of leaves turn yellow. They exhibit light to moderate browning followed by dropping and drying. As the disease advances, the remaining leaves also droop down in quick succession leaving only the spindle with a new unhealthy leaves around. On the stem, the symptoms first appear as exudation of reddish brown viscous fluid from its basal portion. The bleeding patches gradually traverse upwards reaching upto a maximum of 3.5 meter height as the disease progresses. Sporophores of the fungus *Ganoderma lucidum* appear at the base of the affected trunk in some
palms prior to writing or just after the death of the palm in severely diseased palms. Some of the nuts become barren. In the remaining nuts the quality and quantity of kernel, nut water and copra will vary and there will be a decrease in the oil content also in the kernel.

**Integrated management**

Integrated management is now globally recognized that the most effective and acceptable plant protection methods from the view point of preservation of the environment are the integrated methods. They help not only in the destruction of the pathogens, but also in the long term control of various harmful organisms at a safe level with minimum adverse consequence on the environment.

As prophylactic measures, the basins of apparently healthy coconut palms surrounding the affected palm should be treated with the chemical to prevent further infection of the disease. However, for effective check of this disease spread, an integrated approach comprising phytosanitary, cultural and chemical methods are necessary.

Remove the infected dead palms and stamps in the garden and destruction of the bole and roots of these palms by burning. Isolation of diseased palms from health ones by digging circular or square trenches one m deep and thirty cm wide around the diseased palms at a radial distance of about 3.5 m. Ploughing should be avoided around infected palms so that the translocation of fungal inoculum is prevented to the neighbouring palms. Irrigation of palms during summer provided preferably by drip method or by basin irrigation. Flood irrigation should be avoided. Moisture conservation techniques like coconut husk burial in the basin followed if no irrigation facility available. Application of neem cake five kg/palm, year in addition to the recommended organic manure (fifty kg F/M or green leaves) and chemical fertilizers. Fungicide treatment will be effective in controlling the basal stem rot disease of palms only in the early stages of disease.
Raising disease antagonisation inter-crops like banana wherever irrigation is possible (Ganesha Naik, R. et al., 2000).

**Control**

The control of Anabe roga of coconut is based on cultural, chemical, antibiotic and possibly biological principles, field sanitation of the gardens, uprooting and burning of the diseased tree stumps in the pit before the formation of dangerous brackets. Isolation of affected palms by digging out trends 50x50cm around the palm and application of sulphur, providing good drainage and application of balanced fertilizer preferably after soil testing. The possibility of controlling the disease with antibiotics, as reported here, appears to be the most promising method of control at the present time. It should be coupled with cultural practices such as application fertilizer, providing drainage and isolation of infected palms (Govindu, H.C. et al., 1982)
References


Map 1. Major coconut growing states in India
Map 2. Major coconut growing districts in Karnataka