ARECANUT

AL PLANTATION CROPS RESEARCH INSTITUTE
(INDIAN COUNCIL OF AGRICULTURAL RESEARCH)
Kasaragod - 671 124, Kerala

कराफअस
CPCRI

ARECANUT

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FOREWORD

The arecanut (*Areca catechu* L.) is an important cash crop of India. The economic produce is the fruit called 'betel nut' and is used mainly for masticatory purposes. It is used in India in several socio-religious ceremonies. Its cultivation is concentrated in South Western and North Eastern regions of India. Arecanut industry forms the economic backbone of nearly ten million people in India and for many of them it is the sole means of livelihood. The *Areca* palm is a monocot belonging to the family Palmae. The commonly cultivated species is *A. catechu* in most of the countries where it is used for chewing. India ranks first in the world in area of cultivation and production.

The Central Arecanut Research Station was started in 1956. The systematic research on arecanut production technologies were started then has resulted in self - sufficiency in its production. Consequent to establishment of Central Plantation Crops Research Institute in 1970, the CARS became Regional Station of the Institute with a mandate to carry out research on arecanut and cocoa. The Regional Station lies in the heart of arecanut growing areas in idyllic surroundings. The Regional Station has evolved production technologies of arecanut and released several high yielding varieties. Plant protection methods for various pest and diseases have also been standardized.

The book on Arecanut gives a comprehensive review of the work done on all aspects of arecanut in the country. I am sure that the book will be of great help to all concerned with arecanut research and development.

(G. KALLOO)

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1. INTRODUCTION

D. Balasimha and V. Rajagopal

The arecanut palm, *Areca catechu* L., family Palmae is the source of arecanut commonly referred to as betelnut or supari in India. It is used in Indian and other South East Asian countries as a masticatory. It forms one of the ingredients of betel quid commonly used in India. It has an integral part in several religious and social ceremonies.

ANTIQUITY

The use of arecanut has been mentioned in ancient Sanskrit texts. It has been quoted by Sisu Mayana in 'Anjana Chaitra' as early as 1300 B.C. (Bhat and Rao, 1962). Arecanut cultivation and chewing have been mentioned in the works of Magha (650 B.C.) in 'Sisupala Vadha' and 'Raghuvamsa' by Kalidasa (4th Century A.D.). The popularity of the arecanut in 6th century A.D. has been described by Amar Simha in his 'Amara Kosha'. One of the oldest pictorial references can be seen in Ajanta caves (Fig.1) dating from 2nd to 4th century A.D. (Mohan Rao, 1982). The palm provides a backdrop to Padmapani Budha in this cave painting.

Fig.1. Ajanta painting of Budha with areca in backdrop

ORIGIN AND DISTRIBUTION

The exact origin of arecanut palm is not fully known as there are no fossil records of genus *Areca*. Geologically the palms extended to the Cretaceous period of upper Mesozoic

Arecanut (Balasimha, D. and Rajagopal, V., Eds), CPCRI, Kasaragod - 671 124

era (Mahabale, 1982). It is a native of Cochin China, Malay Peninsula and neighboring islands (Blume 1836; Watt, 1889). It is also reported to be a native of Indonesia (Gode, 1961). Arecanut has been reported from Philippines (Beccari,1919), Indonesia (Petelot *et al.*, 1926), Sri Lanka (Blatter, 1926), Southern China (Hsiao-Liang, 1936), Taiwan (Yama Moto,1939) and Java (Meijar, 1946). The exact native country of arecanut is uncertain as the palm was cultivated from time immemorial in East Indies (Blatter, 1926; De Condolle, 1886). The range of distribution in a locality where the plant is thought to be wild may throw light on its origin (Furtado, 1933). The maximum species diversity (24 species) and other indicators suggests its original habitat in Philippines, Malaysia and Indonesia (Bavappa, 1963; Raghavan, 1957).

Arecanut is largely cultivated in the plains and foot hills of Western Ghats and North Eastern regions of India. Area and production in different states indicate that Karnataka, Kerala and Assam account for over 90 per cent. Two wild species viz *Areca triandra* and *A. nagensis* are found in Andaman and Nicobar islands and Assam respectively (Kulkarni and Mulani, 2004). These have ornamental value.

Arecanut is grown in Bangladesh, China, Malaysia, Indonesia, Vietnam, Philippines and Thailand. India accounts for about 57 per cent of world production. It is followed by China, Bangladesh and Myanmar.

USES

The arecanut is chewed either alone or in combination with betel leaves or 'pan' (*Piper betle* L.), lime, tobacco, camphor, which is locally called 'Tambula' or betel quid. It has both religious and medical significance. Chewing increases production of saliva, gastric juices and strengthens gums. Traditionally betel nut and betel leaves are offered in religious functions.

The history of betelnut chewing has been established among Aryans atleast 2000 years ago (Gode, 1961). The tradition of 'Tambula' offerings was probably prevalent as early as Gupta period. The chewing habit is also prevalent in other countries like Nepal, Sri Lanka, Burma, Thailand, Philippines, Africa, Arabia, South China, Pakistan and Bangladesh. The habit of areca chewing has been mentioned by Marco Polo in 1298 A.D. (Watt, 1889). The receipt of betelnut and betel leaves in marriage ceremonies have also been depicted in inscriptions at the times of Nayaks of Tanjore (Gode, 1961). In Assam and West Bengal arecanut is used as an important commodity in religious ceremonies and chewing (Murthy, 1968).

The medicinal uses of arecanut was known to Vagbhata as early as 4th century A.D. He has described its use against leucoderma, leprosy, cough, epilepsy, worms etc. Bhavamista (13th century A.D.) had used it as stimulant and appetizer. Powdered nuts were used as antihelminthic for dogs (Watt, 1889).

Fig.2. Laboratory building of Regional Station, Vittal

ORGANIZATION OF RESEARCH AND DEVELOPMENT

Research

Very little research was done earlier to 1950s, although arecanut has been an important commercial crop. Earliest known works were those of Coleman (1910) on fruit rot or 'kolergoa' in erstwhile Mysore state. Due to lack of scientific knowledge on agronomic aspects and pest & diseases, considerable crop losses were encountered in cultivators fields. Further, after the partition, the country lost about 50 per cent of areca to Bangladesh. These necessitated import of arecanut in 1950s and 1960s for internal requirements. To address these issues, the Government of India set up an ad-hoc committee under ICAR to consider and formulate coordinated schemes for the purpose. On the recommendations of this committee, Indian Central Arecanut Committee (ICAC) was constituted in 1949. The main objectives of ICAC were :

1) Production of arecanut in India to be enhanced to meet deficit by increasing yield per unit area as well as increasing area under crop.
2) A Central Research Station for the fundamental and applied studies to be set up as no research on arecanut had ever been done anywhere in India.
3) Establishment of four or five regional research stations in important arecanut growing areas.
4) Establishment of arecanut nurseries to supply quality seedlings.
5) Obtaining correct statistics regarding area and production of arecanut.
6) Extension programmes for doing propaganda among the growers to be taken up.

Based on these recommendations Central Arecanut Research Station was established at Vittal, Karnataka in 1956 (Bhat, 1982). Subsequently, five Regional Stations were also

started during 1958-1959 at Palode, Peechi (Kerala), Hirehalli (Karnataka), Mohitnagar (West Bengal) and Kahikuchi (Assam). The Vittal Station (Fig.2) is situated in the heart of arecanut growing region with soil and climatic conditions ideal for arecanut cultivation. Consequent to the establishment of Central Plantation Crops Research Institute, at Kasaragod, CARS became Regional Station and five regional stations became Research Centres.

Some of the early programmes of research and achievements are described by Bhat (1982) and briefly mentioned below:

1) Suitable techniques for seed selection and nursery management.
2) Crop improvement programmes led to release of high yielding variety 'Mangala'.
3) Identification of dwarf mutant Hirehalli Dwarf which was later exploited in breeding work.
4) Agronomic recommendations including manures, fertilizers, cultural practices and irrigation
5) Mixed cropping trials with annuals, biennials and perennials.
6) Pest control methods for root grubs and spindle bug.
7) Control measures for diseases like fruit rot and Anabe roga.
8) Etiology of yellow leaf diseases.
9) Etiology and control of bacterial leaf stripe disease in Maidan parts caused by *Xanthomonas arecae.*
10) Technological research on alternative uses of arecanut and by - products with the help of other National Research Institutes under the financial assistance of the Karnataka State Agricultural Marketing Board.

The research programmes of the Arecanut Research Station and Centres during the two decades after formation has led to evolving improved varieties and agro-techniques. This is one of the most visible success stories when the self-sufficiency was achieved by mid 70s. Production of arecanut which was 75,759 tonnes during 1956-57 got doubled in about 14 years and stands now at 3,79,200 tonnes (2000-01), a five-fold increase. During this period yield was 788 kg, 863 kg and 1211 kg respectively. The increase in production was both due to increase in area of cultivation and productivity. Quality planting materials, improved agro-techniques and superior varieties have all contributed to this tremendous increase in arecanut production.

Development

As part of developmental activity, the ICAC launched several programmes for extension of area. Efforts were made to improve cultivation and production by arranging supply of inputs like planting material, fertilizers and pesticides. These steps were very efficient and rewarding (Bhat, 1982).

Establishment of nurseries for supply of quality seedlings was one of the most important development programmes of ICAC. The finances are provided under four categories: (1) grant-in-aid nurseries of State Governments with 50% aid from Committee; (2) Second Five-Year Plan nurseries sanctioned by Central Govt.; (3) Research Station nurseries; (4) Certified village nurseries. These were operational in all the major arecanut growing states.

Under the publicity programmes, the ICAC published a periodical (Arecanut Bulletin) which is presently continued as Arecanut & Spices Journal by the Directorate of Arecanut & Spices Development, Calicut. Several leaflets and pamphlets were made available in local languages. Such pamphlets on cultivation practices are continued to be published by CPCRI in later years. Besides documentary films and recently video/digital films have been prepared for dissemination of information. Participation in exhibitions, Kisan Melas at Research Stations and Scientists field visits have helped farmers in the arecanut cultivation both under ICAC and later by CPCRI.

Another important development programme was the promotion of Co-operative societies. With active support Govt. of Karnataka and Kerala, a farmers' Co-operative viz., The Central Arecanut Marketing and Processing Co-operative Ltd. (CAMPCO) was established in 1973. This has helped in stabilizing the market prices of early 1970s. Similar co-operative for red arecanut, the Malnad Arecanut Marketing Co-operative Society Ltd. (MAMCOS) was established.

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2. BOTANY

K. S. Ananda

INTRODUCTION

The areca palm *Areca catechu* L. is one of the important plantation crops of India and it is widely cultivated in Tropical Asia. Arecanut, which has been under cultivation for the past many centuries, has attracted the attention of botanist from systematic point of view. The commonly cultivated species in almost all the countries is *Areca catechu* Linn.

Bentham and Hooker (1883) described the genus *Areca* as the first one in the family Palmae under the tribe Arecae in their treatise *Species Plantarum*. The genus *Areca* was first identified as a monospecific (*Areca catechu* L.) in Linnaeus's *Species Plantarum* (1753) and cultivated widely in tropical Asia. The genus expanded rapidly from its monospecific status and at present it is believed to exist in about 76 species. Among these, *A. catechu* is the only cultivated species, the nuts of which is chewed as a mild stimulant and nuts of a few other species such as *A. triandra* Roxb. and *A. concinna* Thw. are also used as a masticatory (Murthy and Pillai, 1982). The plants fruiting in wild state in the virgin forests of Attappadi ranges in Kerala at an altitude of about 1000 m was noticed by Fisher (Blatter, 1926). Raghavan (1957) indicated that since majority of the species of *Areca* have been reported from Malay Archipelago, the Philippines and other East Indies Islands, the center of origin of *A. catechu* is likely to be around the region while studying the distribution pattern of *Areca* species. Bavappa (1963) observed that the contiguous area of Malaya, Borneo and Celebes having a maximum of 24 species could well be the area where the greatest diversity and wealth of forms of *Areca* are concentrated. Thus the East Indies group of islands may be taken as the centre of maximum variation and distribution of *Areca* species. It is believed that the name *Areca* was derived from a Malayan word meaning 'cluster of nuts' (Mc Currach, 1960). The possibility of the generic name coined by Linnaeus based on popular Malayalam name 'Adeca' or a variant Kannada name was indicated (Bavappa, 1964).

TAXONOMY

Description of genus *Areca*

The first to attempt to restrict the limits of the genus *Areca* was reported by Martius (1832-1850) but the attempt was not satisfactory as the limitations were not based on real affinities. The genera now recognized *as Dictyosperma, Oncosperma, Dypsis, Acanthopheonix* etc. were retained in the genus *Areca*, while the closely related palms were excluded from

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it. Separation of various species was done (Blume, 1836) till then grouped under *Areca* into different genera, based on the nature of albumen, the position of ovule, the distribution of male and female flowers on the spadix. Blume's arrangements, however was not accepted by Martius (1832-1850), Griffith (1850) and Miquel (1868, cited by Furtado, 1933) among others. Bentham and Hooker (1883) listed 24 species under *Areca* and disagreed as to the limits placed on the genus by Scheffer (1871, cited by Furtado, 1933) and Beccari (1919). In ascribing only 14 species to the genus *Areca*, Drude (1889, cited by Furtado, 1933) followed Bentham and Hooker (1883) in excluding *Mischophloeus* from *Areca*, but included only those species which Scheffer (1871) and Beccari (1919) had retained under the genus.

The views of Bentham and Hooker (1883) and Drude (1889) have been followed by Blatter (1926). But Furtado (1933) found it impossible to maintain Mischophloeus as a genus and amalgamated it with *Areca*. For the sake of convenience and for the purpose of bringing out better affinities, he divided the reconstituted genus *Areca* into two subgenera *Blumeoareca* and *Beccarioareca*. The character that distinguishes these two subgenera is the arrangement and the glomerules of the male flowers, being unilateral or distichous in *Blumeoareca* and spiral in *Beccarioareca*. Furtado (1933) again subdivided *Blumeoareca* into three sections *Arecella* Wendl. Et Drude, *Oeotheanthe* Scheff. and *Axonianthe* Scheffe. The subgenus *Beccarioareca* was also subdivided into two sections. The first section was called *Microareca* Furtado, consisting of small plants known to occur only in Malay peninsula, Lingga Island and Borneo. The other section *Mischophloeus* Becc. Included massive plants known only from the region between Celebes and the Solomon Islands.

The genus *Areca* was described based on generic traits by Blatter (1926). The characters are; erect stem with smooth green in the upper portion and annulate, leaves are pinnate in nature and base of the petiole expanding into smooth green amplexicaul sheath. Leaflets are thin and often confluent with several midribs, which are attached to the rachis in a vertical line. Spadix androgynous situated below the leaves and branched with numerous closely set spikes and spathes several. The male flowers are numerous and minute, occupying the upper portion of the spikes. Sepals are small and petals much longer with obliquely lanceolate and valvate. Stamens vary from 3 to 6, filaments short. Anthers are basifixed and erect. The female flowers much larger and placed at the base of the spikes. Perianth is accrescent. Sepals and petals are orbicular and imbricate. The petals have acute valvate tips. Ovary 1-celled and stigma 3 in number and sessile. Ovule is 1, basifixed and erect. The fruits are ovoid or supported by persistent perianth. The mesocarp is normally fibrous. The seeds are with a truncate base. Endosperm is deeply ruminate with basilar embryo.

Areca species according to their sections as furnished by Furtado (1933) is enumerated below and their distribution is illustrated in Fig.1. From the available references on the systematics, it appears that there are seventy six species of *Areca* recorded so far (Murthy and Bavappa, 1962).

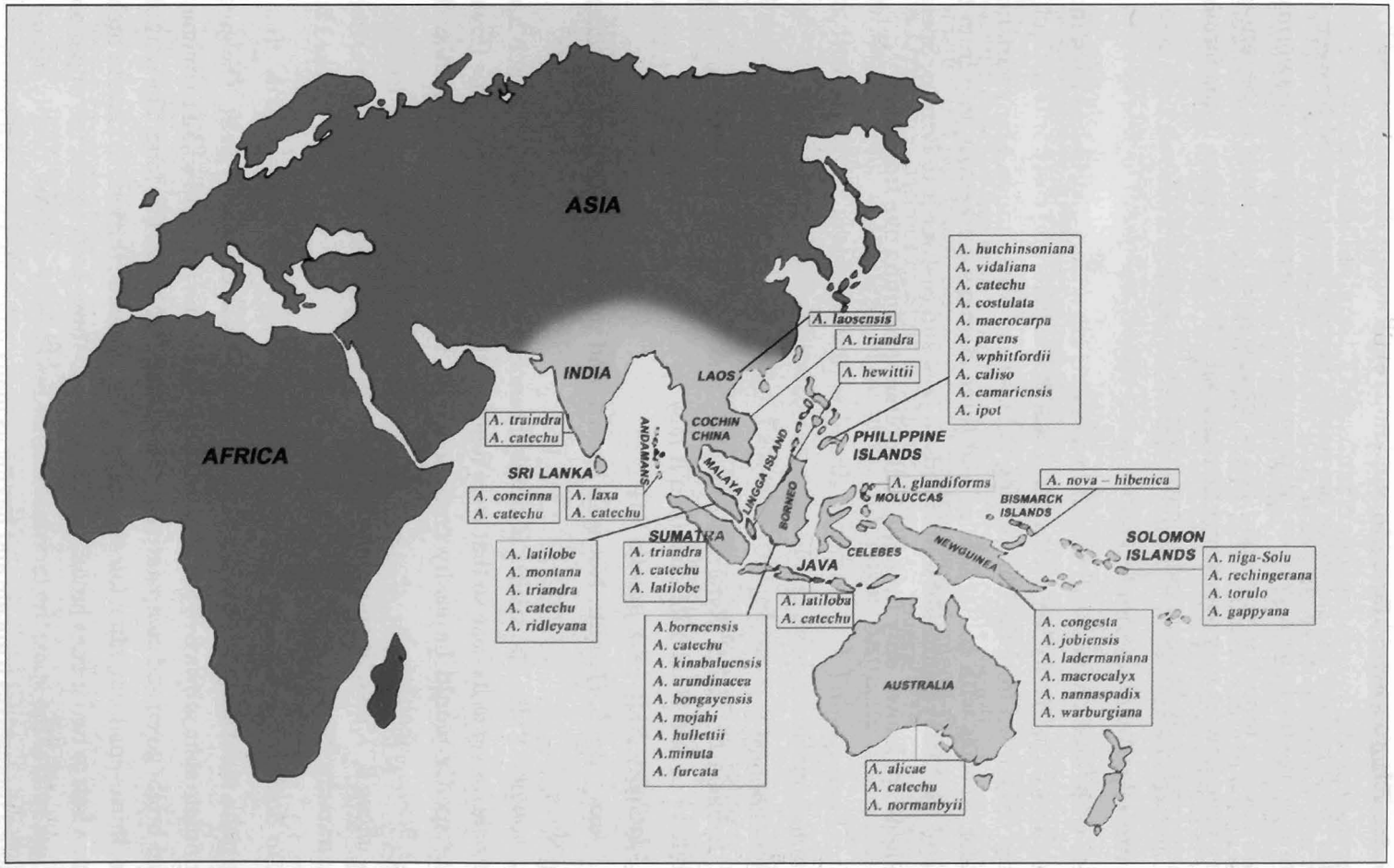

Fig. 1. Geographical distribution of *Areca* species (Furtado, 1933)

Subgenus 1. *Blumeoareca* Furtado

Species coming under the subgenus are having female flowers seated between two male flowers although the latter may often fall prematurely. The male glomerules normally consist of two flowers, though in some portions of the spikelets, principally in the terminal ones, solitary male flowers may sometimes be observed. The male flowers in the terminal parts may also frequently be observed to have dropped off prematurely.

Section 1. *Arecella* Wendl. et Drude

Species with three stamens and soboliferous stems are widely distributed from Indo-Malaysia southwards to Trinity Bay on the east coast of Australia and eastwards to Cochin-China, but are not known from the Philippines, Celebes and New Guinea. Many variations or forms occur. Species with solitary stems and three stamens are known only from the Andamans and the Malay peninsula southwards to Java and eastwards to Borneo. Species with six stamens are known only from the Philippines, excepting one from Laos.

Stamens 3

A. Stamens 3

B. Stem solitary

1. *A. borneensis* Becc. Referred doubtfully and not certain whether the stem is solitary or not. If soboliferous, then it may be a form of *A . triandra.*
2. *A. latiloba* Ridl. (=*A. pumila* B1)
3. *A. laxa* Buch.-Hamilt. Not well known, and may be a variety of *A. triandra* Roxb.
4. *A. montana* Ridl. The spadix is simply branched and almost every branch has a female flower at its base so that were it not for the disposition of the male flowers the spadix would be easily confused with that of the section *Axonianthe.*

BB Stems soboliferous

5. *A. alicae* F. Muell. It appears to be a variety of *Areca triandra* Roxb.
6. *A. triandra* Roxb. (=*A. pumila* Ridl.)

Areca triandra Roxb

The palm is shrubby and throws out offsets/suckers at the base (Fig. 2). The green, distinctly annulate stem grows five to seven feet high and is one inch and a half in diameter. The leaves are bright green and comparatively large, being four to five feet long. The pinnules are alternate, linear-ensiform, often falcate, obliquely acuminate, thirteen to sixteen inches long, one and a half to two inches broad, with one, two or three keels above; the upper ones are more or less split at the apex; the terminal leaflets are broadly cuneate, deeply bipartite, forked, the lobes themselves truncate and having as many bidentate lobes as there are keels on their undersides (Murthy and Bavappa, 1962).

The green smooth spathe has a short blunt point, and is from six inches to a foot long and from two to three inches broad. The peduncle and branches of the much-divided spadix are compressed. A linear bract, half an inch in length, is to be seen at the base of the lowermost branch. The branches are spreading and much divided; the secondary divisions are stoutish towards the base, where they bear a female flower, close to which they branch into two slender flexuose spikes, from which the male flowers arise, or oftener are attenuated into one. Male flowers angular, small cream-coloured, in pairs pressed together and second on the outer side of the spikes. Sepals three, minute, ovate-oblong, unequal. Petals oblong, obtuse, valvate, three or four times longer than the sepals. Stamens three, opposite the sepals; filaments stout, short, united at the base; anthers sagittate. Rudiment of the pistillum conical-subulate. Female flowers rather large, generally placed between a pair of rudimentary males, suffulated by two broad, short, pointed bracts. Sepals roundish green. Petals similar, but smaller and less tough. Six very small rudimentary stamens. Ovary ovate, one-celled, white. Ovule one, ascending. Style O. Stigma of two, or generally three erect unequal acute lobes. Fruit oblong, of the form of an olive, but longer, distinctly mammillate, smooth, when ripe of a lively orange colour, at length becoming red. Pulp in small quantity, and mixed with many longitudinal strong, ligneous fibres. Seed coniform. Albumen much ruminated. Embryo basilar. The normal somatic cells of the species contain-thirty-two-chromosomes in their complement. The chromosomes, on an average, range from medium to short size as compared to other palms. The chromosomes of *A.triandra* are longer than those of *A.catechu.*

AA. Stamens 6, stem apparently solitary

7. *A. hutchinsoniana* Becc.
8. *A. vidaliana* Becc.
9. *A. laosensis* Becc.

Section 2. *Oeotheanthe* Scheff.

Distributed in the Philippines, Celebes and North Borneo and *A catechu* L. in this section is widely cultivated throughout the tropics. *A. concinna* Thw. is reported to be wild in Sri Lanka.

10. *A. catechu*
11. *A. celebica* Burr. This may be a form of *A. oxycarpa* Miq.
12. *A. costulata* Becc.
13. *A. kinabalensis* Furtado.
14. *A. macrocarpa* Becc.
15. *A. oxycarpa* Miq.
16. *A. parens* Becc.
17. *A. whitfordii* Becc.
18. *A. concinna* Thw.

Areca concinna Thw

Trunk 8-12 feet high, 1½-1¾ inches in diameter, cylindric, green. Leaves few, 3-3½ feet long, spreading, subglabrous (Fig. 3). Leaflets 2 feet long, 2½ inches broad, lanceolate, falcate, caudate-acuminate, lower simple, 1-costate, upper of 2 or more confluent, acuminate or toothed at the apex, terminal shorter, more or less confluent in toothed laminae. Sheath 16 inches long; spadix paniculately branched, a foot or more long,very shortly peduncled; rachis short, stout, compressed, smooth, branches filiform, terminating in pendulous male spikes. Male flowers biseriate, 1/10 inch long; sepals oblong, obtuse; petals nearly thrice as long; obliquely ovate-lanceolate, acuminate, striate; stamens 6; anthers subsesable, linear oblong, acute, cells-parallel; pistillode trigonous. Female flowers 1/4-1/3 inch long; calyx an obsure unequally 3-lobed cup; petals broadly ovate, oblong, obtuse. Fruit 1½ inch long, subfusiformly ovoid, umbonate, scarlet (Murthy and Bavappa, 1962).

Section 3. *Axonianthe* Scheff.

The disposition of the male flowers is important in recognizing this section. The main axis of the spadix may sometimes divide into two or more branches, but these in their turn function like the main axis of the unbranched spadix and bear simple floriferous branchlets on all sides. The distribution of the species are limited to the region between Celebes Westward to the Soloman Islands and Northward to the eastern regions of the Philippines.

19. *A. caliso* Becc.
20. *A. camariensis* Becc.
21. *A. congesta* Becc.
22. *A glandiformis* Lam
23. *A. ipot* Becc.
24. *A. jobiensis* Becc.
25. *A. ledermaniana* Becc.
26. *A. mannospadix* Burr.
27. *A. niga-* solu Becc.
28. *A. rechingeriana* Becc.
29. *A. torula* Becc.
30. *A. warburgiana* Becc.
31. *Areca macrocalyx* Zipp.

Areca macrocalyx Zipp

Fruit 2.9cms long, 1.3cm. broad, weight 1.17 gms. Volume 3.0 c.c; thickness of husk 0.1cm, weight of husk 0.17g; kernel 1.1 cm long and 1.1 cm broad, weight 1.0g. Volume 1.2 ml, percentage of kernel to fruit by weight 85.5, kernel hard with close ramifications, taste moderately astringent; embryo small, oval (Murthy and Bavappa, 1962) (Fig. 4).

Fig. 2. *A. triandra* Roxb.

Fig. 3. *A. concinna* Thw.

Fig. 4. *A. macrocalyx* Zipp.

Fig. 5. *A. normanbyii* F. Muell.

Subgenus II. *Beccarioareca*

Section 4. *Microareca* Furtado

In most cases fully mature fruits are not known. One species in this section comes from the southern parts of the Malay peninsula, one from the Lingga Island and the rest from the northern parts of Borneo.

A. Stamens 6

B. Leaves entire, bifid at apex

32. *A. arundinacea* Becc.

33. *A. bongayensis* Becc.

34. *A. hewittii* Furtado

BB. Leaves divided

35. *A. amdjahi* Furtado Spec. nov. Leaf segments 2 or 3 on each side of the rachis; the leaves larger than in the next two species.

36. *A. hullettii* Furtado. The male flowers are not known and the species is doubtfully placed. The leaves have three pairs of segments.

37. *A. minuta* Scheff. The leaves have two pairs of segments.

38. *A. furcata* Becc.

AAA. Stamens 21-24. Leaves flabelliform

39. *A. ridleyana* Becc.

Section 5. *Mischophloeus*(Scheff) Becc.

Distributed from the Celebes westward to the Bismarck Archipelago and Solomon Islands, but not known from the Philippines.

40. *A. guppyana* Becc. The species appears to be very close to *A. novo-hibernica* Becc. The entire spadix is not known but judging from the fragment, it appears to be simply divided as in A. *novo- hibernica* Becc.

41. *A.henrici* Furtado. It has a compoundly divided spadix and is easily distinguished from all the other species in this section by its narrow leaflets.

42. *A. novo- hibernica* Becc.

43. *A. paniculata* (Miq) . Scheff.

44. *A. normanbyii* F. Muell

Revised name of this species is *Normanbyii normanbyii.* It is a manotypic genus, popularly called as 'black palm' originated in Australia. Trunk is slender enlarged at base, leaves pinnate, 6-8' long, petiole very short, leaflets arranged in groups of two or three attached to the base but divided and spreading outward, flower stalk below the crown

shaft, much branched fruits 3.8cm long pear-shaped colour of peach, fleshy seeds are broadly ovoid, 2 cm in diameter and roughly ridged (Fig. 5).

45. Areca nagensis Griff.

This species is not well known having imperfect specimens of leaves, an imperfect spadix with immature fruit, and a perfect fruit (Griffith, 1850). The trunk rises from 30-40 feet high and is attracted to the soil by innumerable black fibrous roots. The leaf stalk is naked for about three feet, the blade measuring about four. Pinnules sub-opposite or alternate, falcate, very acuminate, nineteen or twenty inches long, about one and a half inch broad, above with two or three stout keels; the terminal one deeply bilobed, variously partite, the laciniae or division bidentate; the less divided broader part obliquely truncate with irregular teeth. The leaves may be open to doubt, from their resemblance to those of *Areca gracilis* (*Pinanga gracilis* Blume).

The spadix measures about one foot; the compressed peduncle is divided from near the base into stout flexuose branches. The female flowers are on the lower parts of the branches, each with a scale-shaped bract. Sepals are round, oblong, obtuse; petals larger, sub-cordate with a short obtuse cuspis.

Fruit oblong–ovate, one inch long and 5 lines wide, attenuated to both ends, base surrounded by the perianth, apex rostrate-mammillate, truncate, with a small mammilla in the center; fibres numerous, stout, whitish. Seed erect, ovate, half an inch long, marked with many veins arising from the hilum, these are generally dichotomous, anastomosing reticulately on the dorsal face. Albumen cartilaginous, horny, ruminate, opaque white with embryo basilar (Murthy and Bavappa, 1962).

Related *genera*

In the regions where arecanut is cultivated, two kinds of palms are found to be growing widely. Even though these palms are similar to *Areca* in many of their morphological characters, it has been found that botanically they belong to a different genera altogether. In spite of this, in all places of their occurrence, they are termed as 'Wild arecanut'. Botanical description along with other particulars is as furnished by Murthy and Bavappa (1962).

Actinorhytis calapparia Wendl. & Drude.

Occurrence of this genus is believed to be in Saigon. Locally it is known as in different named as 'Rama Adike', 'Pandavara Adike', 'Katadike', 'Kam supari'. It is not cultivated, but found in groups along the Western Ghat forest areas and arecanut gardens. The stem is erect, unbranched, and annulate. solitary trunk, ornamented with scars of fallen leaves. Height 40 to 100 feet, circumference 20", Greyish brown in colour. Internodal distance at the crown and 9th node portions are half an inch and six inches, respectively. Leaves formed at the tip end of the stem in a compact crown. Pinnate leaves about 11. Petiole; plano-convex, length of leaf 86 inches lanceolate acuminate in outline, leaflet about 178, free and

alternately arranged, length of leaflet: namely tip leaflet 8", middle leaflet 27" and basal leaflet 11". Maximum breadth of the leaflet being 1¾". Leaflet linear, acuminate, unequally bipartite, shining, very smooth. Length of leaf sheath 44" and maximum breadth of sheath 16". Inflorescence covered by a boat shaped spathe, glabrous, compressed.in two whorls. Spadix ascending, altogether green, branches stiff, stout,opened spadix measures about 26"x 24" with 103 rachis approximately (Fig. 6).

Male flowers are many immute, triangularly shaped, situated on either sides of the female flowers and also in pairs at the tips of spadix, sepals imbricate, hard, shorter than petals, petals valvate hard oblong lanceolate and sub-obtuse, stamens 24-30, anther linear, pistillode, small. Number of female flowers in a spadix being about 1000, big, situated at the base and half the length of the rachis, sepals and petals imbricate with very broad bases staminode 3 or none, ovary large, white, oblong, one celled subcompressed divided at the apex into three, ovule one. Colour of the tender fruit will be green and the fully tree ripe nut will be crimson red, shape large oval; size: 2.7" length x 1.9" breadth. Outer skin of the fruit being brittle.

Kernel is very hard 1.5" length and 1.4" breadth, with a truncate base. Central white core extended to the periphery at certain points in between the brown lines. The outer cuticle of the kernel is highly fibrous and is hard. Thickness of the husk is 0.4". Embryo is basilar and the taste is Astringent. The nut is normally used for chewing. The tender nuts are husked, mashep and boiled to extract the tannin ('chogaru') which is used for colouring the boiled tender arecanuts. Of late, it has also been observed that tender nuts husked, sliced and dried are being chewed in certain areas of Malnad (Murthy and Bavappa, 1962).

Pinanga dicksonii Bl.

Locally it is known as 'Kadu Adike', 'Jinjadike'. This is solid type and found in-group in the forests of Western Ghats. The stem is usually short, erect; slender unbranched, sending out basal off shoots. Greyish brown colour trunk with scars of fallen leaves 16-20 feet height, circumference 6". Leaves are formed at the tip of the stem, 6 to 7 in number, three feet long, leaflets free and arranged alternately, and elongate, 12" to 24" long and ¾" to 1" broad with numerous spiral veins. Inflorescence is covered by a boat shaped glabrous spathe, spathe simple, rigid and compressed. Spadix is compound ramifications 4 to 8 alternate, simple equal, 6" to 8" long stout, clothed with imbricating flowers. Male flowers are large pink in colour, triangular in shape, calyx three cleft arranged in two rows on either side of the female flowers, stamens 20 to 30, filaments short and anthers linear. Female flowers are smaller subtended by two male flowers arranged alternately in two rows, staminode-six, clavate, style short, stigma three lobed. Fruit is berry, green when tender slightly reddish when fully ripe, small, size 1.9 cm. Long and 0.9 cm broad number of fruits from 100 to 150, pointing at the tip and with persistant calyx. Kernels hard, structure as in *Areca catechu*, size 1.4 cm x 0.7 cm. With broad white core in the centre and broader lines

at the sides. Small embryo situated at the basal center and astringent taste. In certain areas it has been reported that the tendernuts are boiled and used for mastication (Murthy and Bavappa, 1962). .

Even though the solid palms are not economically important, it has been reported that they are resistant to common pests and diseases that attack arecanut. It is possible to exploit these characters as well as other economic characters like size of nut, hardness of the palm etc. for the further improvement of arecanut crop.

Areca catechu L.

Regarding the specific epithet of betelnut palm there is some disagreement among the taxonomists. Linnaeus (1747, cited by Moore, 1959) first used the epithet *catechu* in connection with *Areca* in his treatise *Flora Zeylanica*. The same author in his *Species Plantarum* (1753) used the term *catechu* for the specific name of the arecanut palm, but in the index *to the* volume used the term *catechu* as well. According to Bailey (1949) the name is commonly misspelled as *catechu* and they adopted *catechu* as the correct specific epithet. McCurrach (1960) and Bhat *et al.* (1963) also maintained *A. catechu* as the correct name of the species. Moore (1959) dealing with the nomenclatural history of the taxon, derived evidences to show that the valid name for arecanut is *Areca catechu*. Based on the supporting evidences available greater usage and provisions in the International Code of Botanical Nomenclature, *Areca catechu* is to be accepted as the correct botanical name of arecanut palm (Furtado, 1960; Bavappa, 1964).

Trunk solitary, quite straight, 12-30 m high, usually about 20 inches in circumference, uniformly thick, leaves 1.2-1.8 m, leaflets numerous, 30-60 cm, upper confluent, glabrous (Fig. 7). Spathe double, compressed, glabrous. Spadix much branched, bearing male and female flowers. Rachis stout, compressed, branches with filiform tips. Male flowers very numerous, sessile, without bracts; calyx 1-leaved, small, 3-cornered, 3- parted; petals 3, oblong, rigid striated; stamens 6, anthers sagittate. Female flowers solitary or 2 or 3 at or near the base of each ramification of the spadix, sessile, without bracts; sepals 3,cordate, rigid, fleshy, permanent; petals 3, like the sepals permanent; staminodes 6, connate, styles scarcely any; stigmas 3, short, triangular. Fruit 3.8 -5.0 cm long, smooth orange or scarlet (Blatter, 1926). The normal somatic cells of the species contain thirty-two chromosomes (Venkatasubban, 1945). On an average the chromosomes are short in size as compared to those of other palms (Bavappa and Nair, 1982).

Cultivars

Rau (1915) described a new cultivar of arecanut from Mysore based on the sweet kernels of mature fruits and designated it as *A. catechu* var. *deliciosa.* Beccari (1919) recognized four cultivars of arecanut from the Philippines and termed them as *A. catechu var. communis, A. catechu var. silvatica, A. catechu var. batanensis and A. catechu var. longicarpa,* based on the size and shape of fruits and kernel. Cultivars available in Malaya,

Sri Lanka and South India have been designated by local names (Aiyer, 1966; Grist, 1926; Molegode, 1944; Nambiar, 1954; Sands, 1926). According to Kannangara (1941) there are apparently no distinct varieties of arecanut in Mysore, though some palms bear yellow and green fruits. The range of variation in flowers, size and shape of fruits in different cultivars of *A. catechu* occurring in Assam was described by Raghavan and Baruah (1956a). Murthy and Bavappa (1962) identified 64 cultivars based on fruit size, from Kerala, Karnataka and Maharashtra. The pattern of variation differed in relation to the topography of the tract. Variation in plant morphology, fruit colour, shape and size was observed in different accessions occurring in Konkan and North East region (Ananda 1999). Based on the variation in number and size of nuts and stomatal characters pertaining to four cultivars of *A. catechu*, the cultivars could be identified based on the number of stomata per unit area (Bavappa 1966). Variability existed in respect of vegetative and nut components in indigenous accessions (Ananda and Anuradha Sane, 1999). Bavappa and Pillai (1976) found highly significant differences in respect of number of leaves shed, spadices and female flowers produced, nut set, number of nuts harvested and weight and size of nuts among thirteen cultivars of *A. catechu* from eight countries. Significant differences among the 17 Andaman collections in respect of 14 morphological and 12 fruit component traits were observed (Ananda, 2001).

The areca palms could be broadly classified into tall, semitall and dwarf types. The height ranges between 60 cm and 360 cm as recorded at the seventh year of age. A dwarf arecanut mutant was reported by Naidu (1963a) from Hirehalli, Karnataka and 40-year-old mutant attained a height of only 4.57m. The nuts were of medium size and slightly elongated.

The characterization of Dwarf types was done on the basis of morphological and reproductive traits. The dwarf showed distinct differences in morphological characters (Fig. 8) as compared to Hirehalli Tall Local. The main features of the Dwarf areca is the complete suppression of internodal space, erect crown shape, reduced leaf length, leaf breadth, leaf sheath length and leaf sheath breadth. Dark green colour of leaves is another distinguishing character of this dwarf. The inflorescence and floral characters were similar to *A. catechu* (Ananda, 2000). Further, Hirehalli Dwarf showed distinct differences in reproductive characters and recorded lower values as compared to Hirehalli Local. About 41.2 per cent higher fresh nut yield palm / year was recorded in Hirehalli local (H. Local) over H. Dwarf. However, a higher recovery percentage from fresh (29.4%) nut to chali yield was observed in H. Dwarf as compared to H. Local (25.3%). The placement of bunches on the palm was erect in case of H. Dwarf whereas drooping bunches were noticed in H. local. The yellow to orange red colour and round to oval shape and smaller nut size is the distinguishing characters in this dwarf (Ananda, 2002). About 94 per cent typical dwarfs were recovered when inflorescences/female flowers were selfed, whereas in open pollinated, only 64 per cent dwarf seedlings were recovered. This confirms the outcrossing nature of dwarfs (Ananda, 2000).

Fig. 6. *Actinorhytis calapparia* Wendl. & Drude

Fig. 7. *Areca catechu* L. (cv. South Kanara)

Fig. 8. Hirehalli Dwarf- A natural mutant of *A.catechu* L.

Fig. 9. Root system (seedling)

MORPHOLOGY

Arecanut normally attains a height of 16-18 meters with a graceful, erect and unbranched stem. The stem has scars of fallen leaves in a regular annulated form. The crown is compact with pinnate leaves, which are partly free and partly fused. The basal region of the leaves forms a broad sheath, which completely encircles the stem so as to protect the developing inflorescence until a few days prior to opening.

Roots

Arecanut palm has an adventitious root system (Fig. 9). The first root of arecanut is formed from the pro-stem of a germinating nut, earlier to the development of the first leaf. This takes place in about 30 days after sowing. The root at this stage is about 0.6 cm in length. Within 20 days more roots are produced from the region of the first root. The later forming roots emerge from the points opposite to the emergence of the first root. Rootlets of various sizes are formed in about 90 days after sowing. The cotyledon grows almost to its full size in about 50 days after sowing and by this time the sprout is visible outside the husk (Bavappa and Murthy, 1961).

As the age of the seedling advances, more and more roots are produced from the nodes formed as a result of leaf fall in the initial three years of growth. A Fully-grown up base of the palm is found to have about 10-12 rows of roots corresponding to the number of leaves shed within the first three years of growth. It is quite possible that the root production is mainly confined to the nodes formed by the leaf- fall. This root-producing zone which has the shape of an inverted cone is about 28 cm in length and 23 cm in diameter, with a slant distance of 32 cm and it is termed as 'bole' (Bavappa and Murthy, 1961). The root tip is protected by a root cap which is having a diameter greater than that of the roots. The absorbing zone of the growing tip is found to be located just behind the root cap and is normally white in colour. The vertical penetration capacity of the root is rather low and most of the roots spread laterally. The main roots measure 1.96 m in length on an average. They are fairly uniform in thickness ranging from 9 mm to 18 mm. The main roots produce large number of laterals, which further branch profusely. Normally many roots are not formed above the 'bole' region even when buried in the ground (Fig. 10).

Numerous short conical outgrowths resembling a flower bud, attached to the roots with constricted filament, are found to be distributed all over the roots. Middle-aged and old palms have larger number of such outgrowths than the young ones. It appears that these outgrowths perform breathing function and may be termed as pneumatophores. They originate like rootlets, but remain short and bulged. Their cortical cells develop prominently and get hardened to some extent enclosing numerous micropores, which are impervious to water (Davis, 1961; Bavappa and Murthy, 1961). These cavities have direct connection with the aerenchyma of the root from which the pneumatophores originate and thereby

Fig.10. Root systems (adult palm)

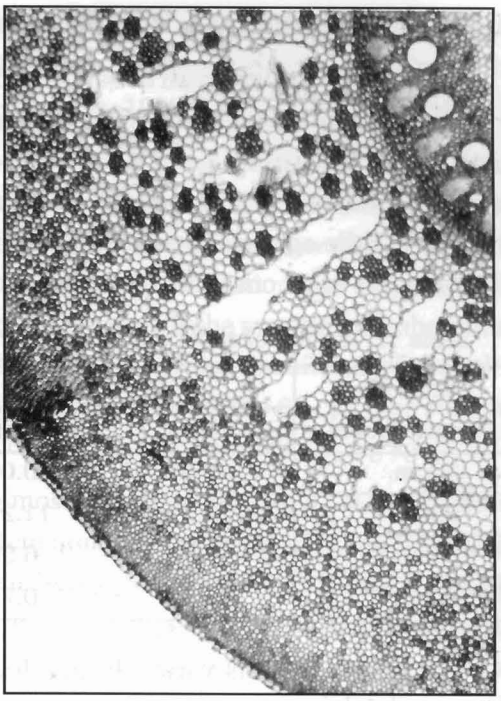

Fig.11. Transverse section of root

Fig.12. Arecanut stem showing nodes and lichen growth

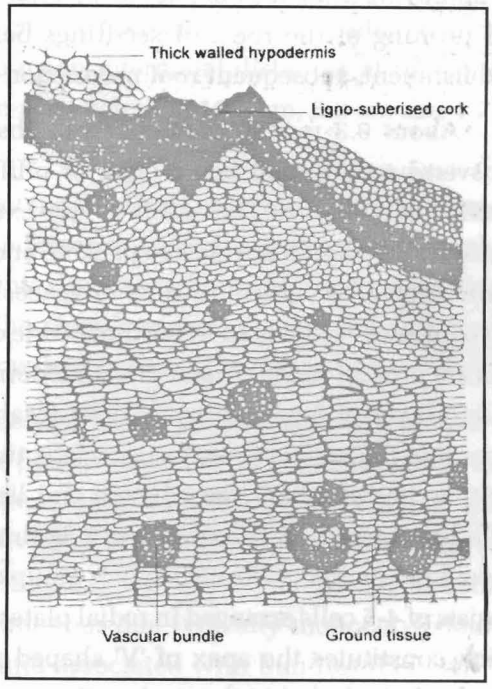

Fig 13. Transverse section of stem showing lingo-suberized cork

enable the roottip buried under water or in marshy soil to have contact with the atmosphere.

The roots spread from all the sides and generally grow in the direction in which they start. The number of roots in a palm depends upon its age and has been estimated to be about 175 in a 10-year-old palm, 385 in a 35-year-old palm and 78 in a 68-year-old palm. In older palms, the earlier formed roots are found to decay. The maximum concentration of roots in a middle-aged palm is within the first 60 cm depth from the ground level, and within a radius of 60 cm from the palm (Table 1).

Table 1. Number of roots per 30 cm at varying depths and distance from the palm

Depth from ground level	Distance from the palm				
	30 cm	60 cm	90 cm	120 cm	180 cm
30cm	29.50	10.00	2.00	2.25	2.25
60cm	57.75	11.25	3.00	2.25	2.50
90cm	17.75	6.50	0.50	0.50	0.75
150cm	1.50	0.75	0.50	0.75	0.50

The colour of roots varies during development with age. The roots produced by a seedling upto an age of one year are creamy white in colour, which slowly change into light brown during the next two years of the growth. These roots become darker in colour with age and by the time they are about 10 years old, they become dirty brown. It was observed that pruning of the roots of seedlings before transplanting affects adversely the field establishment, subsequent root production and growth (Bavappa and Murthy, 1961).

About 9.3 mm in diameter was observed in the root of areca palm through the transverse section and has a layer of piliferous lignified square cells. Below it lies the lignified hypodermis. The cortex is very extensive having numerous small irregular round fibre bundles, which are closely packed, and large fibre bundles lying scattered. The cortex is interrupted by vertical rows of airspaces. A broken ring of sclereids and an incomplete ring of pigment cells occur in the inner cortex. Raphide sacs are numerous and a few mucilage cells are present in the cortex. The endodermal cells belong to the 'C' type and are followed by one layer of large pericycle cells (Mahabale and Udwadia, 1960; Raghavan, 1957). According to Drabble (1904) pericycle is two-layered in small roots . The stele consists of 80-90 arches of xylem and phloem and lies in a continuous mass of conjunctive, thick-walled and lignified parenchyma. It is thrown into rays enclosing islands of xylem and phloem below the pericycle. Xylem groups are either 'I' or 'V' shaped. Each xylem strand consists of 4-5 cells arranged in radial plates and terminates in a relatively large metaxylem, which constitutes the apex of 'V' shaped xylem strand. Such large metaxylem cells are completely included in the conjunctive parenchyma. They generally have a single layer of thin-walled unlignified parenchyma around them. The conjunctive tissue is thrown to zig-

zag lobes on its inner margin. The central pith is 3520 m broad, contains numerous fibre bundles of different sizes, all hydrocentric (Fig.11). The occurrence of aerial roots in arecanut was reported (Davis (1960; 1961; Murthy and Bavappa, 1959).

Shoot

Murthy and Bavappa (1960a) reported that the stem becomes visible when the palm is about three years old. The stem is marked with scars of fallen leaves in a regular annulated form. The girth of the stem generally depends on the genetic variation and soil conditions. In the initial stages of growth of the palm, the girth of the stem is the maximum. Subsequently the girth gets reduced and thereafter maintains it under normal conditions of growth. In the case of young palms (about 10 years), the girth varies from 38 to 60 cm. The stem may gradually become thinner under unfavorable conditions and with advancing age.

The arecanut stem grows erect under almost all circumstances. Due to the absence of secondary growth, any injury caused to the stem remains unrepaired. It cannot withstand much damage and is liable to break due to such injury. Since the stem is thin, it posesses great mechanical flexibility so that the palm oscillates in strong wind and thus escapes breakage. The bud produces the leaves in succession and when the leaves are shed, permanent scars are left on the trunk. The age of the palm can be approximately gauged by the count of the scars on the stem. The growth of the stem is rather rapid particularly in the initial stage (Murthy and Bavappa, 1960a). Further, the internodal distance at the tenth internode of young palms vary from 13.9 to 34.3 cm and thereafter there is gradual reduction in the rate of growth as the age advances. The mean internodal distances at the bottom, middle and top portions of the stem of a middle-aged palm are 10.5 cm, 6.8 cm and 1.7 cm respectively.

Murthy and Bavappa (1960a) reported that the length of the stem varies with intensity of population, climate etc. The erect unbranched stem is typically cylindrical throughout and is derived from a single terminal growing points situated at the top of the trunk enveloped by leaves in various stages of development. The stem is green when young and greyish brown when old, sometimes with epiphytic growth of lichens (Fig. 12).

A heavy layer of cuticle in epidermis of the stem in early stages of growth is observed and cells are more or less isodiametric with the presence of stomata (Tomlinson, 1961). In the older stem, the outer cortex including the epidermis and hypodermis become thick-walled and as a result of the meristematic activity of the etagen-type a distinct layer of lingo-suberized cork is produced (Fig. 13). In younger stages, the hypodermal cells contain abundant chloroplasts. Vascular bundles are numerous and typically monocotyledonous. A girdle of sclerenchyma cells is invariably found associated with bundles (Fig. 14). The ground tissue consists of symmetrically arranged rows of cells, which form a sort of spongy network towards the centre of the stem with small air spaces. Due to the absence of cambium

there is no secondary thickening. The stem of the seedling increases in growth due to meristematic activity producing more and more cells and vascular bundles and results in a thick stem (Raghavan, 1957).

Abnormalities like stem - splitting at the base at different heights, stem twisting, twisting of crown to a side caused by the twisting of internodes, and longitudinal splitting of the stem have also been reported (Murthy and Bavappa, 1959; Naidu, 1959; 1963b). Transformation of inflorescence to vegetative branches due to injury of the growing point has been attributed to be the cause of branched arecanut palms (Davis, 1950a; 1950b; Jacob, 1940; Murthy and Bavappa, 1959; Naidu, 1963b; Thomas, 1964).

Leaf

The crown of the palm is located left at the top of the trunk, subtended by the leaf sheaths, has leaves at various stages of development. The number of leaves varies depending on the age and vigour of the palm, nutritional status of the soil etc. One-year-old seedling has normally 4-5, two-year old 6-7 and three year old 7-8 leaves on the crown. In adult palms the number of open leaves on the crown ranges from 7 to 12. In the arrangement of leaves on the crown, the sixth leaf strands over the first with a spiral of two circles and the eleventh leaf over the sixth with similar spiral. Thus, there are five rows of leaves (orthostichous) placed at 2/5 distances of the circle, giving a phyllotaxy of five ranked or pentastichous with an angular divergence of 144^0 (Fig. 15). The bud produces leaves in succession and the young leaf makes its appearance in the center of the crown with all the leaflets held together and is termed as the spindle. As the leaf gets older it bends and during this process the leaflets get opened. The longevity of the leaf after its emergence is about two years.

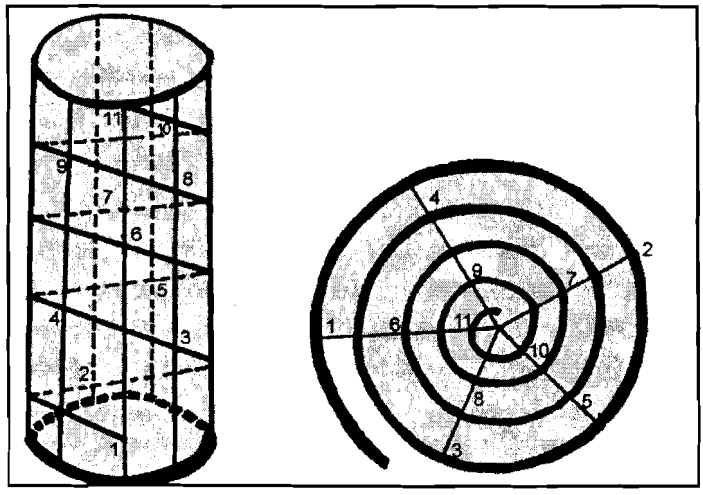

Fig.15. Phyllotaxy of arecanut palm

A mean of 43 days interval between successive leaf emergence, leaf fall was noticed. The leaves are pinnatisect and consist of a sheath, a rachis (leaf-stalk) and leaflets. The leaf stalk extends as the midrib till the end of the leaf and ends as leaflets. The leaf sheath completely encircles the stem forming a protective covering for the developing inflorescence. The sheath is about 54 cm in length and 15 cm in breadth. The average length of the leaf is 1.65m and varies with the vigour of the palm and fertility of the soil. The total number of leaflets situated on either side of the leaf is about 70. The leaflets near the base are about 62.5 cm in length and 7 cm in breadth. Those near the apex are 30.0 cm in length and 5.8 cm in breadth whereas in the center they are 69 cm in length and 7 cm in breadth. The leaflets are partly fused and partly free and arranged alternatively on eitherside of the petiole. At the distal end of the petiole, two or three pairs of leaflets of each side are fused to form a bifid tip (Fig. 16). The leaflets have one or more midribs. The leaf blade is leathery and soft. The colour of the leaves depends on the shade, heavier shade giving a dark green colour (Murthy and Bavappa, 1960b).

The anatomy of the leaflet shows an upper epidermis consisting of a single layer of cells with a thick cuticle, palisade parenchyma, vascular bundles, spongy parenchyma and lower epidermis (Fig. 17). The vascular bundle consists of xylem and phloem and the number of spongy parenchymatous cells are much less. The stomata are small and distributed on the centre of the surface (Fig. 18). The mean number of stomata and epidermal cells per unit area, stomatal index and the correlation coefficients of the number of epidermal cells of four cultivars of arecanut are given in Table 2 (Bavappa, 1966). Bhat (1962) noticed two leaves in the same node of an arecanut palm arranged in an opposite fashion, enclosing two productive spadices. The occurrence of two spadices enclosed by a single leaf also has been reported.

Table 2. Stomatal index and correlation coefficient between number of stomata and number of epidermal cells in four cultivars of *A. catechu*

Cultivar	No.of stomata / Unit area	No. of epidermal cells/unit area	Stomatal index	Correlation coefficient
South Kanara	104.2	832.3	11.1	0.9474**
Shimoga	58.4	748.6	7.2	0.9148**
Palahat	50.0	701.4	6.7	0.6472**
Coimbatore	35.9	658.4	5.2	0.6683**

** Significant at 1 percent level of probability

Inflorescence

Arecanut palm flowers in about four years when grown under the best conditions (Sands, 1926). In "South Kanara" cultivar, the first inflorescence appears at the tenth node

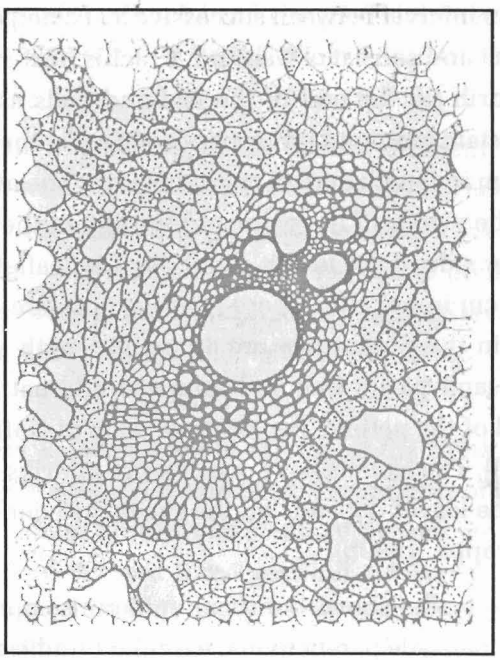

Fig.14. Transverse section of stem showing vascular bundles

Fig.16. Arecanut leaf showing bifid tip

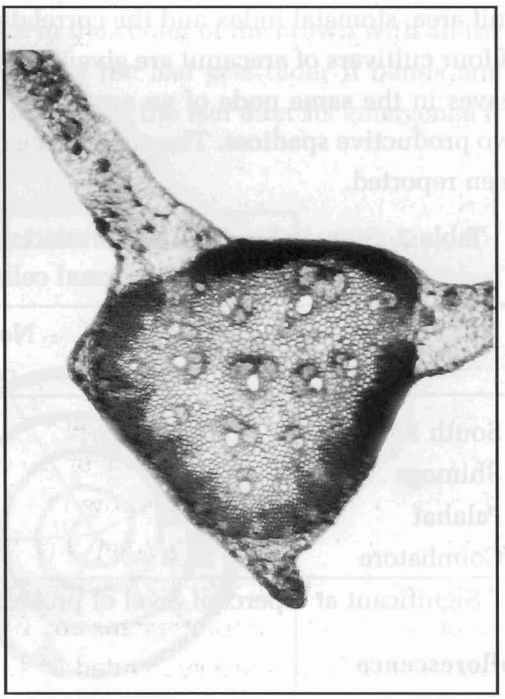

Fig.17. Transverse section of leaflet

at a height of about 1.52 m from the ground (Murthy and Bavappa, 1960b). The inflorescence of arecanut is a spadix, which is produced in the leaf-axils (infra-foliar). Each spadix is completely enclosed in a sealed, boat-shaped spathe having a mean measurement of 75.0 cm long and 45.9 cm wide (Nair,1962). The spathe is very thin in texture and the expanding spadix easily bursts the spathe along its upperside in a central longitudinal line and frees itself.

The production of spadices depends upon the number of leaves produced. The absence of bunch in any node must be due to abortion of the young spadix (Murthy and Bavappa, 1960a). The mean number of spadices produced by a young, middle- aged and old palms are 3.8,3.5 and 3.1 respectively. The spadix is short-stalked, 69.0 cm long with a main rachis giving rise to 12-16 secondary rachis which inturn bears the tertiary rachis. The female flowers are confined to the tertiary rachis and to the distal end of the secondaries. The male flowers are produced on filiform branches (15-25 cm long), which arise below and beyond the female flowers. The male flowers are arranged in pairs of two rows along the upper part of the thin branches but occassionally one or two are found adjoining a female flower (Fig. 19). The spadix of a grown-up palm produces upto 644 female flowers and 15,000-48,000 male flowers. Some palms in *Malnad* area (Karnataka) have been observed to produce upto 1,457 female flowers (Murthy, 1977; Murthy and Bavappa, 1960a; Raghavan, 1957).

In the first flush, an inflorescence bears hundred or more of female flowers. Towards the end of the flowering period when the reserve food materials which the palms are known to accumulate in abundance becomes exhausted, the number of female flowers in an inflorescence become progressively reduced till in the last produced ones only a dozen or less female flowers are found (Rao, 1959). It is also seen that in the region of transition between the female and male parts of the spike in which the food material becomes attenuated, bisexual flowers or sessile female flowers are produced.

The crown of adult palms, which has 8-9 opened leaves, consists of leaf primordia at various stages of development. Inflorescence initiation is noticed in every leaf axil upto the growing point. The inflorescence primordium is initiated along with leaf primordium. The rate of growth of inflorescence is slow till it reaches the sixth leaf axil. Thereafter the length of inflorescence doubles in each of the successive leaf axil. The inflorescence primordia at the fourth unopened leaf show the initial differentiation of primary rachis and the inflorescence in the second unopened leaf differentiates into secondary rachis. The spathe covering the spadix also differentiates at this stage. The inflorescence located in the first unopened leaf has tertiary rachis and filaments. The initiation of male flowers commences from the inflorescence subtended by the spindle. Female flowers begin to develop when the inflorescence is in the axil of the first opened leaf. Initiation of male and female flowers is complete in the inflorescence at the sixth leaf axil (Bavappa and Rao, 1970).

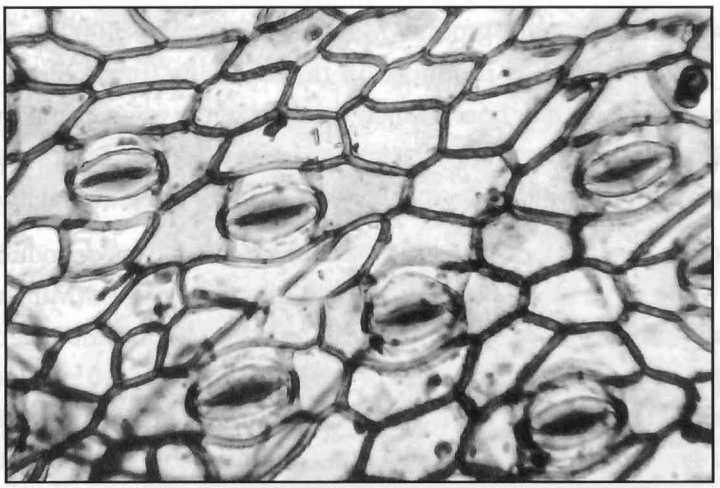

Fig.18. Distribution of stomata in the leaf

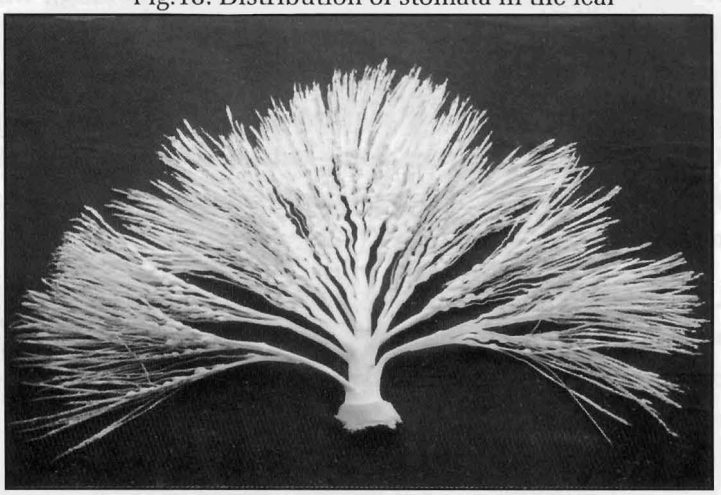

Fig.19. Inflorescence showing male and female flowers

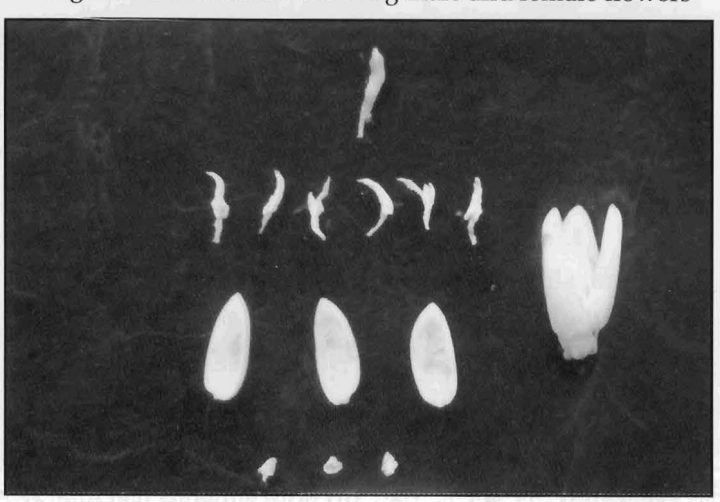

Fig.20. Structure of male flowers

Male flowers

In cultivated *A. catechu*, the male flowers are sessile, creamy white, triangular with two whorls of perianth consisting three-minute sepals and three large stiff lanceolate petals. The sepals are imbricately arranged and are about 0.1 cm in length. The petals are about 0.35-0.4 cm in length with acute valvate tips. The stamens, which are six in number have basi-fixed anthers and are situated in a ring next to the petals (Bavappa, 1966). The rudimentary ovary (pistillode) situated in the center is trifid and slightly larger than the stamens. The anthers are closely addressed to the pistillode (Fig. 20).

Female flowers

The female flowers are sessile with two whorls of perianth (3+3), the outer boat-shaped green whorl of sepals and an inner whorl of ovate petals in imbricate aestivation. The petals, which are closely adpressed to the ovary, are also imbricately arranged (Murthy and Bavappa, 1960a). There are six flattened minute staminodes whose bases are joined together encircling the base of the ovary. The ovary has a dome shaped trifid stigma formed by three stiff stylar projections (Fig. 21).

Abortion of inflorescence

Table 3. Seasonal variation in leaf fall and inflorescence production

Month	Average number of leaves shed from 1575 trees	Average number of inflorescences developed in 1575 trees	Percentage of inflorescences to the leaf fall
July	549.5	101.0	18.5
August	543.5	86.5	15.9
September	541.5	118.5	21.9
October	871.5	286.0	32.8
November	1014.0	552.5	54.5
December	391.5	678.5	76.1
January	1205.5	1048.5	87.0
February	1208.5	1063.0	88.0
March	1206.5	1124.5	93.2
April	1006.5	866.0	86.1
May	851.0	491.5	57.9
June	611.5	148.0	24.2

The presence or absence of inflorescence in the leaf axil regularly in 300 progenies of 10 mother palms, for seven years from the commencement of their bearing was recorded (Murthy and Bavappa, 1960a). They observed considerable variation in the production of inflorescence in different months of the year (Table 3) as well as between different years. More than 50 percent inflorescence aborted, in leaves shed in July, August and September.

Bavappa and Rao (1970) reported considerably high percentage of inflorescence abortion under neglected condition.

Aborted inflorescences had more or less equal length, indicating that abortion in all the inflorescences took place after they had grown to a uniform extent (Bavappa and Rao, 1970). It also appears that the time of abortion coincides with the period at which the inflorescences start to develop at a rapid rate.

Fruit

The arecanut fruit is a mono-locular one-seeded berry. The colour of the nut is orange red to scarlet when ripe and consists of a thick fibrous outer layer, the husk which encloses a single seed. The endosperm is ruminating, opaque, white and astringent (Murthy and Bavappa, 1960a; Bavappa, 1966). Fruits may be of various sizes and shapes such as round, long, oblong etc (Raghavan, 1957). Usually about 100-250 fruits are found in each bunch. In the younger stages, they are green and as maturity approaches the colour gradually change. The endosperm of the seed is reddish brown with dark wavy lines giving it a marbled appearance. There is a single embryo situated at the base of the seed (Fig. 22).

The mature fruit consists of three zones exocarp, mesocarp and endocarp which are more or less distinct in structure. The exocarp consists of the epidermis covered by a cuticle and parenchymatous cells inter-mixed with stray collenchyma and separate strands of thin fibres. The upper 10-12 layers of parenchyma contain chloroplasts. The mesocarp which is a continuation of exocarp is characterized by more or less parallel rows of parenchyma cells with lignified fibres. About four fibres per unit area occur both as separate strands and as sheath or bundle caps associated with vascular bundles. The endocarp consists of highly pitted and elongated parenchymatous cells covered by thick-walled inner epidermis and the thick cuticle.

FLORAL BIOLOGY

The arecanut palm is monoecious with male and female flowers occurring on the same spadix. Arecanut palm is essentially a cross fertilized species (Bavappa and Ramachander, 1967). Opening of male flowers start same day or 1-11 days after the spathe bursts exposing the spadix. In some stray cases, male flowers in open condition are found shedding in large numbers along with the bursting and falling of the spathe, thereby indicating that the male phase must have commenced in the spadix while it was still inside the spathe. The opening of the individual flower is found to commence at sunrise, with a persisting strong aroma. The sequence of opening is from tip of rachillae downwards (Bavappa, and Ramachander, 1967). The anthers dehisce simultaneously with the opening of the flower. The male flower drop off either on the same day or the following morning. After the male flowers are shed, a clear nectar is found to ooze out from the point of attachment of male flowers. The male phase (the interval between the opening of the first

male flower and the last male flower in a spadix) in arecanut lasts 25-46 days, the mean being 31 days (Bhat *et al.*, 1962b ; Murthy and Bavappa, 1960a).

The female flower buds at the time of opening of spathes are generally cream coloured turning green within about a week after exposure to light. They open between 2 a.m and 10 a.m. just prior to opening; the corolla lengthens and attains an attractive colour of shiny cream or ivory white. The calyx also looses its green colour and turns greenish yellow or white with a green tinge. The initial opening of the flower is indicated by the formation of a very minute slit at the corolla and this aperture, which attains 'Y' shape widens slightly in the course of the next five or six days by the slight falling apart of the tip of the free petals, exposing the stigma. Generally the female phase extends from three to ten days.

The maximum receptivity of the stigma is on the day of opening of the flowers under Coimbatore condition. The stigma continues to remain receptive on the second and third days and thereafter there is a rapid decline in receptivity (Bhat *et al.*, 1962b). Under Dakshina Kannada condition, the stigma remains receptive upto six days (Murthy and Bavappa, 1960b). The maximum receptivity is between the second and fourth day of opening. Beyond the 6th day, stigma looses its receptivity. Middle-aged palms have a higher stigmatic

Table 4. Stigmatic receptivity (percentage of fruit set) of palms of different age groups.

No. of days after opening	Percentage of fruit set			
	Young palm	Middle aged palm	Old Palm	Mean
1	16.7	27.5	13.4	19.8
2	19.9	41.9	13.6	25.1
3	30.1	31.1	8.5	23.2
4	23.3	35.2	8.1	22.3
5	14.1	21.8	5.4	13.8
6	8.7	6.0	4.6	6.4
7	-	-	-	-

Table 5. Inflorescence characters of arecanut varieties

Varieties/ Characters	Spadix		No. of female flowers/ inflorescence	Duration of male phase	Duration of female phase	Production of inflorescence /palm/year
	Length cm	Breadth cm				
Mangala	62.83	14.83	282.94	22.04	4.90	5.00
Sumangala	66.74	16.97	335.15	25.12	5.36	4.16
Sreemangla	63.75	15.68	259.45	26.02	5.11	3.83
Mohitnagar	70.59	14.37	324.76	23.22	4.23	5.16
VTL-12	67.95	14.23	235.67	25.05	4.80	4.5
CD	8.63	NS		2.63	NS	0.83

receptivity than the young and old palms (Table 4). It has been estimated that about 13 per cent inter-spadix and 4 per cent intra spadix overlapping of male and female phases take place in arecanut (Murthy and Bavappa, 1960a).

Ananda and Rajesh (2002) studied the inflorescence characters, duration of male and female phase, nut set and also seasonal variation in production of spadices in improved varieties of arecanut under Dakshina Kannada conditions. The spadix length varied between 62.83cm in Mangala and 70.59cm in Mohitnagar with a mean of 66.37cm while maximum spadix breadth of 16.97cm observed in Sumangala and minimum of 14.23cm in VTL-12. Variety Sumangala exhibited superiority for the production of female flowers and all the floral characters (Table 5). In arecanut only monoecious inflorescences have been reported but occasionally few numbers of bisexual flowers observed on the same rachis between male and female flowers in varieties (Ananda and Rajesh, 2002; Raghavan and Murthy, 1954). Duration of male phase varied significantly among the varieties (Ananda and Rajesh, 2002).

In arecanut, when all the male flowers have completed the blooming and shed, the female flowers begin to open from bottom to top. In general female phase was found to be

Table 6. Artificial pollination and fruit set in arecanut varieties

Variety	No of female flowers pollinated	Fruit set	Fruit set range	Percent of fruit set
Mangala	408.29	275.50	249.0-325.0	67.48
Sumangala	310.75	202.92	106.0-318.0	65.30
Sreemangala	392.83	235.58	201.0-294.5	59.97
Mohitnagar	360.83	228.00	172.0-281.0	63.19
VTL-12	340.84	157.79	82.0-238.34	46.29
CD	NS	58.38*	-	-

*Significant at 5% level

shorter (Table 5; Ananda and Rajesh, 2002). Overlapping of male and female phase by 2.33 days was noticed in Mangala. Though cross-pollination is predominant in areecanut, selfing of flowers to a very small extent of 0.8 percent of the total number of nuts produced can take place (Murthy, 1977). Interspadix overlapping have been observed in Sumangala (0.83 days) and VTL-12 (2.76 days) while variety Mohitnagar showed no sign of overlapping between spadices of the same palms indicating the complete out crossing nature. An average of 60.45 per cent fruit set recorded in grown up palms of released varieties while Mangala had maximum of 67.18% nut set through artificial and minimum of 46.29 per cent in VTL-12 (Table 6).

In general, inflorescence emerges in increasing trend from October to February and gradually declines from March onwards. Production of maximum numbers of inflorescences

observed during the months of December to March in released varieties and South Kanara Local cultivar (Ananda and Rajesh, 2002; Murthy, 1977).

Breeding behavior traits in eight hybrid combinations involving Hirehalli dwarf (HD) and five parents *viz.*, Mangala, Sumangala, Sreemangala, Mohitnagar and Hirehalli dwarf showed significant variations with respect to most of the floral characters (Ananda and Rajesh, 2003). It was observed that the number of female flowers production in an inflorescence ranged between 221 (HD x Sreemangala) and 530 (Mangala x HD). The duration of male phase ranged from 18.50 (Mangala x HD) to 26.50 (HD x Sreemangala) days with a mean of 20.93 days, while female phase from 2.5 (HD x Mohitnagar) to 11.00 (HD x Mangala) days. The longer female phase necessitates the pollination of same inflorescence many times, while the early receptivity of the flowers leads to emasculation and bagging of the inflorescence before spontaneous dehiscence of the spathe. The production of more number of female flowers, longer female phase and gap between male and female phases are found to be advantageous and could be favourably utilized in arecanut breeding programs (Ananda and Rajesh, 2003).

POLLINATION

Pollen dispersal

The dispersal of *Areca* pollen was studied in a garden isolated all round by 5 km using aeroscope, for catching pollen and obtained pollen catch upto a distance of 1.2 km (Murthy and Bavappa, 1961). Pollen intensity was maximum at 8 am. Gradual reduction was observed in the total pollen from the first week of March to the last week of April. Maximum pollen was obtained at 12 m height and nearest to the garden. The pollen dispersal was maximum between four and seven hours after anthesis (Raghavan, 1957).

Male flowers are visited by various bees and other insects, which appear to collect and feed on pollen grains. The role of insects in pollination is doubtfull, since no insect visitors are reported on female flowers. Pollen is carried by wind and the flowers are usually cross-pollinated. Only under exceptional circumstances self-pollination takes place (Murthy and Bavappa, 1961; Raghavan and Barauh, 1956b; Sands, 1926). However, two species of thrips and other insects such as ants visiting the flowers are reported (Bhat, 1963; Murthy and Rao, 1961). Floral abnormalities such as abnormal male flower (Raghavan, 1957) proliferation of flowers (Murthy and Bavappa, 1959), perianth lobes ranging from 4 to 10 arranged in two or more whorls, bisexual flowers and their occurrence with male flowers have been reported (Bavappa and Murthy, 1961; Raghavan and Murthy, 1954).

Germination of pollen

Arecanut pollen remains viable for 8-9 hr under normal conditions (Raghavan and Baruah, 1956b). Increased longevity of pollen from 15 to 21 days by storing in a desiccator at room temperature was reported by Bhat *et al.* (1962b). Pollen grains germinate rapidly in

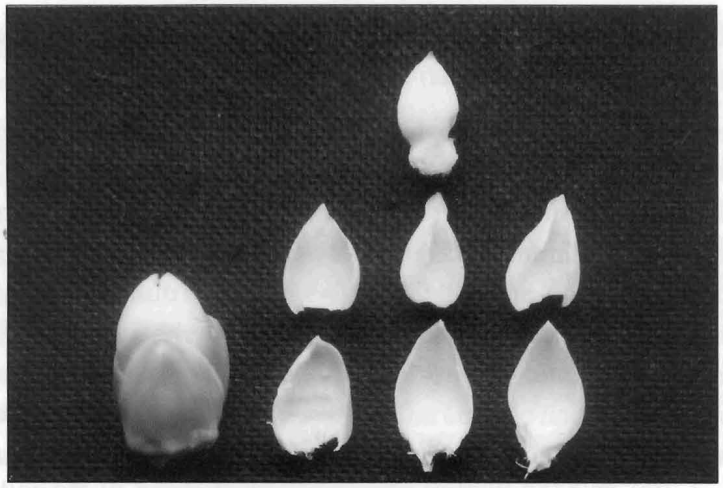

Fig.21. Structure of female flowers

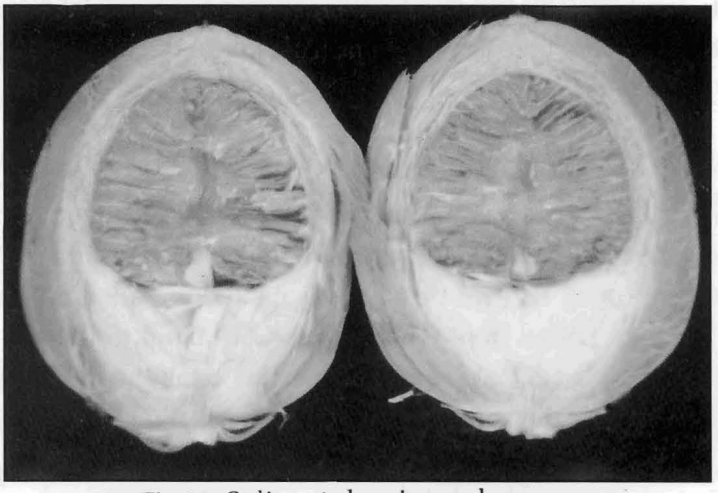

Fig.22. Split nut showing embryo

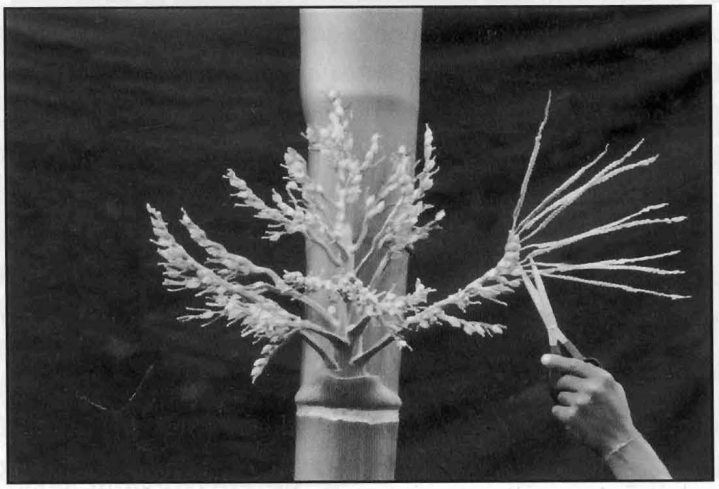

Fig.23. Emasculation of male flowers

nutrient media, the percentage depending on the medium employed, its concentration and the type of grains used. A medium consisting of 0.5% sucrose and 0.1% agar was found ideal for pollen germination in arecanut at Vittal (Anonymous, 1967). Further it was observed that addition of 100 ppm boric acid and 500 ppm gibberellic acid to the above-mentioned medium increased the germination percentage (Anonymous, 1969). Raghavan Barauh (1956b) obtained optimum germination in a basic medium of carbohydrates consisting of sucrose 0.75 per cent or glucose 0.5 per cent or starch 0.5 per cent. Addition of growth regulators like 3- indoleaceticacid, 3- indolebutyric acid and 2- naphthalene acetic acid to the medium stimulated germination of pollen grains. The length of pollen tubes varied from 15 to 600m depending on the type of nutrients used. The percentage of germination in crushed aqueous stigmatic extracts had no appreciable variation and the length of pollen tubes did not in any concentration exceed 320m in 24 hr (Raghavan and Barauh, 1956b). The optimum temperature for germination of pollen was found to be 28° C whereas 15° C, 30° C, and 35° C were inhibitory.

Crossing technique

In arecanut the hybridization technique consists of removing the portion of rachillae having male flowers (emasculation) soon after the emergence of the inflorescence (Fig. 23)

Table 7. Artificial/Assisted pollination and fruit set in arecanut palm

Treatment	No. of palms selected	Total female flowers	No. of flowers set	Percentage of set
Sprayed with aqueous solution of sucrose.	36	8969	1080	12.0
Sprayed with pollen held in suspension in sucrose solution.	36	10352	2727	26.4
Control (Open pollination only).	36	7960	958	12.0

and covering the spadix bearing female flowers with a cloth bag (Fig. 24). When the female flowers open, the anther from the desired male parent is rubbed against the stigma or the pollen is dusted on the stigmatic surface, by removing the bag (Fig. 25). The bag is replaced over the inflorescence immediately after pollination. The process is repeated daily for about a week till all the female flowers in the spadix open. The process is repeated daily for about a week till female flowers in spadix open and fruit set can be seen after 20 days (Fig. 26).

The artificial method of pollination in *Areca* was reported by Bhat (1963; 1965). In this technique, fully opened male flowers are collected from the selected palms and are

transferred to a reagent bottle containing 0.5 per cent solution of sucrose and the bottle is shaken gently. The pollen grains thereupon get released in the aqueous solution. The solution with the pollen grain in suspension is transferred to an ordinary hand atomizer and sprayed on to newly opened female flowers. The spraying may have to be done three to four times as all the female flowers do not open at the same time. About 14 per cent increase in fruit set was obtained by this method and the same could be successfully used in commercial crop hybridization (Table 7).

FRUIT DEVELOPMENT

Under normal condition only about 30 per cent of the female flower get fruit set. The problem of low fruit set was investigated from various angles and it was observed that lack of pollination was one of the causes for shedding of female flowers. Fungal as well as insect association was also observed in the case of dropped female flowers and tender nuts. Maximum shedding was observed on the 6^{th}, 7^{th},and 8^{th} day after the first flower was shed (Anonymous, 1967). Observations on such flowers showed that 77.7 per cent of these shed flowers were properly opened, 13.0 per cent partially opened and 2.3 per cent unopened.

Male sterility and 3-54 per cent female fertility in different cultivars of *A.catechu* have been noticed (Raghavan and Barauh, 1956b). The probable cause of female sterility according to these authors were dichogamy, presence of sterile pollen grains, failure of pollen grains to germinate, length of pollen tubes being insufficient to reach the ovule, shorter longevity of pollen grains and the receptivity of stigma and effect of temperature on the germination of pollen grains. In *A. catechu*, which had a high pollen fertility (82.7-98.2 per cent), the nut set was less than 50 per cent. The fruits set in this species varied from 12.0 to 42.2 per cent in different cultivars of this species (Bavappa, 1974).

The spraying to emerging inflorescences with 100 ppm GA, or 50 ppm 2,4-D, or 200 ppm B-995 increased fruit set in arecanut (Yadava *et al.*, 1974). The source and type of pollen also influenced fruit set to a greater extent. Pollination of palms with bulked pollen from selected palms gave 60 per cent fruit set against 32 per cent observed by open pollination (Pillai and Murthy, 1972a; 1972b). A palm producing only barren nuts gave 50 per cent fruit set when pollinated with pollen from another palm of the same source and 66 per cent fruit set with bulk pollination.

Growth of the fruit during the post fertilization period takes place in three stages. In the first stage, there is a rapid increase in length, diameter and volume of fruits. The second stage is characterized by increase in volume and a heavy increase in dry matter accumulation in the kernel, during which period the embryo becomes macroscopic and develops rapidly. In the third stage the final swell of the fruit takes place. The fruit loses its green colour completely and floats when placed in water. The region of most rapid growth is that enclosed by the perianth. The diameter, volume and green weight of the fruit exibit a cyclic growth pattern, while the dry matter accumulation takes place continuously though at a slower rate during the first 15-20 weeks of growth. The dry weight of the entire fruit is influenced

to a great extent by that of seed. The kernel gains more than 80 per cent of the dry weight during the last two stages while the husk attains about 50 per cent of the total dry weight even in the first stage itself. The total period from full bloom to maturity of the fruit ranges from 35 to 47 weeks depending upon the individual palm (Fig. 27). The number of heat units (total of the mean daily temperature above 10° C) from full bloom to maturity range from 7,244 to 8,866 (Bhat *et al.*, 1962a). The maximum and minimum temperature during the fruiting period at high elevation were highly inadequate for the proper development and hardening of the kernel (Pillai and Murthy, 1973).

A rare occurrence of double fruit having increased number of perianth lobes and two embryos has been noticed (Nair, 1965b). Polyembryony, polycarpy, vivipary etc. in arecanut have been reported (Das, 1966; Murthy and Bavappa, 1959). Stray occurrence of fruits without seeds has also been reported. (Bhat, 1962). Abnormalities of young palms such as suckering, fused leaflets, very narrow and long leaves, chimera, and chlorophyll deficiency have been reported (Murthy and Bavappa, 1959; Nair, 1965b). The number of days, required for starting and completion of germination of the nuts has been found to be 53 and 94 days respectively. In general, 94 per cent of seeds germinate. However, failure of germination due to embryo rot, death of embryo and absence of embryo has been reported (Bavappa *et al.*, 1957). The embryo development, which leads to germination, starts by about 20 days after sowing. The differentiation of plumule and radicle and emergence of the first root take place about 30 days after sowing, and a small shoot which emerges out above the husk is visible in another 20 days (Bavappa *et al.*, 1957).

EMBRYOLOGY

The development of microspore and male gametophyte.

Raghavan (1957) reported the development of microspore in arecanut. The primary sporogenous cells function directly as microspore mother cells in *A.catechu* (Fig. 28). Microspore tetrads are usually tetrahedral though decussate and bilateral tetrads are occasionally met with. Mature pollen grains are 2-celled, ellipsoidal or nearly spherical and monocolpate. The exine shows reticulate thickening. The vegetative cytoplasm is packed with starch and the generative cell is crescent shaped (Fig. 29; Rao, 1959). The fertile pollen grains are more or less round in shape, but sterile grains are ellipsoid to sharply defined oval structures. The fertile grains have been classified as big oblong, big round and small oblong. The average sizes of fertile and sterile grains are 29.5-34.0m and 29.0-31.5m respectively. There were wide differences in the shape and ornamentation of pollen grains of red and white flowers (Nair, 1965a). Initiation and development of ovary and ovule The ovule primordium is basal in origin and strongly curved in *A. catechu*. By the time the megaspore mother cell is fully-grown, it becomes horizontal and stretches transversely in the locules, in which position it remains throughout its development. At first the funicle is as thick as the body of the ovule (Rao, 1959). Since ovule grows vertically in the chalazal

region, the body of the mature ovule becomes perpendicular to the funicle (Fig. 30). The ovules are hemianatropous and transverse in *Areca*. A few vascular bundles enter the funicles of young ovules, but these increase in number and branch profusely as the ovules grow. The funicle of young ovules is lined by radially elongated glandular cells. These divide and give rise to extensive tissue which functions as obturator.

Swamy (1942) reported that the initials for both the integuments become demarcated simultaneously. The outer integument is as a rule more massive than the inner. The cells of the outer integument and chalazal region accumulate tannin from early stages. Due to the growth of the ovule, mainly in the chalazal region, the integuments are separate from each other only for a small distance around the micropyle. Ruminations develop from the chalaza and outer integument. The whole of the inner integument becomes crushed early in the course of seed development and the outer integument and chalaza from the seed coat (Raghavan, 1957; Rao, 1959). Rao (1959) noticed occassionally orthotropous ovules or those in which the micropyle pointed against the side of the locules. Rarely two ovules were seen in an ovary, of which one was normally oriented while the other was abnormal and sterile.

Development of megasporogenesis and female gametophyte

In arecanut a single hypodermal archesporial cell differentiates in the ovule primordium (Fig. 31) and cuts off the primary parietal cell which gives rise to 2-3 layers of perietal tissue. The fully-grown megaspore mother cell has the characteristic elongated and tapering form (Fig. 32; Rao, 1959). The megaspore tetrad may be linear or T shaped. The embryo sac develops according to the normal type (Fig. 33). The synergids show either rounded protuberances or hooks on their free sides and the polar nuclei fuse before fertilization. The antipodals enlarge considerably. Their lower ends extend to the base of the socket like depression in the postament and their upper ends become large and sac like (Fig. 34).

Development of endosperm and seed formation

The ruminations in endosperm are apparent in the mature ovule and become prominent after fertilization. In the mature seed they appear as branched or unbranched plates. The ruminations usually develop to the inside vascular bundles and sometimes the branches of the vascular bundles extend into the rumination (Fig. 35). The vascular strand is surrounded by some colourless and tannin bearing cells (Rao, 1959). The nuclear type of endosperm develops and a few endosperm nuclei are formed by the time syngamy is completed. The endosperm nuclei become distributed in a thin peripheral layer of cytoplasm which is distinct from the main mass of cytoplasm filling the central part of the sac. At about 4-celled stage of the embryo, a central vacuole appears, which persists till a late stage in the seed development.

Fig.24. Covering of emasculated inflorescence

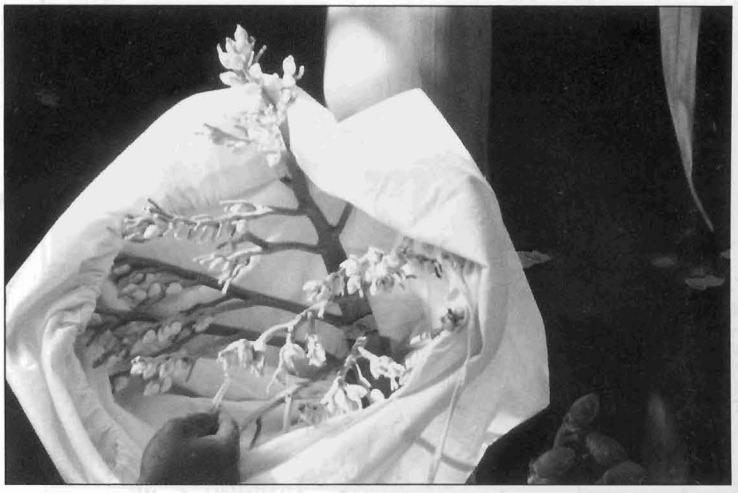

Fig.25. Artificial pollination of female flowers

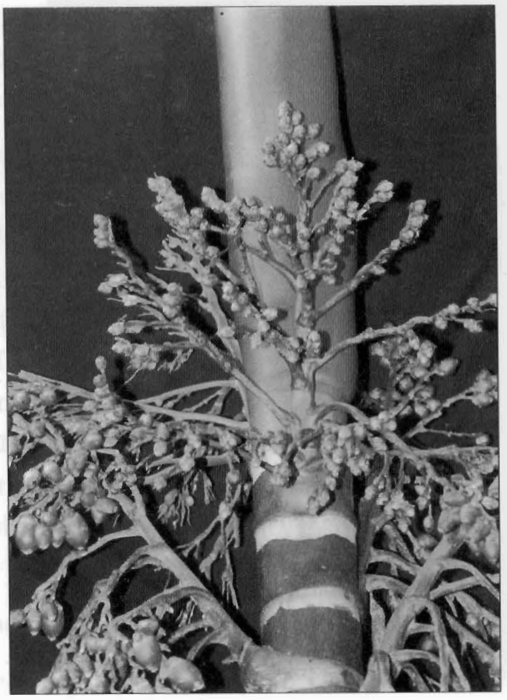

Fig.26. Nut set after pollination

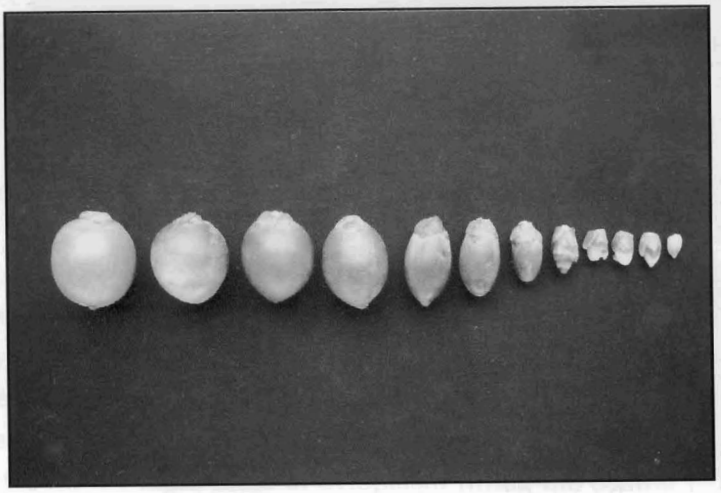

Fig.27. Stages of fruit development

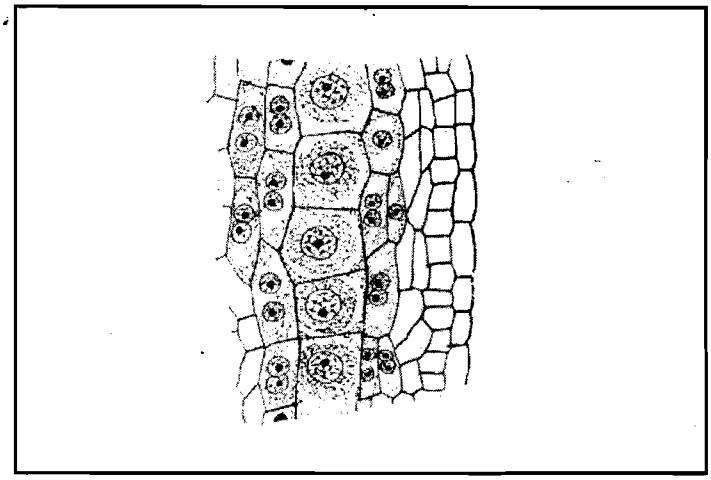

Fig.28. Microsporogenesis showing microspore mother cells

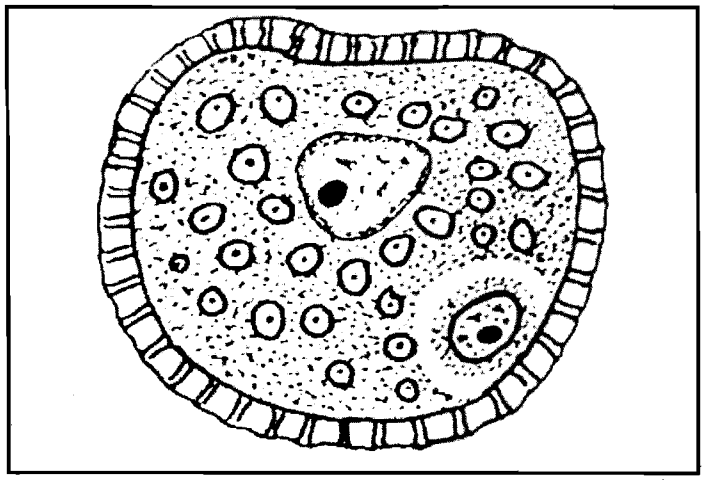

Fig.29. Mature pollen grain

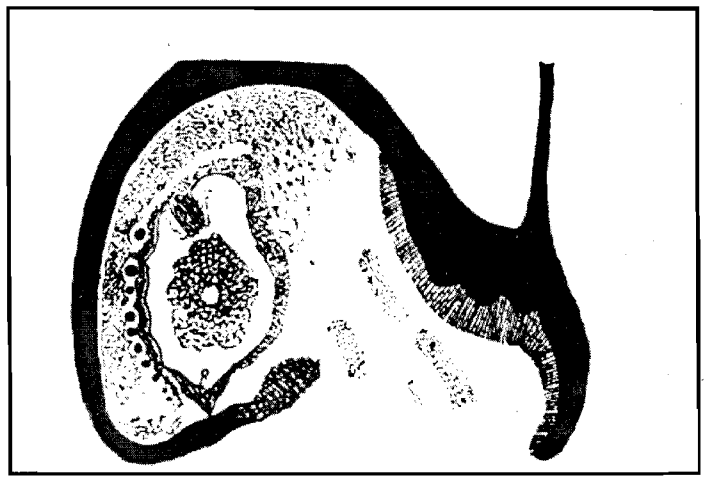

Fig.30. Development of megaspore mother cells

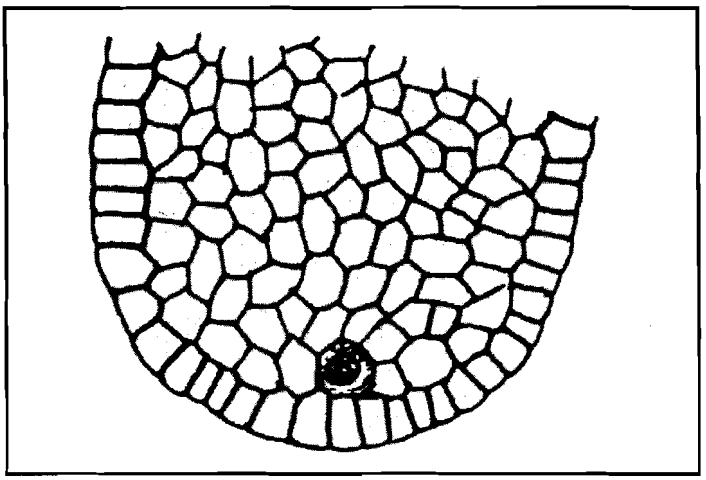

Fig.31. Longitudinal section of ovular primordium with archesporium

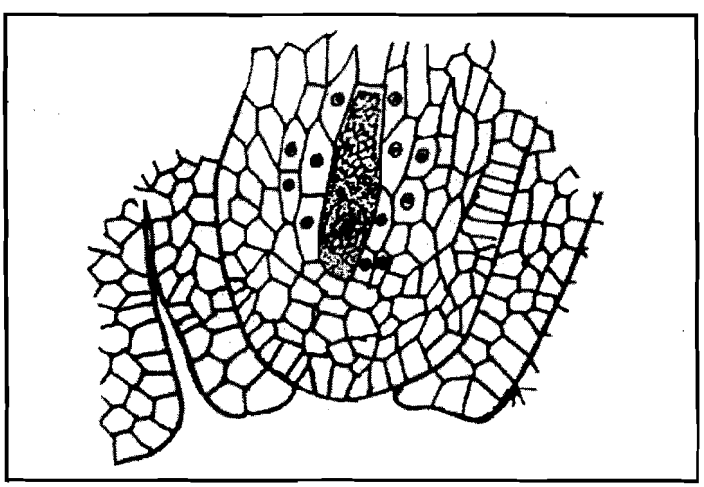

Fig.32. Nucellus with full grown megaspore mother cell

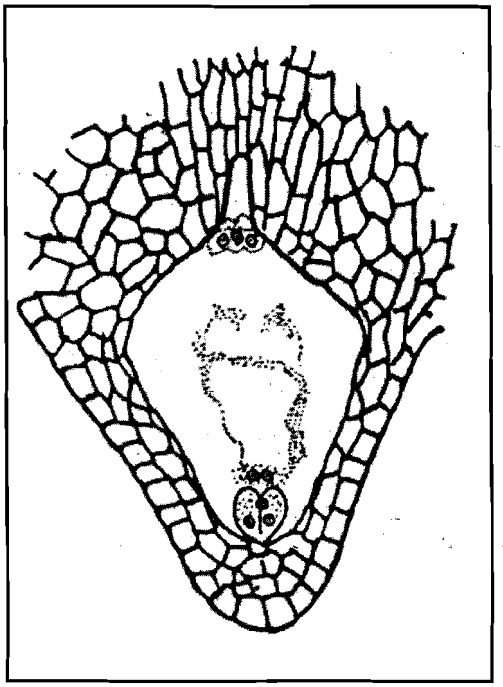

Fig.33. Development of embryo sac

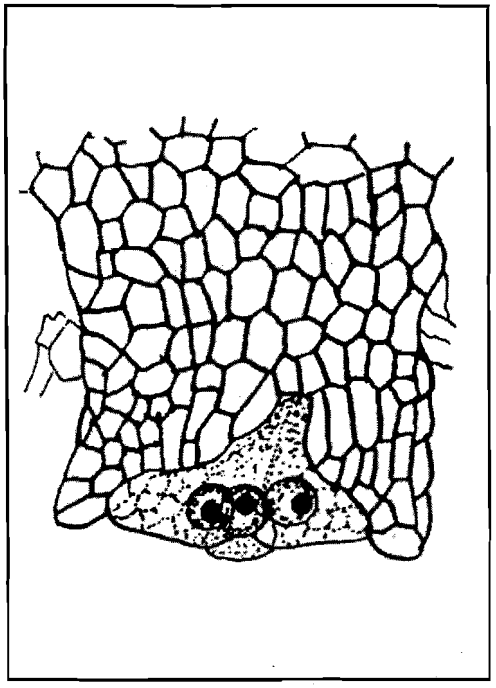

Fig.34. Antipodals from enlarging embryo sac

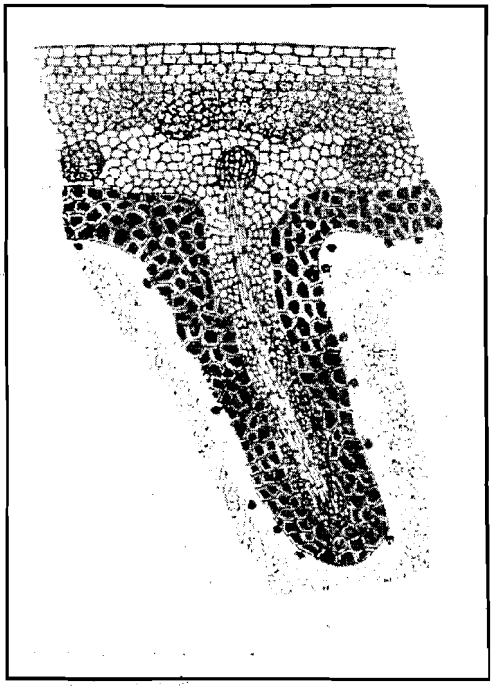

Fig.35. L.S of endosperm through rumination

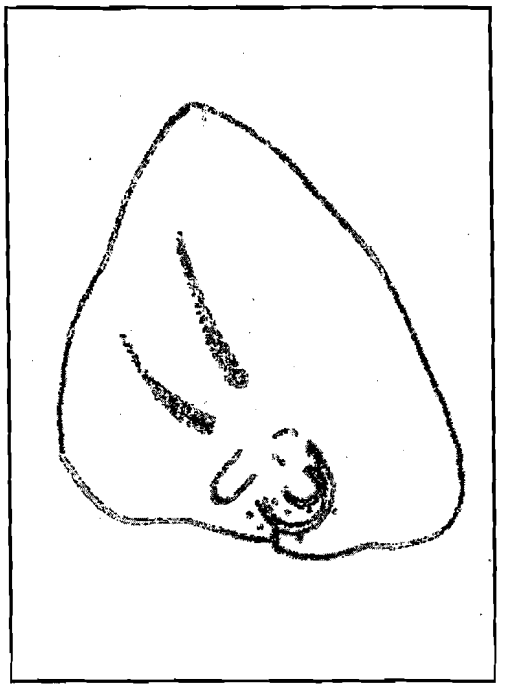

Fig.36. Development of embryo

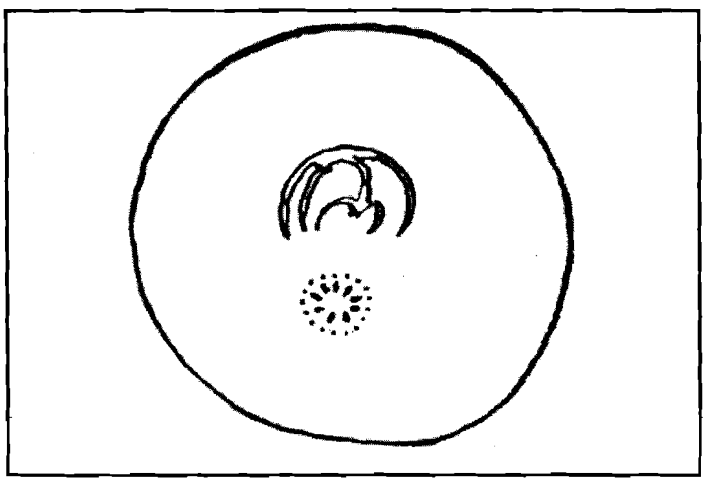

Fig.37. Transverse section of embryo

Development of embryo

The development of embryo in the arecanut has been reported (Rao, 1959). The fertilized egg divides transversely and gives rise to two cells. The upper cell divides obliquely and gives rise to a larger and a smaller cell. The larger cell undergoes another oblique division and forms a triangular epiphyseal cell and a rectangular cell. The smaller cell gives rise to two similar cells. The derivatives of the lower cell of the first division give rise to a massive suspensor, which becomes detached and absorbed during the course of the development. The cotyledon becomes massive and surrounds the plumule, leaving a small pore for its emergence during germination (Fig. 36). In the mature embryo the plumule and radicle are oriented towards the micropyle. The hypocotyl shows a ring of vascular bundles, branches from which extend into the cotyledon and radicle (Fig. 37). The structure of the fully developed embryo is conical having 4-4.5 mm length and 3-3.5mm diameter at the base. The single cotyledon completely encircles the plumule leaving only a pore for its emergence during germination. It shows several leaf primordial each with some procambial strands. Vascular strands also extend nearly to the tip of the cotyledon from the procambial strands of the primary axis. The cells of the embryo are devoid of reserve food materials. The embryo is surrounded by copious ruminated endosperm in which hemicellulose and starch are stored (Rao, 1959).

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3. CYTOGENETICS AND BREEDING

K. V. A. Bavappa

INTRODUCTION

Varying number of species are recognized in the genus *Areca* (Blatter, 1926; Murthy and Bavappa, 1962). Out of these *Areca catechu* L is the only commercially exploited species. The breeding system of arecanut palm (*Areca catechu* L.) its perennial habit and the long juvenile phase constitute the chief barriers in undertaking cytogenetic and breeding investigations in this crop (Bavappa, 1980; Bavappa and Nair, 1982). Though the palm is reported to be growing in sixteen countries of the tropics (Bavappa, 1963), organized research work on the crop is done only in India. Detailed cytological studies in chromosome number, meiotic behaviour, chromosome size, morphology, biodiversity and phylogenetic relationships have been reported in the *Areca* species through a series of papers (Bavappa and Raman, 1965; Bavappa *et al.*, 1975; Bavappa and Nair, 1978; Nampoothiri *et al.*, 1999; Sharma and Sarkar, 1956)). The biometrical methods have been extensively used in improvement of arecanut crop (Bavappa and Ramachander, 1967a, 1967b, 1968a, 1968b; Ramachander and Bavappa, 1972).

CYTOGENETICS

The chromosome number of *Areca catechu* L. was first determined as 2n=32 (Venkatasubban, 1945; Fig.1). This was later confirmed by several authors (Sharma and Sarkar, 1956); Raghavan and Baruah (1958), Abraham *et al.* (1961) and Bavappa and Raman (1965). The chromosome number of 2n=32 reported by Darlington and Janaki Ammal (1945) for *A. triandra* Roxb. was later confirmed by Sharma and Sarkar (1956) and Bavappa and Raman (1965). Nair and Ratnambal (1978) determined the meiotic chromosome number of *A. macrocalyx* Becc. as n=16.

The chromosomes were categorized into seven groups based on their morphology and relative length (Venkatasubban, 1945; Sharma and Sarkar, 1956). They observed that the chromosomes of *A. triandra* were longer than those of *A. catechu*. The chromosomes of *A. catechu* and *A. triandra* differed in size, total chromatin length, position of primary and secondary constrictions and number and position of satellites (Bavappa and Raman, 1965). Based on the assumption of Sharma and Sarkar (1956) that gradual reduction in chromatin matter had taken place in the evolution from primitive to advanced forms of different genera and tribe of Palmae, Bavappa and Raman (1965) considered *A. catechu* as more advanced than *A. triandra*.

The chromosome morphology of a few cultivars of *A. catechu* from Assam was reported by Raghavan (1957). Minor variation in structure and length of individual

Arecanut (Balasimha, D. and Rajagopal, V. Eds), CPCRI, Kasaragod - 671 124

chromosomes, total length of the complement and position of constrictions among the types was noted by him. On the basis of morphology, he recognized nine groups in the somatic chromosomes of the cultivars.

Meiotic abnormalities such as non-disjunction, lagging chromosomes, univalents and pentads were reported in *A. catechu* by (Sharma and Sarkar, 1956). Bavappa and Raman (1965) observed in the meiosis of four ecotypes of *A. catechu*, abnormalities like univalents at diakinesis and metaphase I, non-synchronization of orientation, clumping, delayed disjuction, chromosome bridges and laggards at anaphase I and II, chromosome mosaics and supernumerary spores. However, the meiotic division were quite normal in *A. triandra* except for the presence of 14 and 18 chromosomes occasionally at metaphase II. (Bavappa and Raman, 1965; Sharma and Sarkar, 1956). Intra-cultivar variation in meiotic behaviour of *A.catechu* was reported by Bavappa (1974) and Bavappa and Nair (1978). Intra-palm variation in chromosome numbers also exist in the pollen mother cells of *A.catechu, A. triandra* and their hybrids (Bavappa and Nair, 1978). Cytomixis to an extent of 39% seemed to have contributed to this abnormality. Observations on pollen and female fertility showed that A. catechu has high pollen fertility, while nutset is less than 50 per cent (Murthy and Bavappa, 1960).

A detailed study of microsporogenesis in two cultivars of *A. catechu*, three ecotypes of *A. triandra* and one natural hybrid of these two species showed frequent multivalent pairing (Bavappa and Nair, 1978). The highest configurations observed were decavalent in *A. catechu* and quadrivalent in *A. triandra* and octavalent in *A. catechu* x *A. triandra* hybrid. On the basis of these evidences the probability of an autotetraploid origin for the two species with restricted multivalent pairing was indicated (Bavappa and Nair, 1978). It was also observed that the pollen fertility in *A. catechu* was high in spite of high degree of multivalent associations. They indicated the possibility of the frequency of multivalent formation being under genotypic control and subjected to selection. Partial desynapsis of chromosomes at diakinesis was reported in *A. triandra* and *A. catechu x A. triandra* hybrids (Bavappa, 1974; Bavappa and Nair, 1978). Desynapsis observed at diakinesis was followed by an increase in pairing at metaphase I as reflected by the frequency of bivalents in *A. triandra* and *A. catechu x A. triandra* hybrids and this was attributed to distributive pairing, a mechanism that has been possibly adopted for ensuring their regular segregation (Bavappa and Nair, 1978). The extent of desynapsis was higher in the F_1 hybrids of *A. catechu* and *A. triandra* as compared to A.*triandra*, suggesting that the gene controlling this character may be dominant. The large number of univalents observed in the hybrid as compared to *A.triandra* parent has been attributed to non- homology of some of the parental chromosomes.

Nair and Ratnambal (1978) reported chromosome association in *A. macrocalyx* during microsporogenesis. While 16 bivalents were of the highest frequency at diakinesis

and metaphase I, the maximum configuration observed was one hexavalent at both the stages of division. The chromosome association in *A. macrocalyx* indicated the probability of autopolyploid origin with restricted multivalent formation as in the case of *A. catechu* and *A. triandra*. The pachytene chromosomes in *A. triandra* was in close agreement with somatic chromosomes though the pachytene ones in *A. catechu* were about ten times longer (Bavappa and Raman, 1965; Table 1).

Studies on the karyotypes of *A. catechu* cultivars and *A triandra* ecotypes (Bavappa,1974; Bavappa *et al.*, 1975) revealed considerable differences in their gross morphological characteristics (Fig. 2; Table 2). The karyotypes of the *A. triandra* ecotypes showed a higher frequency of submedian and median chromosomes as compared to *A. catechu*. A classification of the karyotype of the two species according to the degree of their asymmetry which recognizes three grades of size differences and four grades of asymmetry in centromere position (Stebbins, 1958), showed that karyotypes, 1B, 2A, 2B and 3B are represented in *A. catechu* cultivars and only 1A, 2A and 2B are represented in the ecotypes of *A. triandra*. Even within the same cultivar of *A. catechu*, two different types of asymmetry in karyotypes were observed, while there was no such variation in *A. triandra* ecotypes. Thus *A. triandra* has a more symmetrical karyotype than *A. catechu*. In *A. catechu* and *A. triandra* the relative length of chromosomes ranged from 4.12 to 8.59 whereas in the *A. catechu* x *A. triandra* hybrids the variation was from 3.45 to 10.72. This indicated that compensation effect due to differential dimensions of the parental chromosomes has brought about a reduction in the length of the shortest chromosome and an increase in that of the longest chromosome. No consistency in the presence/absence, and the number and position of satellites could be observed either in the parents or hybrids. Thus, use of these in the classification of the karyotypes in *Areca* karyotypes was limited.

Apomictic development of fruits of *A. triandra* was reported (Bavappa and Nair, 1975). All the *A.triandra* x *A.catechu* plants showed considerable morphological similarities with the female parent for stem number, internodal distance, stem girth at fixed mark, leaf number per clump, female flower size, number and size of male flowers, male flower arrangements and maturity period of fruits. While F_1 of *A. catechu* x *A. triandra* showed clear evidences for heterosis and dominance for certain characters, the reciprocal hybrids did not show such genetic effect. These, along with the differences in F_0 nuts observed in the reciprocal crosses (Table 3) and failure of *A. catechu* pollen to germinate on the stigma of *A. triandra* indicated that *A. triandra* x *A. catechu* nuts (F_0) might not be of sexual origin. Apomictic reproduction in *A. triandra* was indicated by the limited degree of meiotic irregularities, reduced pollen fertility, low quantity of pollen, and low chiasma frequency in the species (Bavappa, 1974), together with morphological and genetical evidences obtained from the reciprocal crosses.

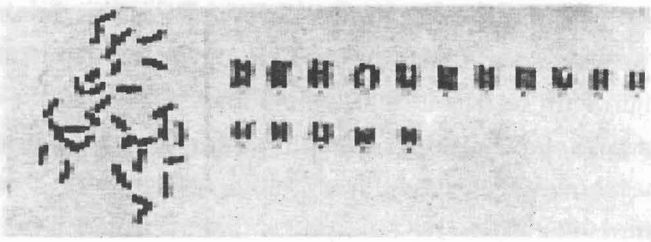

Fig.1. Somatic chromosomes in Areca catechu L.

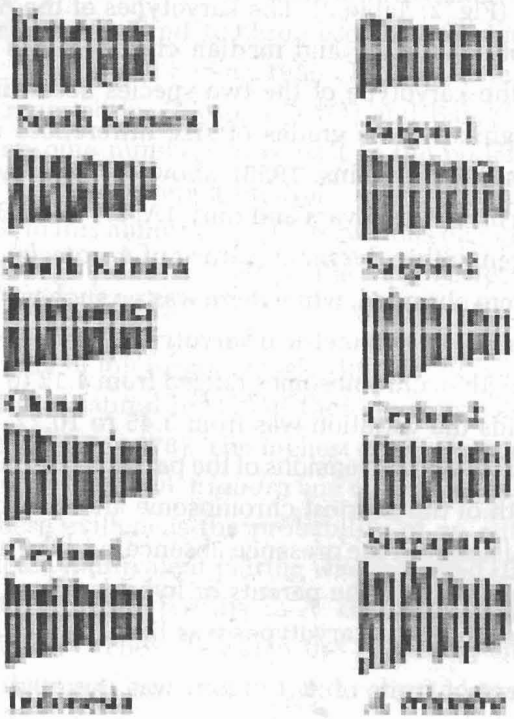

Fig.2. Idiograms of Areca chromosomes

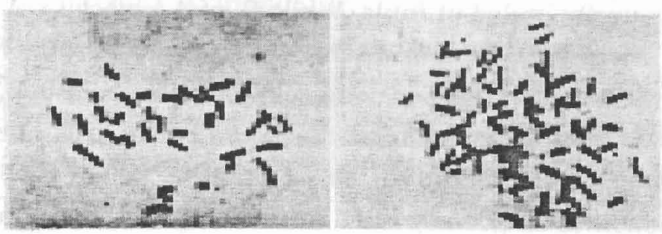

Fig.3. Diploid and tetraploid chromosomes of A. catechu (Sumangala)

Table 1. Comparative analysis of the somatic and pachytene chromosomes of A. catechu

Chromosome	Length in m		Relative length		Arm ratio		Centromere position	
	Somatic	Pachytene	Somatic	Pachytene	Somatic	Pachytene	Somatic	Pachytene
I	4.41	56.63	100.0	100.0	1:1.20	1:1.33	M	Sm
II	4.28	53.89	97.0	95.2	1:1.46	1:1.40	Sm	Sm
III	4.17	49.91	94.5	88.1	1:1.45	1:1.09	Sm	M
IV	3.89	46.86	88.2	82.7	1:2.19	1:1.35	St	Sm
V	3.78	46.00	85.7	75.9	1:1.29	1:1.54	Sm	Sm
VI	3.41	42.63	77.3	75.5	1:2.09	1:4.26	St	St
VII	3.31	42.04	75.1	74.2	1:2.09	1:1.79	St	Sm
VIII	3.28	39.00	74.4	68.9	1:1.88	1:1.45	Sm	Sm
IX	3.21	36.36	72.7	64.2	1:1.83	1:1.25	Sm	M
X	3.11	34.31	70.5	60.2	1:1.83	1:2.21	Sm	St
XI	3.06	30.99	69.3	54.7	1:1.78	1:1.56	Sm	Sm
XII	2.80	30.77	63.5	54.3	1:1.62	1:2.76	Sm	St
XIII	2.47	30.22	56.0	53.4	1:1.11	1:1.04	M	M
XIV	2.44	28.49	56.3	50.4	1:1.87	1:1.14	Sm	M
XV	2.40	25.63	54.5	45.3	1:3.00	1:3.50	St	St
XVI	2.29	22.67	51.9	40.0	1:1.31	1:3.02	Sm	St
Total	52.31	616.40	-	-	-	-	-	-

M=Medium; Sm=Sub-medium; St=Sub-terminal

Table 2. Karyotype differences in *A.catechu*, *A.triandra* and their hybrids

Species/ hybrids	2n	Total chroma-tin length (m)	Range of chromosome length (m)	Chromosome types			Satellite chromosome	Symmetry (Stebbins, 1958)
				Median	Sub-median	Sub-terminal		
A.catechu								
Local (471)	32	49.42	4.13-2.18	-	6	10	3	2A
Local (717)	32	43.97	3.78-1.83	5	11	-	-	1B
China (111)	32	41.64	3.59-1.72	-	1	15	1	3B
Ceylon-1(191)	32	51.79	4.41-2.14	5	9	2	1	1B
Indonesia-6 (61)	32	46.81	4.12-1.93	-	3	13	1	2B
Saigon-1 (176)	32	44.48	3.67-1.92	-	9	7	1	2A
Saigon-2 (180)	32	50.78	4.15-2.13	-	3	13	1	2A
Ceylon-2 (192)	32	47.60	4.43-1.88	-	3	13	1	3B
Singapore (163)	32	44.52	3.62-2.11	-	6	10	2	2A
A.triandra								
Mauritius (109)	32	61.21	5.24-2.52	4	3	9	2	2B
Indonesia-2 (125)	32	48.40	4.04-2.02	-	9	7	1	2B
Indonesia-2 (74)	32	53.73	4.68-2.40	2	8	6	-	2A
Indonesia-2 (154)	32	54.14	4.41-2.44	3	7	6	-	2A
Ceylon-3 (55)	32	56.32	4.72-2.46	1	10	5	-	1A
Ceylon-3 (70)	32	59.77	4.89-2.62	-	11	5	-	1A
Ceylon-3 (87)	32	50.59	4.20-2.14	3	12	1	2	1A
A.catechu x A.triandra								
Palm No. (248)	32	56.80	6.19-2.21	6	4	6	-	2B
Palm No. (287)	32	47.35	4.20-1.68	9	7	-	2	1B
Palm No. (288)	32	55.88	5.77-1.99	2	11	3	2	2B
Palm No. (307)	32	48.69	4.51-1.68	5	10	1	2	1B
Spontaneous hybrid	32	48.19	4.43-1.83	2	12	2	1	1B

Tetraploidy was induced in two cultivars of *A. catechu*, Mangala and Sumangala by treating the emerging sprouts with 0.1 per cent aqueous colchicine (Nair and Ratnambal, 1974; Fig. 3). The tetraploid seedlings were stunted in growth compared to the diploids, and had reduced plant height and number, length and breadth of leaves. They also had fewer epidermal cells and stomata per unit area.

Table 3. Mean size and weight of nuts of *A.catechu, A.triandra* and their hybrids (F_0)

Parents/hybrids	Length (cm)	Breadth (cm)	Weight (g)
A. catechu	5.3	4.2	43.6
A. catechu x A.triandra (F_0)	5.5	3.3	34.2
A. triandra x A.catechu (F_0)	2.7	2.7	3.9
A. triandra	2.7	1.5	3.9

GERMPLASM COLLECTION

Several cultivars have been recognized in Karnataka (Rau, 1915) and Philippines (Beccari, 1919) based on fruit and kernel. Cultivation can be separated on the basis of stomatal characters, size of nuts, leaves shed, female flowers, nut size (Bavappa, 1966a; Bavappa and Pillai, 1976).

The genetic resource programme in arecanut has been undertaken at the CPCRI Regional Station, Vittal. A collection of five species viz., *A. catechu*, *A. triandra*, *A. macrocalyx*, *A. normambyii* and *A. concinna* and two genera *Actinorhytis* and *Pinanga dicksoni* are available. The germplasm holding now consists of 117 accessions. Among these, 23 exotic accessions representing different species were introduced from Fiji, Mauritius, China, Sri Lanka, Indonesia, Saigon, Singapore, British Solomon Islands and Australia. A comparative yield trial of sixteen exotic types revealed that five of these have high yield potential (Table 4; CPCRI, 1974). Besides out of 90 collections representing germplasm from different arecanut growing states of India, 39 accessions have been described based on descriptors.

There is wide range of variations in fruit characters, stem height, internode length and leaf size and shape. The nut size of cultivars in Malnad parts of Shimoga and Chikmagalur districts is small whereas in North Kanara and Ratnagiri it is bigger (Murthy and Bavappa, 1962). There are also wide variations in yield, earliness in bearing, fruit number/bunch, quality, and dwarfness. A study of the physical and chemical characteristics of arecanut cultivar Sreevardhan showed that the average length, breadth, weight and volume of fruits were 3.35 cm, 34.34 g and 44.2 cc, respectively. The weight of the kernel was 4.12-13.07 g with an average of 7.1 g. On the basis of size and quality, they were grouped into eight grades (Nagwekar *et al.*, 1999).

Table 4. Yield (weight of nuts) of 16 exotic introductions of *A. catechu*

Name of the type	Accession number	1964-1965 to 1972-1973 (Average for 9 years) Wet weight of nuts per tree in kg.	Percentage of increase (+) or decrease (-) over Local
Fiji	VTL-1	3.1	– 68.0
Mauritius	VTL-2	6.1	– 37.1
China	VTL-3	10.3	+ 6.2
Ceylon	VTL-5	6.9	– 28.9
Indonesia-1	VTL-6	1.4	– 85.6
Indonesia-2	VTL-7	8.2	– 15.5
Ceylon-2	VTL-15	6.7	– 30.9
Indonesia-6	VTL-11	14.5	+ 49.5
Saigon-1	VTL-12	12.9	+ 33.0
Saigon-2	VTL-13	11.7	+ 20.6
Saigon-3	VTL-14	9.0	– 7.2
Singapore	VTL-17	14.6	+ 50.5
Solomon Islands-1	VTL-18a	2.7	– 72.2
Solomon Islands-2	VTL-18b	5.1	– 47.4
Solomon Islands-3	VTL-18c	3.2	– 67.0
Ceylon-3	VTL-21	2.6	– 73.2
South Kanara (control)	-	9.7	–
S.E. per plot		3.9	
Overall mean		7.6	
C.V. (%)		52.0	
C.D. (P=0.5)		4.5	

The exotic and indigenous collections under evaluation since 1957 for morphology, nut characters and yield attributes (Bavappa and Nair, 1982) resulted in the release of four high yielding cultivars. Of these three are selections from exotic collections. Of the exotic collections, cultivar VTL - 3 introduced from China was released under the name Mangala (Table 5; Fig. 4; Bavappa, 1977). This cultivar has earliness in bearing, more number of female flowers, high yield and lesser stem height as compared to other accessions. Yielding behaviour of individual Mangala palms revealed that 50 per cent of palms give more than 12 kg ripe nuts (Table 6; Rekha *et al.*, 1991). They also showed alternate bearing habit. Other varieties released for cultivation are Sumangala (Fig. 5) and Sreemangala (Fig. 6), introductions from Indonesia and Singapore respectively. High yield potential was observed in one of the indigenous collection from West Bengal and it was released as Mohitnagar variety (Fig. 7). The characteristics of these varieties are given in Table 7 (Ananda and Thampan, 1999). Other promising varieties are SAS - I, Thirthahalli and Calicut - 17. Systematic evaluation of exotic and indigenous accessions and selection for high yield have resulted in release of high yielding cultivars. These are released for different agro-climatic regions of the country. The cultivar SAS-1 has been released by University of Agricultural Sciences, Dharwad for Uttara Kannada region while Thirthahalli is a local variety for Shimoga district, primarily for production of red tender processed nuts.

BREEDING

Selection

Studies on selection of arecanut seedlings showed that considerable increase in yield of the plantation could be obtained by judicious selection of seedling at the time of planting, as well as in subsequent stages (Bavappa and Ramachander, 1967a, 1967c; Bavappa,1970; Ramachander and Bavappa, 1972). The number of leaves at the time of planting, girth at collar one year after planting and number of nodes two years after planting have high heritability and have positive genotypic and phenotypic correlations with the yield. Based on these studies the selection criteria to be used are seedlings with four leaves at the time of planting, and a girth of more than 20 cm after one year, and four nodes or more after two years of growth in the field after transplanting.

Multiple regression and path analysis was used to study the relationship between yield and ten vigour traits in the local variety 'South Kanara'. High correlation and direct effects were found for plant height, internode distance (at a fixed position), maximum leaf length and girth (at a fixed position). A vigour index was developed by regressing these four variables on yield. This index is considered a more suitable selection criterion for *Areca catechu* than selection on yield alone (Bhagavan and Nair, 1989). Selection within the cultivar 'South Kanara' showed that the close selection method used reduced nut yield

Table 5. Comparative yield of Mangala (1967 planting)

Cultivars	Wet weight of nuts/palm/year						
	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	Total
Mangala	-	4.73	16.75	12.36	16.04	14.15	64.03
South Kanara	-	1.57	4.80	5.11	6.62	8.89	26.99

by 70% in progeny due to inbreeding depression. Girth, number of nodes and height were highly correlated with nut yield. Significant phenotypic correlations were observed in height, girth at permanent mark and node number. These 3 characters together with girth at last exposed node and leaf number showed significant genotypic correlations. The parent-progeny correlation for yield characters was low (Ravindran *et al.*, 1985).

Bavappa and Ramachander (1967c) tested the validity of the earlier method of selection of seed material as a means of genetic improvement which consisted of collection of seeds from phenotypically high yielding mother palms located in gardens reported for their high average yield (Bavappa *et al.*, 1958). The progeny performance as judged from the yield of 41 such mother palms showed that though the mother palms had been selected for high yield, there was wide variability in the performance of their progenies. It was also observed that the mother palms having high progeny performance were present in all the gardens more or less uniformly and there was no advantage in selection of mother palms giving stress to the garden in which they are located. They also observed that the progeny performance had no relation with the regularity in the yielding behaviour of mother palms (Bavappa and Ramachander, 1967b;CPCRI, 1969a). An examination of the yield pattern of palms of different bearing ages by Bavappa and Ramachander (1967c) showed that palms which came to bearing early are consistantly better yielders.

A field trial initiated at Vittal during 1963 to critically evaluate the possible beneficial effects of the existing practice of selection of seednuts from healthy and regularly high yielding palms and to fix selection standards for mother palms, seednuts and seedlings showed that in respect of selected seednuts significant correlations of seed weight, seedling girth and age at first flowering existed yield. There has also been an improvement in heritability values for all the characters except for height and number of leaves due to selection of nuts. However, heritability values for number of nuts and weight of nuts were low thereby suggesting that selection based on yield alone may not be worth practicing (Bhagavan *et al.*, 1981).

Besides the seedlings and mother palm selection standards worked out, a modified mass pedigree selection programme (Bavappa and Ramachander, 1967c; 1968a; 1968b) with selected mother palms and applying bulk norm and individual norm tests to the families

Table 6. Yield pattern of individual areca palms in Mangala (weight of ripe nuts)

Sl. No.	Wet wt. of nuts (kg/palm)	No. of palms in the group	Per cent of palms	Total yield (kg)	Per cent yield to the total garden yield
1.	0-3	24	7.5	32.2	0.75
2.	3-6	26	8.1	122.83	3.05
3.	6-9	43	13.4	333.26	8.27
4.	9-12	68	21.3	715.57	17.76
5.	12-15	56	17.5	741.19	18.40
6.	15-18	43	13.4	731.97	18.17
7.	18-21	24	7.5	473.24	11.75
8.	21-24	23	7.2	512.46	12.72
9.	24-27	6	1.9	152.70	3.79
10.	27-30	2	0.6	57.81	1.43
11.	> 30	5	1.6	157.66	3.91
	Total	320	100.0	4028.9	

From: Rekha *et al.* 1991.

Table 7. Characteristics of released arecanut varieties

Variety	Habit	Shape/size of nut	Yield (kg/palm)	Recommended for
South Kanara	Tall	Round/bold	2.00	Coastal Karnataka, Kerala
Mangala	Semi-tall	Round/small	3.00	-Do-
Sumangala	Tall	Oval/medium	3.20	Karnataka, Kerala
Sreemangala	Tall	Round/bold	3.28	-Do-
Mohitnagar	Tall	Oval/medium	3.67	West Bengal Karnataka, Kerala

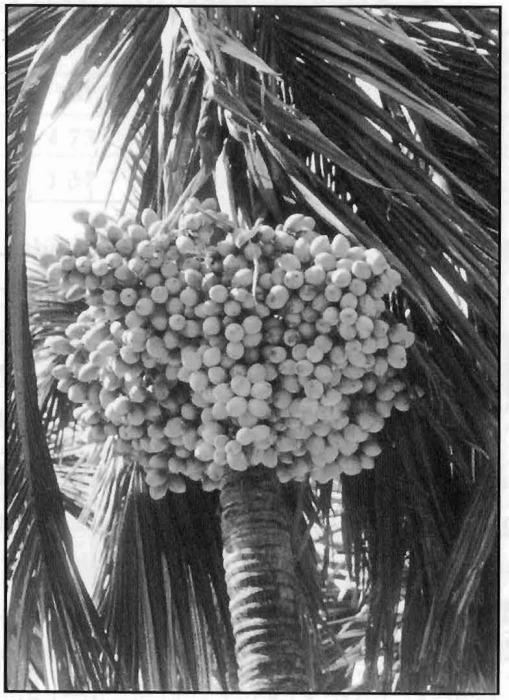

Fig. 4. Mangala

Fig. 5. Sumangala

Fig. 6. Sreemangala

Fig. 7. Mohitnagar

Fig. 8. Dwarf x Sumangala

and individuals within the selected families showed that in all the families, the observed and expected genetic gains for number and wet weight of nuts were very low. The result in effect showed that selection as practiced in the experiment was ineffective in improving the yield (CPCRI, 1981).

A further refinement of the above selection programme was suggested (Bavappa and Ramachander, 1967b). They presumed that screening individual plants based on characters of high heritability and correlation with yield, prepotency, selection index, desirable characters such as resistance to pests and diseases and effecting controlled pollination between selected palms in addition to the bulk norm test and single norm test is likely to be more advantageous.

Hybridisation

The hybridization programme was initiated for exploiting the existing variability in the *Areca* germplasm for evolving high yielding, regular bearing, high quality and semi-tall ideotypes (Bavappa and Nair, 1982). Interspecific hybrids of *A. catechu* x *A. triandra* had only one stem as in *A.catechu* indicating dominance of this character (Bavappa, 1974). The hybrids mostly equaled the parents in internodal length. They also exhibited hybrid vigour for a number of characters like number of male flowers, female flowers, spadix length and stem girth.

The *Areca* species and cultivars mainly from South East Asia and South Asian countries maintained at CPCRI Regional Station, Vittal possess large number of desirable characters and offer choice of selection as parents depending on the breeding objectives. Distribution of such desirable characters in different accessions of *Areca* is listed in Table 8.

Table 8. Distribution of characters in different accessions

Characters	Probable donors
High yield	*A.catechu* Singapore *A.catechu* Mangala
Early bearing	*A.catechu* Mangala
Greater number of fruits/bunch	*A.catechu* Thirthahalli
Better quality	*A.catechu* Sreevardhan
Fruit size (large)	*A.catechu* South Kanara
Regular bearing	*A.catechu* South Kanara
Dwarfness	*A.catechu* Dwarf mutant
Tolerance to yellow leaf disease	*A.catechu* Dwarf mutant
More number of female flowers per bunch, High percentage of fruit set, Suckering habit	*A.triandra*

An inter-varietal crossing programme involving Mangala,South Kanara (Local), Sreevardhan, Thirthahalli, Indonesia 1, Indonesia 2, Andaman and hybrids derived from Mangala and four selected exotic types (Indonesia 6, Saigon 1, 2, 3), Mohitnagar and Dwarf mutant was in progress since 1965. Among these Mangala x Sreevardhan, was vigorous as observed from increased height and girth of stem and number of leaves (CPCRI, 1971).

Hybrids derived from crosses South Kanara x Indonesia (VTL 47), South Kanara x Andaman (VTL 45), South Kanara x Indonesia (VTL 48) and Andaman (VTL 46) x South Kanara showed earliness in bearing, large sized inflorescence, large number of female flowers and heavier crown habits (CPCRI, 1970). Hybrid vigour for leaf length, number of leaves, number of leaflets, length of leaflet, breadth of leaf sheath and girth at crown has also been observed for these characters (CPCRI, 1971).

Inter-varietal crosses were carried out at Vittal among Mangala, Indonesia 6, Saigon 2, Sreemangala, Mohitnagar, Thirthahalli and Dwarf mutant during 1975. The seedlings raised from these crosses were planted in a field trial at Palode, South Kerala during 1976 with a view to studying the disease reaction to the yellow leaf disease of arecanut. Observations indicated that hybrids Dwarf x Indonesia 6, Mangala x Dwarf, Saigon 2 x Dwarf, Mohitnagar x Dwarf and Thirthahalli x Dwarf showed some degree of tolerance to yellow leaf disease in initial years. However this could not be sustained over the years.

Detailed morphological and cytological investigations on reciprocal crosses between *A.catechu* and *A.triandra* were made by Bavappa (1974). The F_1 hybrids of *A.catechu* x *A.triandra* had only one stem as in *A.catechu* indicating the dominance of single stem. As discussed elsewhere the reciprocal hybrids are soboliferous like *A.triandra* parent and based on this, as well as other supporting evidences *A.triandra* is considered to be apomictic (Bavappa 1974; Bavappa and Nair, 1975). The *A.catechu* x *A.triandra* hybrids mostly equaled the parents in respect of internodal distance at fixed mark and leaf length and it was suggested that a dosage effect of gene for these characters are operative in *Areca*. The similarity of the hybrids to their respective female parents in respect of leaves per clump indicated that this character might be maternal in inheritance.

A. catechu x *A. triandra* hybrids exhibited hybrid vigour for number of male flowers per bunch, number of female flowers, length of spadix and girth of stem at fixed mark, the maximum hybrid vigour being for the number of female flowers. However, variation in hybrid vigour expression in hybrids derived from different cultivars of *A.catechu* and ecotypes of *A.triandra* was observed. These interspecific hybrids between *A. catechu* and *A. triandra* showed high sterility. This is to be expected in an interspecific cross involving genetically divergent parents.

The studies on intercluster divergence showed that the genetic distance between A. *catechu* and *A. triandra* is wide (Bavappa, 1974). Since it has been possible to backcross

Table 9. Growth parameters of parents and dwarf hybrids (fifth year after planting)

Hybrid/Parent	Plant height (m)	Stem girth (cm)	No. of leaves	No. of nodes
Dwarf	2.00	14.99	9.40	14.55
Mangala	2.70	13.38	8.06	15.04
Sumangala	4.31	13.50	8.67	17.33
Sreemangala	4.20	13.12	7.80	16.17
Mohitnagar	4.68	14.13	9.21	16.40
Mangala x.Dwarf	2.16	13.07	8.74	12.89
Dwarf x Mangala	2.43	14.34	9.14	13.68
Sumangala x Dwarf	2.47	13.71	8.73	12.07
Dwarf x Sumangala	2.27	16.81	9.19	16.31
Sreemangala x Dwarf	3.08	13.52	9.64	17.64
Dwarf x Sreemangala	2.20	14.38	9.58	13.19
Mohitnagar x Dwarf	2.20	14.94	9.64	14.59
Dwarf x Mohitnagar	2.19	13.39	9.21	12.64
CD (±0.05)	0.79	NS	NS	3.61
CV (%)	16.8	9.42	8.42	14.95

From: Ananda, 2000.

Table 10. Nut characters of dwarf hybrids and parents

Hybrids	Fruit length (cm)	Fruit breadth (cm)	Fresh fruit wt. (g)	Dry fruit wt. (g)	Kernel weight (g)	Kernel length (cm)	Kernel breadth (cm)	Yield (Fresh wt.) (kg/plant)
Mangala x Dwarf	5.47	3.65	32.33	10.80	6.93	2.13	2.32	8.75
Dwarf x Mangala	4.20	3.63	22.47	8.00	5.07	1.64	2.22	4.51
Sumangala x Dwarf	5.37	3.72	34.07	12.47	8.07	2.05	2.51	8.81
Dwarf x Sumangala	4.89	4.09	28.00	11.67	7.40	1.72	2.61	9.14
Sreemangala x Dwarf	4.70	3.75	26.87	9.67	4.47	1.58	2.37	4.05
Dwarf x Sreemangala	4.22	3.98	28.47	10.00	5.80	1.66	2.36	5.91
Mohitnagar x Dwarf	4.84	4.18	35.00	12.13	7.47	2.00	2.45	8.91
Dwarf x Mohitnagar	4.49	3.77	29.00	12.13	8.20	1.99	2.60	7.85
Dwarf	3.66	2.73	10.53	4.73	3.00	1.58	1.99	1.14
Mangala	4.68	3.99	28.80	11.87	8.07	1.88	2.60	7.75
Sumangala	5.91	4.39	41.67	16.00	8.67	2.10	2.66	9.67
Sreemangala	5.63	4.64	43.93	15.73	9.00	1.88	2.78	9.05
Mohitnagar	5.12	4.30	43.40	15.13	8.07	1.80	2.65	12.08

From: Ananda, 2002.

the F_1 hybrids of *A. catechu* x *A. triandra* to *A. catechu*, the possibilities of transferring high fruit set reported in *A. triandra* (Bavappa, 1966a, 1966b) to *A. catechu* are bright. As the sterility observed in the hybrids appears to be due to disharmonious interaction between the cytoplasm of *A.catechu* and genotype of *A. triandra*, restoration of fertility through repeated backcrosses to *A. catechu* may be feasible and it may be possible to evolve better varieties combining qualities of both the species.

The tall nature of the palm hinders various operations like spraying and harvesting and makes them labour intensive. A major thrust of breeding research in arecanut has been to induce dwarfness. A natural dwarf mutant was identified and was named Hirehalli Dwarf (Naidu, 1963). The mutant however has low yields coupled with poor quality nuts. An attempt was made to cross the high yielding varieties with Dwarf to exploit the dwarfing nature (Ananda, 2000). There were significant variations in morphological characters among hybrids, some of them promising (Table 9). Among the different crosses made the maximum dwarfs and intermediates were recovered from Sumangala x Dwarf, Mohitnagar x Dwarf and Mangala x Dwarf crosses Hybrids, Sumangala x Dwarf, Dwarf x Mohitnagar and Mangala x Dwarf showed promising yield traits and heterosis while retaining the dwarf nature (Ananda, 2002). Hybrid vigour in respect of eight nut characters (Table 10) were estimated based on mid-parental values. Wide significant variations among hybrids and parents were noticed. The highest heterotic effect for kernel characters were found in Sumangala x Dwarf and Dwarf x Mohitnagar. The highest fresh nut yield (kg/palm/year) of 9.14 kg was recorded in Dwarf x Sumangala (Fig. 8) followed by Mohitnagar x Dwarf (8.91kg) and Sumangala x Dwarf (8.81kg). The parents Mohitnagar and Sumangala recorded yield of 12.08 and 9.67 respectively.

Hybrid vigour expression of varying degrees was observed in the following crosses:

Mangala x Sreevardhan	Height, girth of stem, number of leaves
South Kanara x Indonesia South Kanara x Andaman Andaman x South Kanara	Earliness in bearing, inflorescence size, No. of female flowers, crown size, leaf length, no. of leaves and leaflets, sheath, girth at breadth of leaf crown
Dwarf x Sumangala Mangala x Dwarf Saigon 2 x Dwarf Mohitnagar x Dwarf Thirthahalli x Dwarf	Tolerance to yellow leaf disease
Dwarf x Sumangala Mohitnagar x Dwarf Mangala x Dwarf	High yield and dwarfness

Genetic divergence

Bavappa (1974) studied morphological, anatomical and yield characters for 13 cultivars of *A. catechu* and four ecotypes of *A. triandra* during the years 1963, 1966 and 1972. The analysis of variance of the results obtained in 1963 showed that the differences between cultivars are highly significant for all the six morphological characters. A combined analysis of the data for two years for 24 common characters recorded during 1967 and 1972 also revealed significant interaction between cultivars for all characters. A significant interaction between years and cultivars was seen for height, girth, internodal distance, number of bunches and inflorescences on the palm, length and breadth of leaf sheath, length and volume of nut and length, breadth, weight and volume of kernel.

Bavappa (1974) also worked out 136 D^2 values between cultivars, the number of characters being unequal in different years. The magnitude of D^2 values indicated that considerable divergence exists between cultivars in all the years. He grouped 13 cultivars and four ecotypes from nine countries into six clusters for the independent years 1963, 1966 and 1972 and found that though the number of clusters were the same, constituents in the different clusters were slightly different in different years. The number of clusters and pattern of clustering were more or less similar for the years 1966 and 1972. In the pooled analysis, the number of clusters got reduced from six to five. However, the pattern of clustering was more or less in conformity with the groups obtained for the individual years. The spatial diagram showing the distribution of clusters in 1966 and 1972 (pooled) is given in Fig. 9.

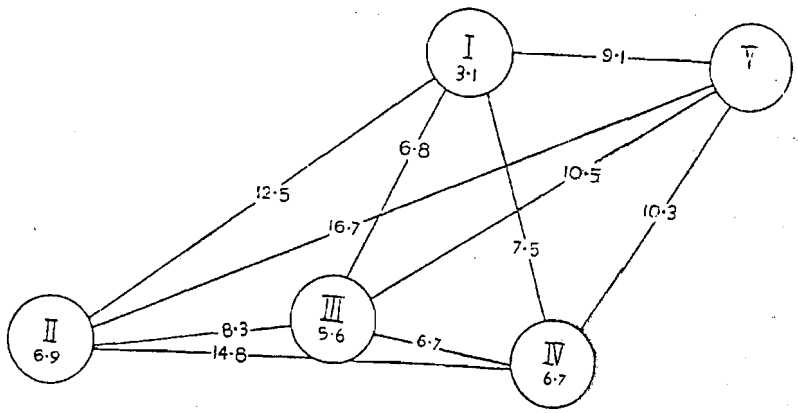

Fig. 9. Spatial diagram showing distribution of clusters (Cluster I-Br.Sol.Is 1,Br.Sol.Is 2,Br.Sol.Is 3; Cluster II-Indonesia 1, Indonesia 2, Mauritius, Ceylon 3; Cluster III- Ceylon 1, Indonesia 6, Saigon 1, Saigon 2, Saigon 3, Singapore, South Kanara; Cluster IV-China, Fiji; Cluster V-Ceylon 2)

All the four ecotypes of *A. triandra* were in one cluster in the pooled analysis and this cluster continued to show maximum divergence from the rest. The divergence between clusters IV and V was due to the differences in nut and kernel characters, breadth of leaf sheath, breadth of leaflets and number of leaflets. On the basis of this analysis it was concluded that detection of genetic divergence in the early years of productive phase is of considerable advantage for formulating breeding programme in a perennial crop like arecanut (Bavappa, 1974).

The rankings of different characters during 1966 for their contribution towards overall genetic divergence showed that the mean volume of nut and breadth of kernel were the characters of primary importance. For divergence between *A. triandra* and *A. catechu*, mean length of fruit characters for 1972 and the pooled data also revealed the importance of nut and kernel characters in differentiation within *A.catechu* cultivars and between *A. catechu* and *A. triandra* types. The results obtained from canonical analysis were also in broad agreement with the clustering pattern found from D^2 analysis. However, canonical analysis is of limited utility only in view of the fact that the first two canonical roots accounted for only 85% less of the variation (Bavappa, 1974).

The grouping obtained by D^2 analysis revealed that the three cultivars each from Saigon and British Solomon Islands and the two ecotypes of *A. triandra* from Indonesia were invariably in one cluster. As against this, close similarity between cultivars from different countries has also been observed. The cultivar from Singapore grouped with the three cultivars from Saigon in one cluster. A similar affinity between the two geographically distant cultivars was shown by Ceylon-1 and Indonesia-6, both always coming within the same cluster. The local cultivar has been found to be invariably associated with the cultivar from Singapore in forming the cluster. Of the two cultivars of *A. catechu* from Ceylon, Ceylon-2 was always forming a separate cluster indicating its distinct nature of divergence. The clustering pattern of cultivars and ecotypes revealed that geographic diversity need not always be related to genetic diversity (Bavappa, 1974).

Cultivars

Rau (1915), based on the sweet kernel of mature fruit, described a variety from Mysore (India) as *A. catechu* var. *deleciosa*. On the basis of fruit size and shape, Beccari (1919) identified four varieties of arecanut in the Philippines, viz., *A.catechu* var. *communis*, *A. catechu* var. *silvatica*, *A. catechu* var. *batanenesis* and *A. catechu* var. longicarpa. Sands (1926), Grist (1926), Molegode (1944), Iyer (1950) and Nambiar (1954) have designated the varieties occurring in Malaya, Sri Lanka, and South India by local names. On the basis of a number of fruit and inflorescence characteristics, Raghavan and Baruah (1956) described the variations of arecanut occurring in Assam. Murthy and Bavappa (1962) identified 64

cultivars based on fruit size from the Indian States of Kerala, Karnataka and Bombay. They have also discussed the pattern of variation in fruit size in relation to elevation of the tract. Significant variations between the different cultivars and ecotypes of *A. catechu* and *A. triandra* for various characters were observed in the study of the yield components in a germplasm collection of arecanut (Bavappa and Pillai, 1976). The possibility of distinguishing different cultivars of *A. catechu* and the related species, *A. triandra*, on the basis of growth characters and epidermal pattern of leaf has been brought out by Bavappa (1966a). He observed that the varieties of *A.catechu* could be identified by the number of stomata per unit area and that climatic factors influenced stomatal frequency.

Stability performance of arecanut showed that the three high-yielding varieties (Indonesia, Singapore, Andaman 4) proved suitable when planted in favourable environments (years) only. Two others (Saigon 1 and Andaman 1), with fairly high yields, were considered stable in all environments (Natarajan *et al.*, 1982). Comparative studies on field performance of five arecanut cultivars (Mangala, Sumangala, Saigon 1, Saigon 2 and Sreemangala) revealed that Mangala, Saigon 1 and Saigon 2 were most productive (Thangaraj *et al.*, 1980). A comparative yield trial involving five high yielding varieties of arecanut viz., Mangala, Sumangala, Sreemangala, Mohitnagar and Thirthahalli at Thirthahalli showed that Mangala registered significantly lower height with high percentage of flowering palms. Mangala performed better than other varieties with highest yields in the initial years of bearing closely followed by Thirthahalli and Sreemangala (Ananda *et al.*, 2000).

While increasing productivity by improved cultivars/hybrids are of primary importance in arecanut breeding, selection of varieties of intercrop species is also relevant. This approach will lead to a system of most profitable crop combinations. Future research activities should also emphasize on evolving YLD resistant lines, gene/environment interactions and exploitation of dwarf genes. Molecular marker based selections needs to be intensified for identifying specific characters. Tissue culture techniques for somatic embryogenesis are to be developed for future use in transgenics for improvement.

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4. CROP MANAGEMENT

Ravi Bhat and S. Sujatha

INTRODUCTION

The systematic research on arecanut was initiated when the erstwhile Mysore Government started an Arecanut Research Station at Marthur (Nambiar, 1949). This led to establishment of many research stations to work on arecanut and substantial information on management of the crop has been generated.

For better output from the crop scientific cultivation practices of the crop should be followed. The varied conditions under which arecanut is grown makes it difficult to formulate a uniform agronomical practice. This chapter gives information about the climate and soil requirement of the crop and scientific cultivation practices for the crop.

CLIMATE

The yield potential of a palm mainly depends on climate. Generally more than 50% of variation in yield is due to climatic differences. Though, arecanut is grown under different agro-climatic conditions, it is very sensitive to extreme climatic conditions (Bhat and Abdul Khader, 1982). The most important climatic factors that influence the growth and development are altitude, relative humidity and rainfall. Temperature also influences the crop growth and yield to some extent. Regression analysis of weather variables of 12 years indicated that arecanut yield is influenced by relative humidity, evaporation and rainfall (Vijaya Kumar *et al.*, 1991).

Altitude

The cultivation of arecanut is mostly confined to 28° North and South of the equator. In general arecanut is mainly grown in low altitudes. This to some extent depends on the latitude. In North-East region of India (Assam and West Bengal) major areca growing area is in plains, since at higher elevations the winter temperature would be too extreme for the crop. Although areca palms grow at altitude up to 1000m above MSL, at higher levels the quality of the fruits will not be good (Nambiar, 1949). In the high altitude areas like Wynad (Kerala) and Coorg (Karnataka) the endosperm of the fruit does not develop sufficient hardness. It is also reported that high altitudes affect the germination of seeds and quality of chali (dry kernel) (Pillai and Murthy, 1973). The percentage of germination of nut and the proportion of dry weight of kernel to whole fruits are less at altitudes above 850m than in the lower altitudes.

Temperature

Areca palms grow well within the temperature range of 14°C-36°C. However, the crop is being grown in temperatures ranging from 5°C (as in places like Mohitnagar,

Arecanut (Balasimha, D. and Rajagopal, V. Eds), CPCRI, Kasaragod - 671 124

West Bengal) and at 40°C (Vittal in Karnataka and Kannara in Kerala). Nambiar (1949) reported that extremes of temperature and wide diurnal variations are not conducive for the healthy growth of the palms. Smith (1958) reported heavy damage to foliage and death of palms in Florida during December 1957 when the minimum temperature was below -2.8°C. Even temperature around 5°C with low humidity cause severe foliage damage, which was observed in Dakshina Kannada district during early seventies (Bhat and Abdul Khader, 1982).

Rainfall

Arecanut flourishes well in tracts of very heavy rainfall. However, it is grown in areas with wide variations in rainfall such as Malnad of Karnataka where the annual rainfall may go up to or even more than 4500 mm as well as in low rainfall areas like Maidan parts of Karnataka or parts of Coimbatore district in Tamil Nadu where the annual rainfall is about 750mm. In areas of prolonged dry spell, the palms are irrigated.

Relative humidity

Very high or low relative humidity is not conducive for growth and development of arecanut. Relative Humidity directly influences the water relations of palm and indirectly affects leaf growth, photosynthesis, pollen dispersal, occurrence of diseases and finally economic yield. High humid conditions provide congenial conditions for the rapid spread of diseases like fruit rot, bud rot etc. It has considerable influence on evapotranspiration hence on the water requirement of arecanut.

SOILS

Arecanut cultivation was predominant in gravelly laterite soils of red clay type of Southern Kerala and Coastal Karnataka during pre-independence period (Nambiar, 1949). In plain region or Maidan part of Karnataka, it is cultivated in fertile clay loam soils. In areas where tank irrigation is common practice, the soils may have admixture of tank silt. Deep black fertile clay loam soils supported luxuriant palm growth. Aiyer (1966) reported that sticky clay, sandy, alluvial, brackish and calcareous soils are not suitable for arecanut cultivation. In Malaysia and Fiji, arecanut is cultivated in the hot, moist, rich alluvial areas of the coastal belt. Arecanut needs deep soil preferably not less than 2 meters for well developed root system. Studies have shown that under well drained deep soil conditions the arecanut roots traverse down to about three meters and the roots confine to only about 1.40 meters under shallow soil condition (Bhat and Leela, 1969; Bhat, 1978).

Native soil fertility of arecanut belt

Bhat and Mohapatra (1971) identified major soil groups of arecanut growing tract (Table 1). Arecanut is mostly grown in red/lateritic soils in and around western ghat region, West Bengal and Assam, and clay loams in plains of Karnataka (Mohapatra, 1977; Mohapatra and Bhat, 1982). Soils in the western ghat region are mainly derived from granite, gneisses

and schists (Babu, 1981). The soils are sandy loam to clay loam and well drained. The soils in arecanut belt are poor in native soil fertility with abundant sesquioxides and low bases. Further, excessive rainfall aggravated the problem by leaching away of nutrients like N and K. In these soils, N and K are highly mobile and labile, while P is highly immobile and fixed. Even though the parent materials have their distinctive influence on the development of acidity in soils, rainfall and temperature in general appeared to be more dominant factors. Intense leaching of bases accompanying the high rainfall conditions, presents a distinct acid character to the soils. The CEC of the soils is quite low. Kaolinite is the dominant clay mineral and as such there are no K fixation sites.

Table 1 Soil types in arecanut belt

Location	Soil group	pH
Vittal (South Kanara)	Lateritic	5.2
Peechi (Kerala)	Alluvial, lateritic	5.6-6.8
Palode (Kerala)	Lateritic	4.2-5.0
Mohitnagar (West Bengal)	Alluvial	4.5-6.0
Kahikuchi (Assam)	Lateritic	4.4-4.8
Hirehalli (Karnataka)	Clay loam	6.2

Information gathered on the fertility status of the areca growing soils from the Arecanut Research Stations situated in different states of the country gives an idea about the fertility status of the arecanut belt (Mohapatra, 1977; Mohapatra and Bhat, 1982). In general the organic carbon content of the soil was higher. Available P is medium in the soils of Peechi (Kerala), Mohitnagar (West Bengal) and Kahikuchi (Assam), where as it is low in soils of Vittal, Hirehalli (both in Karnataka) and Palode (Kerala). Soils from all the stations except that of Mohitnagar are found to be medium to high in available K status. The pH of the soil is acidic to neutral except that at Hirehalli where it is neutral to alkaline. The total CaO and MgO contents of soils from Vittal and Palode are lower than those of others. The Al_2O_3 content is more than that of Fe_2O_3 in all the soils (Table 2). Texturally the soils of Hirehalli are clay loam and that of Vittal are sandy clay loam, while those from Peechi, Palode, Mohitnagar and Kahikuchi are sandy loams (Mohapatra, 1977). Continuous use of inorganic fertilizers led to slight acidification of soils in arecanut tract (Mohapatra and Bhat, 1990). However, regular application of organic manures results in proliferation of microbial organisms like bacteria, fungi and actinomycetes in laterite soils and congenial soil conditions (Bopaiah and Bhat, 1981).

Total N content of the soils in some of the arecanut gardens in Karnataka varied from 0.03 – 0.22% (Iyengar, 1954). Khadilkar *et al.* (1964) described the soil profiles from arecanut growing areas of Kolaba and Ratnagiri districts of Maharashtra. The major soils are lateritic, mildly acidic, rich in total N and micronutrients and low in bases, P and K. The alluvial soils from the coastal region are found to be neutral, base saturated and rich in organic matter. The physico-chemical properties of laterite soils of Puttur region in South Kanara district indicated

Table 2. Nutrient status of soils (0-25cm depth) of experimental stations under arecanut

Stations	pH	Organic carbon %)	Total N (%)	Available (ppm)		Cao (%)	MgO (%)	Fe_2O_3 (%)	Al_2O_3 (%)
				P_2O_5	K_2O				
Vittal (Karnataka)	5.3–5.6	0.7-1.1	0.05 - 0.09	3.8-7.1	34-85	0.07 - 0.30	0.6-1.7	8.8-12.0	12.0 - 21.4
Hirehalli (Karnataka)	6.5-8.2	0.3-1.4	0.04 - 0.19	Trace-5.5	30-108	0.30 - 0.38	0.6-1.1	7.2-19.2	11.3 - 39.0
Peechi (Kerala)	5.1-5.6	1.0-2.0	0.06 - 0.16	50-81	115-130	0.53	1.7-2.3	8.0-11.2	17.1 - 24.6
Palode (Kerala)	4.9-5.0	0.7-1.4	0.06 - 0.13	Trace-3.0	81-91	0.15 - 0.23	0.6-1.1	4.8-7.2	18.0 - 30.9
Mohitnagar (West Bengal)	5.7-6.2	0.1-2.2	0.14 - 0.22	9.2-69.1	8-55	0.23 - 0.30	1.7-2.9	4.0-7.2	4.8 - 14.5
Kahikuchi (Assam)	5.1-5.3	0.5-1.8	0.03 - 0.12	9.6-29.0	70-190	0.15 - 0.30	1.1-2.3	2.4-8.0	6.5 - 13.6

that the soils are acidic with higher copper and iron contents (Badrinath *et al.*, 1998). Further, zinc, manganese and boron content ranged between deficient to adequate.

NURSERY TECHNIQUES

Arecanut is exclusively a seed propagated crop. It needs adequate care in selecting the proper planting material. Four stages are involved in raising of planting material. They are selection of mother palm, selection of seed nuts, selection of proper technique for germination and raising seedlings and selection of seedlings.

Selection of mother palm

Age is an important factor considered by farmers while selecting the mother palms. Some farmers prefer old palms for selection of seed nuts (northern part of Kerala) and some young palms (southern part of Kerala) (Nambiar, 1949). But the farmers in West Bengal and Assam do not believe that age of the palm is an important factor while selecting the seed nuts. In the erstwhile Mysore state the seed nuts were collected from the palms aged between 25 to 30 years (Aiyer, 1966). But the experimental evidences have shown that age of the palm has no influence on performance of the seed nuts (Anonymous, 1967). Bavappa and Ramachander (1967) indicated that substantial yield increase could not be expected by direct selection in a given population as the heritability for yield in arecanut is low (0.20). However, with the available information and the general practices in vogue, certain minimum standards should be followed in selecting the mother palms. According to Bavappa and Ramachander (1967, 1968) age at first bearing and regular bearing habit are two important characters to be considered for selection of mother palm. Other characters to be considered for selection of mother palms are larger number of leaves on the crown, shorter internodes and high fruit set. Mother palms should be selected based on the processing requirement also as all cultivars are not suitable for preparing either chali or tender processed nuts (Naidu, 1962).

Selection of seed nut

Factors considered by farmers while selecting the seed nuts are position of the bunch, position of nuts in the bunch, weight of nuts, maturity of nuts and floating habit of nuts in water. Studies were conducted to verify the effectiveness of these factors in selecting the seed nut. It was found that nuts selected from the middle portion of the middle bunch neither produced better seedlings nor trees with better performance (Anonymous, 1963). The heavier nuts gave better germination (96% against 87% from lighter nuts), produced seedlings with greater vigour and more number of quality seedlings (Bavappa and Abraham, 1961). The nuts which float vertically in water produced more vigorous seedlings (Anonymous, 1964). The nuts harvested at 9½ and 10½ months maturity did not show any difference in germination (Anonymous, 1964). There was a notion that nuts selected from bunch, which are dropped to ground, give poor germination. But there was no difference in germination when bunches were dropped to ground or lowered by means of ropes (Naidu, 1961).

Raising of seedlings

To obtain better quality seedlings it is important to raise the seedlings with proper care. There are two steps to raise better quality of seedlings.

Primary nursery

The seednuts are planted as whole fruits. The earlier practice was to smear the nuts with cow dung, dry for a couple of days under partial shade and then sow in the nursery (Nambiar, 1949). But studies conducted later revealed that sowing the nuts immediately after harvest in soil/sand and watering once in two days result in early and good germination (Bhat, 1956).

Several media like baskets mulched with straw, gunny bags, straw, sand, soil or burnt earth were used for sowing seed nuts. But sowing in straw was inferior which gave 85% germination and 76% establishment compared to 96% establishment when sown in sand/ soil (Bavappa, 1956). The seedlings were more vigorous when seednuts were sown directly in soil/sand compared to sowing in straw or baskets. The nuts have to be sown vertically with calyx end just covered (Anonymous, 1964) at a distance of about 5 cm and water daily (Fig.1).

The nuts commence germination by 53 days and complete by 94 days. About 2% of the nuts do not germinate, while 1.7% nuts do not have embryos (Bavappa *et al.*, 1957) and 1.5% of sprouts die in the nursery. The number of days required for germination increases with altitude. The seedlings are retained in primary nursery for about six months (Fig. 2).

Secondary nursery

For raising the seedlings in secondary nursery, beds of about 150 cm width and 15 cm height is found convenient. The spacing with which the sprouts are planted has significant influence on the growth of seedlings (Bavappa and Mathew, 1960). It was found that sprouts planted at 45 cm are more vigorous than those planted at 15 cm. Thus a spacing of 30-45 cm is

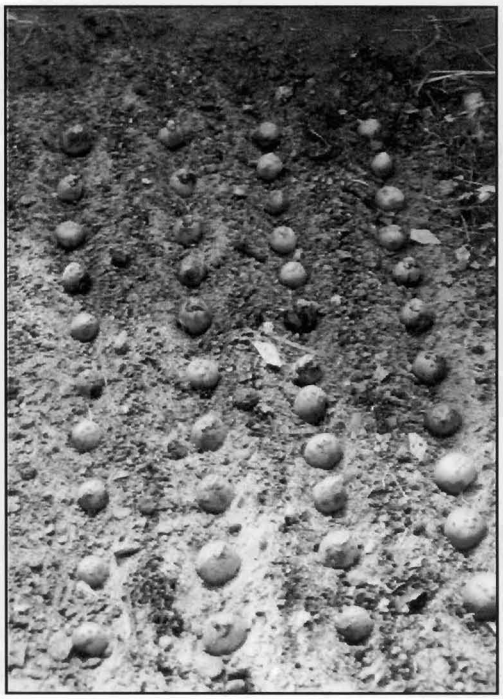

Fig. 1. Sowing of areca seeds

Fig. 2. Primary nursery

Fig. 3. Secondary nursery

Fig. 4. Nursery seedlings in polythene bags

Fig. 5. Planting of seedlings

considered optimum for a growth period of one year in nursery (Fig. 3). The secondary nursery should be given a basal dose of decomposed farm yard manure@ about 5 tonnes per ha.

The sprouts from primary nursery can also be raised in polythene bags (25x15cm, 150 gauge) filled with potting mixture (top soil:FYM:sand = 7:3:2). The sprouts of 3 months old can be planted in polybags (Fig. 4). A reduction in mortality rate up to 15% has been observed when the sprouts are raised in polythene bags (Appaiah, 1970). Areca sprouts and seedlings are highly susceptible to exposure to direct sun. The mortality of sprouts was 19% when fully exposed, 1% under partial shade and 0.13% under complete shade (Bhat, 1970). The growth parameters like height, girth, number of leaves were significantly lower in the seedlings of fully exposed nursery as compared to seedlings in shaded nurseries. The percentage of quality seedlings was higher from shaded nursery (Anonymous, 1969).

The shade may be either of coconut or arecanut leaves spread over a pandal or by planting some fast growing green manures or banana. The commercially available shade nets can also be used for this purpose. *Sesbania aegyptica* has been found to be one of the best live shades in areca nurseries especially in Maidan parts of Karnataka (Naidu and Mashalkar, 1961).

The concept of primary and secondary nursery can be avoided and the seednuts can be directly sown in raised beds (15cm) of 130 cm width at a spacing of 30cm x 30cm in the sub-Himalayan region of West Bengal where the harvesting and sowing seed nuts coincide with rainy season (Paul, 1960).

Selection of seedlings

The seedlings selected should have maximum number of leaves (five or more) and minimum of 90 cm height (Bavappa, 1970). The seedlings have to be uprooted with a ball of earth adhering to roots. Covering the base with ball of earth with plastic sheet/bag will help in keeping the seedlings in good condition for long distance transport (Anonymous, 1964).

Seedlings of different ages are used for transplanting in different regions (Nambiar, 1949; Aiyer, 1966). One or two year old seedlings when used for transplanting produced more vigorous palms with early flowering. The cumulative yield was also higher in such palms as compared to palms raised from older seedlings (Anonymous, 1971b). In Assam, where soil is heavy and problem of water stagnation is seen, planting of 18-30 months old seedlings is reported to be advantageous (Anonymous, 1971a).

ESTABLISHING GARDEN

Site selection and layout

Arecanut thrives well in humid areas when protected against hot sun and heavy wind. It cannot withstand both drought and water stagnation. Thus the site selected should have sufficient drainage to drain away excess water and irrigation facility for irrigation during dry weather. The palms also cannot withstand high temperature and exposure to

direct sun. Exposure to direct sun causes scorching effect on stems and the palms become weak and susceptible to wind fall. So the site selected should have protection against hot sun from southern and western side either by hillock or tall growing trees. All these factors were considered in early days to establish areca garden. So in Malnad areas of Karnataka and Kerala traditionally the plantation existed in valleys of hill slopes which are protected by forest trees growing all around.

Planting methods like square, triangle and quincunx may be followed. Aligning the rows in north-south direction and planting on quincunx system with angling 35° towards west lowers the incidence of sun-scorching (Anonymous, 1971a).

Spacing

The spacing followed in different areca growing regions varied from 1.25 m x 1.25 m to 3.6 m x 3.6 m (Nambiar, 1949). Systematic studies were conducted at different areca growing regions to find out suitable spacing for arecanut. The palms spaced at 2.7 m x 2.7 m produced maximum yield at Vittal (the number and weight of fruits) per unit area (Table 3; Bhat *et al.*, 1972; Bhat, 1978). In central Kerala area also the spacing of 2.7 m x 2.7 m resulted in maximum productivity (Anonymous, 1974). At Hirehalli, though the number of nuts produced was higher with 1.8 m x 3.6 m spacing, the weight of nuts was the maximum with 2.7 m x 2.7 m. But the difference in yield between 1.8 m x 3.6 m, 2.7 m x 2.7 m and 1.8 m x 2.7 m was not significant (Anonymous, 1976). At Kahikuchi (Assam), the nut yield harvested per unit area was the maximum at 2.7 m x 2.7 m and was significantly higher to those obtained under 1.8 m x 1.8 m, 1.8 m x 2.7 m and 3.6 m x 3.6 m (Anonymous, 1977). The root distribution studies in relation to individual palm yield and unit area yield indicated that 2.7 m x 2.7 m spacing is optimum for arecanut (Bhat and Leela, 1969). It was found that under wider spacing the resource utilization was not full and at closer spacing there is heavy concentration of roots in the lower layers of soil resulting in reduction in yield. Thus a spacing of 2.7 m x 2.7 m is recommended in majority of areca growing regions.

Table 3. Cumulative yield (first seven years at Vittal) at different spacing.

Spacing (m)	Nuts/plot (10.8 m x 21.6 m)		Nuts/palm	
	No. ('000)	Wet weight (kg)	No. ('000)	Wet weight (kg)
1.8 x 1.8	17.16	587.01	0.312	10.67
1.8 x 2.7	21.83	726.12	0.662	22.01
1.8 x 3.6	21.30	730.57	0.968	33.21
2.7 x 2.7	27.92	1000.57	1.329	47.65
2.7 x 3.6	21.84	750.97	1.559	53.64
3.6 x 3.6	16.49	575.65	1.649	57.57
CD (P=0.05)	6.63	222.91	0.440	14.77

Table 4. Effect of depth of planting on arecanut yield (Peechi)

Depth of planting (cm)	No. of nuts/palm	Weight of nuts/palm (kg)
30	70.67	2.04
60	100.71	3.05
90	167.78	4.91
CD (P=0.05)	30.60	0.79

Depth of planting

Depth of planting is mainly decided by the soil type and the height of water. In laterite soil with good drainage, the seedlings planted at 90 cm depth were more vigorous and flowered early (Bhat and Leela, 1968) and gave increased yield (Sadanandan, 1973) than those planted at 30 cm or 60 cm (Table 4). But in heavier soils of Hirehalli and soils with higher water table at Kahikuchi (Assam) deeper planting beyond 60 cm did not give added advantage. Deeper planting is always preferred as it provides firm anchorage to the roots and provides large volume of space for spread of roots. When deeper planting is not practiced, the roots get exposed and the palm needs earthing up. Thus in soils where natural drainage can be provided (particularly during the heavy rainfall period) deeper planting of seedlings up to 90 cm depth is preferred. The seedlings may be planted with a ball of earth in the pits after filling half portion with top soil and compost mixture. The base of the seedling should be pressed properly. Then the pit is mulched with green leaves (Fig. 5).

Season of planting

Planting in the main field can be taken up either in the month of May-June or September-October. In areas of heavy rainfall due to south-west monsoon and in river banks where there is likely danger of inundation, planting can be done in September-October. In other areas planting can be done in May-June.

Drainage

For better growth and development of the plants proper drainage is essential since areca cannot withstand water stagnation. The number of drainage channel depends upon the soil type. In light soils the number of channels may be less and in heavy soils the channels should be dug in each row for proper draining of the excess water. The channels should be at least 15 – 30 cm deeper than the depth at which the seedlings are planted. The channels have to be cleaned every year for easy flow of water. The planted pits also should be provided with outlets to drain away the water.

Shading

The palms are highly susceptible for sun scorching. The seedlings should be given protection against the direct exposure to sun. This may be done either covering the plants with areca or coconut leaves or by raising crops like banana in between two rows of arecanut.

Banana planted as shade crop helps farmers to get some revenue also. Sun scorching is mostly seen during October – January. During this period even the stems of young palms have to be protected since the part once lost or got damaged cannot recover. Dry leaves of arecanut can be used to cover the stems. This can also be achieved by planting quick growing shade trees on Southern and Western sides of the garden. The palms have to be irrigated to reduce the effect of scorching.

GARDEN MANAGEMENT

Cultural operations

The cultural operations vary from area to area. In Malnad tracts the purpose of cultivation is different from those in Maidan parts. In Malnad tracts the main purpose of cultivation is to loosen the soil and to rebuild the soil fertility after the heavy rains during monsoon. In Maidan tracts the purpose of cultivation is to conserve the soil moisture and prevent the hardening of the soil, as the soils are heavy in these areas. Coleman and Rao (1918) have recorded the elaborate programmes of cultural operations followed in Maidan and Malnad areas. In Maidan areas, digging is done twice a year once in May-June and again in November-January. In coastal regions area around the palm to an extent of 1 m is opened for applying manures and fertilizers. Farmyard manure is spread on the ground either before or after one of the diggings. But application of farmyard manure was discouraged since this practice encouraged development of surface roots, which dried out during summer. In Malnad digging is done once in three year. The garden is dug and farmyard manure is applied in the first year. During the second year farmyard manure, green leaf and earth are applied without digging and no operations in the third year. Aiyer (1966) has also described a similar elaborate annual cultivation system involving four operations. They are digging the ground at the base of palms, spreading farmyard manure, piling of the green leaves with twigs from the adjacent forest over farmyard manure and covering the whole materials with fresh soil. Since the whole operation was costly, only 1/3rd of the garden used to get all the materials and the remaining used to get only some of the materials. The soil required to spread used to be heaped in between two rows of palms as a mound of about 75 – 100 cm height. The mound is built up of soil obtained by digging drains and by transporting soil cut from adjacent valley side. When the soil of the mound get exhausted over the years new mounds will be built in the row where drainage was dug earlier and new drains will be dug in place where earlier mound existed. Thus the positions of mound and drain are interchanged. Such operations are not seen in Assam and West Bengal. In general the cultivation has found to increase the yield by 10-20%.

Experiments were conducted at Hirehalli and Peechi to find out the relevance of different cultivation practices. At Peechi none of the operations (no intercultivation; digging once in a year; digging twice in a year and digging once in two years) significantly benefited

the crop. At Hirehalli, digging the garden twice a year (June and December) had given higher yield as compared to other methods (scything grass and weeds twice a year (June and December); digging once a year (December) followed by scything weeds (June); and scything weeds twice a year (June and December) and digging once in two years (Sannamarappa *et al.*, 1976). When planting is done on hill slopes, contour planting and clean cultivation gave highest yields (Anonymous, 1975). Mulching is another operation being followed in the arecanut gardens of Malnad and sub-mountane region of Karnataka. They mulch the garden by spreading leaf with twigs. This checks evaporation during summer, erosion during rainy season and keeps the weeds under check and also forms humus and manure to the soil. In some parts (Dakshina Kannada district of Karnataka and Cannanore district of Kerala) green leaves are applied only in the basin of the palms. Sometimes dry leaves are spread in the interspaces during summer. Chopped areca leaves, grass, arecanut husk and dry leaves collected from the forests can be used as mulch in areca gardens. The loss of moisture from the mulched plot was considerably lower than plots without mulch. The weed growth was also suppressed in the mulched plot. (Anonymous, 1967, 1969).

Manuring

Manuring varies with different areca growing regions. In earlier days manuring was followed only in parts of Karnataka, South Malabar of Kerala and Coimbatore district of Tamil Nadu. Manuring was application of green leaves and cattle manures annually or once in two years. The green leaves and cattle manure were used in Malnad areas and tank silt and cattle manure were mainly used in Maidan parts of Karnataka (Coleman and Rao, 1918).

The first systematic study to determine the manurial requirement of arecanut was started at the Marthur Farm in Mysore (Karnataka). The experiments at Marthur during 1920-36 led to the recommendation of 10 cartloads of farmyard manure to be covered with earth and 5 cartloads of green leaves per 400 palms. Apart from this application of a mixture of 90.9 kg groundnut cake, 36.4 kg ammonium sulphate, 90.9 kg concentrated super phosphate and 136.4 kg of potassium sulphate every third year was recommended. A garden once brought to good yielding conditions may be manured once in three years and an yield of over 876 kg can be obtained by application of 56.0 kg nitrogen, 84.0 kg phosphoric acid and 112.0 kg potash per hectare using groundnut cake as a source of nitrogen (Iyengar, 1954) .

The next set of experiments on manurial requirement was started in 1950 under the aegis of erstwhile Indian Central Arecanut Committee in cultivators' field (Lakshmanachar *et al.*, 1966). The experiments were conducted in the sub-mountane and coastal regions of Kerala, Karnataka and plains of Karnataka, West Bengal and Assam. There was an increase in yield by 20 per cent in the sub-mountane region and by 11 per cent in coastal region due to application of manures during the experimental period. The increase in yield in post-experimental period was 52 and 24 per cent respectively in sub-mountane and coastal

regions. The experiments concluded that in sub-mountane region of Kerala application of 22.7 kg of nitrogen, 18.1 kg of phosphoric acid and 64.0 kg of potash for 500 palms was economical. In the coastal regions of Kerala and Karnataka, nitrogen and phosphorus remained same as that of sub-mountane regions of Kerala and potash content was reduced to 34.0 kg for 500 palms.

Table 5. Yield of green matter, nutrient content and amount of nutrients added by different green manure crops

Name of the crop	Mean yield of green matter (tonnes/ ha)	Soil type	Nutrient composition (%)			Nutrient addition (kg/ha)		
			N	P	K	N	P_2O_5	K_2O
Calopogonium muconoides	7.1	Upland	2.63	0.23	2.80	40.5	7.9	51.9
Pueraria javanica	14.3	Heavy soil	3.30	0.24	1.63	99.3	16.5	59.1
Stylosanthes gracilis	12.8	Upland	2.42	0.23	1.63	63.6	13.5	51.6
Mimosa invisa	12.6	Upland	3.96	0.34	2.00	111.7	21.6	67.9
Sesbania speciosa	5.2	-	2.70	0.17	1.12	31.3	4.5	15.6
Centrocema pubescens	6.9	Upland	2.54	0.24	1.75	43.4	9.2	36.0
Crotalaria anagyroides	3.4	Upland	2.81	0.27	2.12	20.5	4.5	18.6
Gliricidia maculata	12 kg/tree	Upland	2.90	0.22	2.32	87*	7*	67*
Sesbania aculeate	25.5	Any soil	3.50	0.26	0.99	232	17.2	65.6
Tephrosia purpuria	7.7	Upland	3.20	0.13	1.08	69.0	2.8	23.3

* g/tree

The third set of manurial experiments were initiated under Central and Regional Arecanut Research Stations, at Vittal, Hirehalli, Thirthahalli, Peechi, Mohitnagar and Kahikuchi covering all the agroclimatic conditions. The experiment involved different levels of N (0, 50, 100 g/palm), P_2O_5 (0, 40, 80 g/palm), K_2O (0, 70, 140 g/palm) and green leaf (0, 7, 14 kg/palm) except at Mohitnagar, where the treatments involved N (0, 100, 200 g/palm), P_2O_5 (0, 40, 80 g/palm), K_2O (0, 140, 280 g/palm) along with application of lime at 0 and 1 kg per palm. The treatments were revised at Vittal and Peechi in1971 to include higher levels. At Vittal, Hirehalli and Kahikuchi there was increase in yield with N application up to 100 g and green leaf application. The application of potash had significant effect on yield at Mohitnagar and Kahikuchi. The application of lime adversely affected the yield at Mohitnagar (Anonymous, 1977). The study indicated that 100 g N, 40 g P_2O_5 and 140 g K_2O along with 14 kg of green leaf is optimum for areca production.

The results of a study in which organic manure (green leaf, cattle manure, bone meal and wood ash) and/or inorganic NPK were applied at equivalent major nutrient rates, showed that the nutrient source did not influence plant growth and crop yield. The nutrient content of the soil was increased after the application of different treatments indicating any form of fertilizer can be used for arecanut (Bhat and Mohapatra, 1989). Trials conducted

Nutrient deficiency symptoms :

Nutrient	deficiency symptoms:
Nitrogen	Growth severely restricted, general yellowing of foliage; leaves small, lower ones lighter yellow than upper ones, yellowing followed by a drying to a lighter brown colour, usually very little abscission of leaves
Phosphorus	Leaflets marginal scorched, lower leaves yellow between veins but often showing a tendency to develop a purplish colouration on the leaf sheath. Vegetative growth less than normal.
Potassium	Leaflets bluish green and slight interveinal chlorosis, curling of leaf margins downward, dead tissues around the margins and between the veins of the leaves is an accurate indicator of potassium deficiency; stunted growth.
Calcium	Growth fairly good, mosaic type chlorosis on the foliage, death of growing point.
Magnesium	Lower leaves chlorotic but usually show no spotting until later stages. Chlorosis starts at the leaf tip progressing downwards and inwards along the margins and between the veins, leaf margins curve upwards, midrib and veins green.
Boron	Mottled chlorosis starting at the tip of older leaves, interveinal chlorotic streaks which may merge to form necrotic lesions, small flowers and fruits, death of growing point,

(Source: Yadava *et al.*, 1972)

at Vittal, Hirehalli and Mohitnagar to screen the suitable green manure crop for arecanut garden showed that *Pueraria javanica* and *Mimosa invisa* are good green manures and cover crops in arecanut gardens form the point of view of their green manure yield and nutrient addition capacity (Table 5; Mohapatra *et al.*, 1970). *Sesbania* was found to be a good crop which can withstand water logging and drought. It can be grown in valleys of Assam, Karnataka and Kerala receiving high rainfall. *Calopogaonium* and *Pueraria* may be used as cover crops also in hilly slopes to prevent the soil erosion. *Tephrosia* is used mainly in some parts of Tamil Nadu for its hardiness and high nitrogen content. It comes up well in loamy soils also. A study was also conducted in Maidan part to screen suitable green manure crop for arecanut garden (Sannamarappa, 1987). The results indicated that Mimosa invisa and Centrosema pubescens produced significantly more green matter, compared with *Pueraria javanica* (*P. phaseoloides*), *Calopogonium mucunoides, Crotalaria anagyroides* and *Sesbania speciosa*. However, *M. invisa* and *C. mucunoides* gave the best improvement in soil organic C status.

Any deficiency of nutrients in plants is expressed through typical symptoms. A study was conducted to identify the deficiency symptoms of major nutrients in arecanut.

Yadava *et al.* (1972) gave key for visual diagnosis of certain nutrient deficiencies of arecanut seedlings grown under sand culture.

With the release of high yielding varieties, it was felt that these varieties may need higher nutrient for higher yield. An experiment was started in 1985 to study the nutrient requirement of high yielding varieties. Arecanut varieties responded positively to higher fertilizer doses up to 200:80:240 g of N, P_2O_5 and K_2O/palm/year (Fig. 6). From economic point of view, it is financially feasible to apply the above dose as it has resulted in higher benefit-cost ratio of 4.25, while zero fertilizer resulted in only 2.52 benefit-cost ratio (Sujatha *et al.*, 1999; Table 6).

Table 6. Effect of different fertilizer levels on yield and economics in high yielding varieties.

Fertilizer levels ($N:P_2O_5:K_2O$ g/palm)	Chali yield (kg/ha)	% increase over control	Gross income (Rs./ha)	Cost of cultivation (Rs./ha)	Net income (Rs./ha)	B:C ratio
0:0:0	2254		1,57,850	59,615	98,235	2.65
50:20:70	3229	43.2	2,26,630	60,958	1,65,672	3.72
100:40:140	3507	55.6	2,45,508	67,316	1,78,192	3.64
150:60:210	3740	65.9	2,61,796	68,951	1,92,845	3.80
200:80:280	4327	92.0	3,02,861	71,088	2,31,773	4.25

Fertilizers are applied in basins around the palm dug to a depth of 15-20 cm and 0.5-1.0 m radius leaving 20 cm from the base of the palm (Fig. 7, 8). After application, the soil is rolled up and covered with organic matter and soil. The fertilizers are to be applied in two split doses. One third of the fertilizer is applied in May - June and two third along with the organics is applied during September-October in basins around the base of each palm.

Organic matter recycling

On an average, 5.5 to 6.0 tonnes of organic wastes are available from one hectare of areca garden per year. The wastes include areca leaf with leaf sheath, bunch waste, leaves of intercrops and weeds (Fig. 9). Direct application of these wastes in the garden leads to immobilization of available nutrients due to high C:N ratio and will not meet the nutrient demand of the crop immediately. These organic wastes could be efficiently converted into vermicompost with a recovery of 75-88% in a composting period of 3 months using *Eudrilus euginae* earthworms (Fig. 10). The arecanut wastes are chopped into pieces of 5-10 cm and filled in tanks or pits. The earthworms cannot eat fresh organic materials and for desirable results, the wastes should be in the preliminary phases of decomposition. To make the wastes more palatable the materials may be mixed with cow dung at the rate of 10 per cent by weight in the form of slurry. This mixed organic waste may be watered regularly to maintain sufficient moisture (30-40%) and incubated for 2-3 weeks to initiate microbial action. One or two turnings may be given to reduce the heat generated. The wastes can also

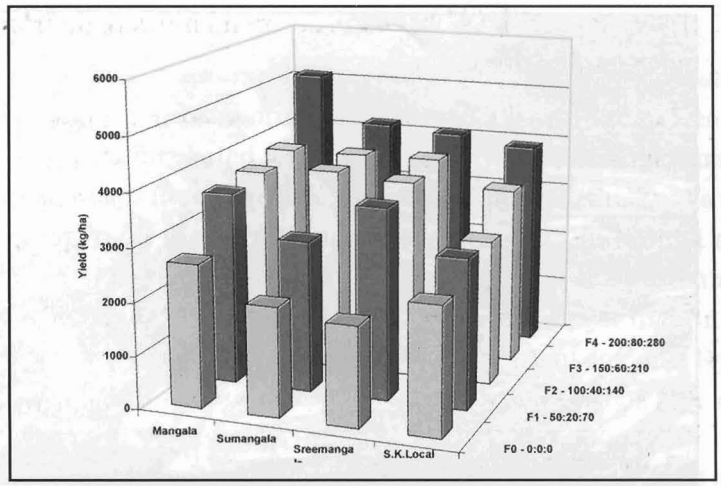

Fig. 6. Interaction effect of varieties and fertilizer levels on yield of arecanut

Fig. 7. Base opening around palms

Fig. 8. Application of fertilizers

Fig. 9. Organic waste materials available in areca garden

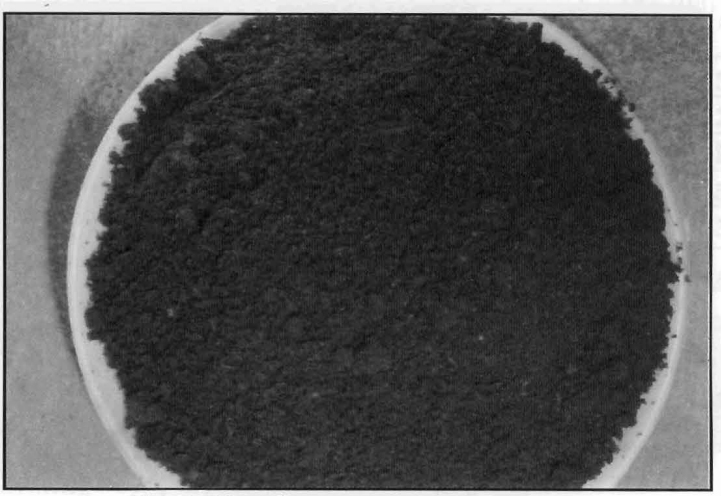

Fig.10. Vermicompost from areca wastes

Fig.11. Drought affected areca palm

be used without chopping. A pit or tank size of 2.5 m x 1.5 m x 0.5 m is sufficient to compost organic wastes from one hectare of arecanut garden because of periodical composting. Then 1 kg of earthworms/1000 kg organic wastes is released into partially decomposed wastes and incubated for another 60 days. Earthworm biomass doubled in a period of 2 months. Major nutrient (NPK) and micronutrient (Cu, Zn, Fe and Mn) contents were slightly higher in all the vermicompost samples than in normal compost (Table 7; Chowdappa, *et al.*, 1999). Vermicompost had lower C:N ratio and pH than normal compost. Microbial population was considerably higher in vermicompost than in normal compost. About 8 kg /palm/year of vermicompost meets the crop nutrient demand. Recycling of organic wastes in the form of vermicompost improved the organic carbon and available nutrient contents to the extent of 30 per cent (Bhat *et al.*, 2002). The yield of the crops was not negatively affected by reducing the chemical fertilizer with the addition of composted wastes.

Table 7. Nutrient composition in vermicompost prepared out of areca wastes

Nutrients	Dried leaves	Vermicompost
Organic carbon (%)	44.20	33.1
N(%)	0.71	1.38
P(%)	0.08	0.35
K(%)	0.94	0.98
C:N ratio	62.25	23.18
Cu(ppm)	100.59	120.18
Fe(ppm)	1745.61	2561
Zn(ppm)	307.08	395.68
Mn(ppm)	81.73	241.68
pH	-	7.3

Water management

Arecanut cannot withstand drought for a long time. Being a perennial crop, once affected by water stress, it may require two-three years to regain the normal vigour and yield. The death of palms due to moisture stress is also not uncommon (Fig. 11). Arecanut, being the most profitable cash crop, irrigation has positive and significant effect on economics of the crop (Dinesh kumar and Mukundan, 1996; Latha and Palanisami, 1996). In West Coast of India, where more than 50 per cent of arecanut is cultivated, rainfall is mostly confined to June-November months. Monsoon is followed by a prolonged dry spell normally extending from November to May. Excess evaporation, faster rate of wind speed, greater vapour pressure gradient in the above ground atmosphere and rise in temperature are the regular features during summer in these regions and as a result, the crop is invariably subjected to drought conditions. If the monsoon is delayed, the drought situation further aggravates. Abdul Khader *et al.* (1985) noticed yield reduction to the extent of 75 per cent with palms irrigated once in 20 days compared to palms irrigated once in 5 days. A three-

fold increase in yield of areca was reported with irrigation from Palode (South Kerala) *(Anonymous, 1976)*. In places with high sub-soil moisture and in areas where the rainfall is well distributed, throughout the year no irrigation is practiced.

Initially the gardens were irrigated through gravitational flow from the tanks situated at the head of the gardens. Irrigation was done by bunding and storing the water in the drainage or irrigation channels and water was allowed to percolate. Other method was splashing water guided into channels. Later on sprinklers (Fig. 12) and perfo-irrigation methods came into operation. Now drip/trickle irrigation is becoming popular. Even fertilizers are applied through drip irrigation, which is called fertigation (Fig. 13).

Table 8. Irrigation requirement of arecanut at different agro-climatic regions

Centre	Irrigation requ'irement	Reference
Peechi, Kerala	189 lit. of water per palm at 3 days interval	Bhat(1978)
Vittal, Karnataka	200 lit once in 5 days and 10 days	Abdul Khader *et al* (1985)
Kahikuchi, Assam	175-200 lit at 7 days interval	Bhat(1978)
Hirehalli, Karnataka	175-200 lit at 5 days interval	Bhat(1978)

Experiments on the irrigation requirement and on the frequency of irrigation were started at Peechi, Hirehalli, Mohitnagar, Kahikuchi and Vittal from early 1960. At Peechi, irrigation once in 3 days with 189.2 liters of water/palm gave the maximum profit. At this rate the water requirement of arecanut was 82.5 cm (Sadanandan, 1973). At Vittal irrigation intervals of 5 and 10 days were found superior over 15 and 20 days (Abdul Khader *et al.*, 1985). When irrigation was scheduled based on IW/CPE ratio, it was found that irrigation of 30 mm of water when the CPE is 30 mm (IW/CPE ratio of 1) is optimum (Yadukumar *et al.*, 1985; Abdul Khader and Havanagi, 1991). This works out an irrigation frequency of once in 7-8 days during November-December, once in 6 days during January-February and once in 4-5 days during March-April and May. The quantity of water to be applied per irrigation was about 200 l. Based on modified Penman method, net irrigation requirement of 899 mm during post-monsoon season and irrigation interval of 6-7 days are sufficient and a lower depletion of 0.5 can be considered (Sandeep Nayak, 1996). At Kahikuchi, irrigation once in 7 days and 14 days was superior over irrigation once in 21 days or no irrigation. The results of various experiments are summarized in Table 8. In all the above cases water was supplied as basin irrigation. The irrigation efficiency in this method was only up to 50-60%.

With the drawback of the conventional methods of irrigation, improved method of irrigation like sprinkler irrigation was invented. It was able to irrigate uneven terrains

Fig.12. Irrigation through sprinklers

Fig.13. Drip Irrigation method

effectively. However the energy required to pressurize the water can become expensive. There will not be much savings in water when this irrigation method is followed. Water required to be given through sprinkler irrigation is about 40-60 l per day per palm with an irrigation interval of 3-4 days (Mahesha, 1987). The irrigation efficiency in this case was about 70%.

The refinement of irrigation method to increase the irrigation efficiency continued and drip/trickle irrigation was invented. The research conducted at Vittal revealed superiority of drip irrigation over conventional method of irrigation. Drip irrigation significantly increased the height, girth, number of nodes, leaf area, number of spadices, percentage of spadices to leaf fall and percentage of nut set compared to palms irrigated by conventional method (Abdul Khader, 1983;1988). A total quantity of 1898 litres of irrigation water per palm was saved by drip irrigation in one season and the quantity of water saved per hectare in one season was 2590 thousand litres (25.9 cm), which amounted to 44% saving as compared to the quantity of water used for irrigation in conventional method. Yield increase by 44% by drip irrigation has been observed over conventional method of irrigation (Table 9). Mahesha *et al.* (1990) based on crop evaporative demand found that optimum depth of water requirement per irrigation was 26 mm and about 8-12 litre of water per palm per day was found sufficient through drip irrigation. Balasimha *et al.* (1996) reported that the photosyhthetic parameters and yield of arecanut increased with increase in drip irrigation levels from 10 lit/day to 30 lit/day in arecanut + cocoa mixed cropping system. The saved water by adopting drip irrigation can be effectively used for irrigation of other crops/ intercrops and depletion of ground water can be checked. It was concluded that areca palm needs 20 litres of water per day when drip irrigation method is followed.

An experiment to study the feasibility of application of fertilizers through drip irrigation is in progress at Vittal. The initial results have shown that for pre-bearing arecanut palms 50 per cent of recommended nutrient is sufficient when it is given through drip irrigation thus saving considerable amount of fertilizer cost (Sujatha *et al.*, 2002; Table 10). Annual maintenance cost could be reduced considerably through saving in labour and fertilizer input over normal practice of basin application of fertilizers and irrigation. Highest root dry weight and root/shoot ratio were observed in ferti-drip method (Sujatha and Abdul Haris, 2000). A two fold and more than four fold increase in number of feeder roots over drip and basin method respectively was observed (Table 11). The fertilizers in the form of urea, DAP and muriate of potash can be given at 20 day interval during irrigation period.

Table 9. Effect of irrigation methods on yield of arecanut (Average of 2 years)

Irrigation Method	Mean yield(kg/palm/year)
Local	9.01
Drip	13.01
CD(p=0.05)	0.46

Table 10. Saving in annual maintenance cost (Rs/ha) during pre-bearing stage

1. Labour requirement per hectare under conventional management	
a. Basin irrigation	170 man days
b. Fertilizer application	83 man days
c. Weeding	40 man days
2. Labour requirement per hectare under ferti-drip irrigation @ 1 man hr/day during post-monsoon season	30 man days
3. Total saving in labour	263 man days
4. Saving in labour cost @ Rs. 50/man day	Rs. 13,150
5. Saving in fertilizer dose (50%)	Rs. 1,300
6. Total saving on input cost	Rs. 14,450

Table 11. Effect of irrigation methods on number of main and feeder roots

Irrigation methods	No. of main roots		No. of feeder roots							
	1997	1998	1997			1998				
			Horizontal	Vertical	Total	Horizontal (cm)		Vertical (cm)		Total
						0-40	40-80	0-40	40-80	
Ferti-drip	22	35	659	310	969	840	982	1071	299	3163
Drip	26	30	323	155	478	453	358	630	256	1697
Basin	17	20	98	327	425	118	-	763	523	1404

HARVESTING

The stage of harvesting varies with the regions depending on the consumer market. Two types of final product are seen in arecanut. One is prepared out of immature nuts and the other from ripe nuts. In both the types time of harvest and the processing type affects the quality of the final produce. At Peechi, it was found that harvesting at six months maturity produced more of vellai choor, which fetches higher price than the other types like choor kora (Anonymous, 1971a). In another study chali from fully ripe fruits produced 8.6 per cent more weight and fetched 72 per cent more price than chali from less mature fruits (Anonymous, 1969).

Various methods are followed for harvesting of arecanut bunches. In some areas harvested bunch will be sent down by a rope or dropped to the ground. In some areas, a long bamboo with a sharp sickle or hook attached to the end is used for harvesting the bunches from the ground. In Malaya it is reported that trained monkeys are used to harvest the arecanut bunches (Nambiar, 1954).

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5. CROPPING SYSTEMS

D. Balasimha

INTRODUCTION

The arecanut palm (*Areca catechu* L.) is an important cash crop of India. The economic produce is the fruit called 'betel nut' and used mainly for masticatory purposes. Its cultivation is restricted in South Western and North Eastern regions of the country. Arecanut industry forms the economic backbone of nearly six million people in India and for many of them it is the sole means of livelihood.

The biological efficiency is increased considerably in multiple cropping systems. The utilization of resources viz., light, water and nutrients is enhanced through a distribution of crop species in time and space. Multiple cropping in arecanut as a productive land use system through the use of interspaces has been practised (Bavappa, 1951, Sannamarappa and Muralidharan, 1982). The long pre-bearing age of arecanut has prompted farmers to grow different annual or biennial crops for economic sustainability. This initial period of 5-6 years is ideal for growing short duration crops. In later years, as the arecanut canopy increases in height, mixed cropping with other shade tolerant perennial crop species are used. Thus, there is an excellent opportunity for a temporal and spatial distribution of crop species in arecanut gardens. The programmes and principles of these farming systems are briefly described in this section.

AGROMETEOROLOGY

The arecanut palm is a crop of subhumid tropics and the altitude at which arecanut grows depends on the latitude (Shama Bhat and Khader, 1982). In North Eastern region, as it is mostly grown in the plains at higher elevations lower temperatures become limiting. In general however, the palm grows at altitudes up to 1000m above sea level and beyond this the quality of nut produced is reduced (Nambiar, 1949). The palm requires a temperature range of 14°C to 36°C, though it is grown in places like West Bengal where the minimum temperature may be as low as 4°C. Arecanut requires heavy rainfall ranging from 3000 to 4500 mm per annum. However, in the plains of Karnataka and Tamil Nadu the annual rainfall is only 750 mm. The gardens in the Karnataka plains are situated in valleys or adjacent to tanks from where there will be water seepage (Nair, 1979). Since, arecanut palms cannot withstand long dry spells, the gardens are usually irrigated during summer months.

The climatic conditions are different in the arecanut growing areas of coastal India. Southern Kerala gets well distributed rainfall as compared to Northern Kerala and coastal Karnataka which receive most of the rains during June to September followed by 5-6 months drought. Hence, in these areas arecanut is grown principally as an irrigated crop.

Arecanut (Balasimha, D. and Rajagopal, V. Eds), CPCRI, Kasaragod - 671 124

Wind is another yield determining factor, as arecanut flowers are wind pollinated. In most of the arecanut growing areas wind does cause sporadic damage to adult palms by breaking the stem. This is found to be more severe in sun scorched arecanut palms where the stems have been already damaged. The intercrops are protected against any wind damage as arecanut palms serve as wind-breaks. This is very important as the synergistic effects of wind and solar radiation can cause mechanical injury in shade plants like cocoa (Alvim *et al.*, 1977; Leite, *et al.*,1980). Arecanut yield is influenced by year to year differences in climatic conditions. Despite the fact that arecanut is irrigated, atmospheric drought might cause such yield fluctuations.

ROOTING PATTERNS

The distribution of arecanut roots under different spacings were reported (Shama Bhat and Leela, 1969). The rooting patterns in arecanut and cocoa are shown in Fig.1. It was observed that 61-67 per cent of all roots were concentrated within 50 cm radius of the palm and 80 per cent of all roots were within depths of 85 cm radius. The cultural operations of arecanut base are also restricted within this radius. The 0-50 cm and 51-100 cm soil depth contained 66-67 per cent and 18-24 per cent of all roots respectively. The roots of closely planted palms penetrated deeper than those planted at wider spacing. The general conclusion was that based on yield and rooting pattern, 2.7 x 2.7 m spacing was optimum. Considering this, on a surface area basis, the area in between four palms is 7.29 m^2; this area is occupied by 1/4 of each of the four palms bringing the total area covered by entire roots to 2.27 m^2. Thus in a pure arecanut garden nearly 68.9% of area is not effectively utilized and is available for growing other crop species. In cocoa the root distribution was upto 50 cm lateral distance and 350 cm vertical depth. Under mixed cropping system the lateral root distribution was upto 50 cm in arecanut and 125 cm in cocoa. Depth wise most of the roots were upto 100 cm in arecanut while in cocoa it was found upto 160 cm (Shama Bhat,1983). There was better exploitation of the root regions of 51-100 cm depth in mixed cropping.

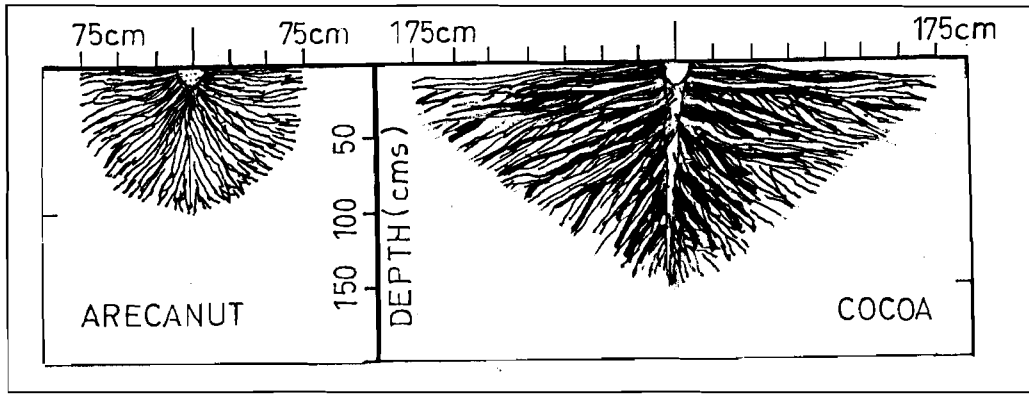

Fig. 1. Rooting pattern of arecanut and cocoa

LEAF CHARACTERISTICS AND PHOTOSYNTHESIS IN ARECANUT

On an average 8-9 leaves are borne in adult arecanut palm. The canopy area and leaf area are about 11.2 m^2 and 22.0 m^2 respectively. The arecanut canopy covers a ground area of 9.1 m^2 and the leaf area index is found to be 2.44. The areas of photosynthesis in arecanut leaves ranges from 2.4 to 8.2 μmol CO_2 $m^{-2}s^{-1}$ depending on the cultivar and leaf position. The first fully open and third leaves showed highest Pn. The total chlorophyll content also varies among the species of *Areca* and highest content was recorded in *A. triandra* (Yadava and Mathai, 1972).

Hydro carbons and b-diketone were the major constituents of the epicuticular wax of arecanut leaf (Subbaiah, 1982). These are known to offer water repellent properties to the leaf surface and regulate the wettability. These are important in view of absorption and penetration of plant protection chemicals sprayed as well as the infectivity by fungal spores.

INTERCROPPING SYSTEMS

Annuals/Biennials

A number of annual crops like paddy, sorghum, cowpea, vegetables and yams are grown as intercrops of arecanut palms (Abdul Khader and Antony, 1968; Abraham, 1974; Muralidharan, 1980; Shama Bhat, 1974; Shama Bhat and Abdul Khader, 1970; Thomas, 1978). When these crops are cultivated the cultural and nutritional practised were followed as used for the pure stands (Sannamarappa and Muralidharan, 1982). Leaving the 1.0 m radius around the arecanut palm, the interspaces are prepared for cultivation of intercrops during the pre-monsoon period. Crops like paddy, sorghum, corn, cowpea are sown in rows and groundnut and sweet potato are sown in furrows. Pits or trenches are taken for Dioscorea, elephant foot yam, banana and pineapple. Crops like ginger (Fig. 2), turmeric (Fig. 3), arrowroot, chillies etc. are planted in raised beds of convenient size. The productivity of these crops in arecanut and as sole crops were studied (Muralidharan, 1980; Table 1). The biological productivity of these intercrops except banana and beans were lower in comparison to sole crops. In most of the studies at different regions, no deleterious effect on main crop due to intercropping was noticed (Abraham, 1974; Muralidharan and Nayar, 1979; Sadanandan,1974).

Banana is another popular intercrop and gives income during early years of planting of arecanut (Fig. 4). Banana and other intercrops fetch interim revenue in the initial years, which will help the farmers in cash flows (Chinnappa, 2002; 2003). Long term experiments in all areca growing regions showed the beneficial effects (Bavappa, 1951; Brahma, 1974; Muralidharan and Nayar, 1979; Shama Bhat, 1974; Singh *et al.* 1982; Sundaramurthy, 1950). The yields of main crop was not affected by growing banana (Bhandary, 1974; Nagaraj, 1974; Roy, 1974).

Table 1. Productivity of different intercrops

Location	Intercrop	Economic produce	Yield (kg/ha)
Vittal	Arrow root	Roots	4000
	Elephant foot yam	Root/tubers	12000
	Banana	Fruits	4000
	Paddy	Grains	396
	Groundnut	Pods	807
Palode	Greater yam	Roots/tubers	6744
	Elephant foot yam	"	6496
	Tapioca	"	10246
	Sweet potato	"	712
	Pineapple	Fruits	3942
Kahikuchi	Banana	"	12200
	Pineapple	"	15700
	Ginger	Rhizome	9800
Kannara	Ginger	"	2650
Hirehalli	Ginger	"	107
	Turmeric	"	1416
	Greater yam	Roots/tubers	6771
	Elephant foot yam	"	12822
	Sweet potato	"	3594
	Chicory	Fruits	1345

Table 2. Mean yield of pepper (green berries and ripe arecanut)

Spacing (m)	Arecanut yield (t ha^{-1})	Pepper yield (t ha^{-1})	
		Panniyur-I	Karimunda
1.8 x 1.8	20.0	4.82	7.26
1.8 x 2.7	13.8	6.09	9.48
1.8 x 3.6	10.8	3.34	6.43
2.7 x 2.7	9.2	7.12	6.05
2.7 x 3.6	9.3	3.96	4.55
3.6 x 3.6	5.7	2.43	3.47
Mean	11.5	4.63	6.21

Patchouli (*Pogostemon cablin*) belongs to the family Lamiaceae and is tall, bushy herb with large aromatic leaves. The Patchouli oil extracted from dry leaves is used in the perfumery industry. The oil also has various therapeutic applications. It is a native of Philippines and grows wild in Malaysia, Indonesia and Singapore (Sarwar *et al.*, 1983). It is

cultivated for commercial use in Indonesia, India, China and South America. It grows well in warm, humid climate with a fairly heavy and evenly distributed rainfall of 2000-3000 mm per year and temperature of 25° C to 35° C, requiring shade. In recent years it is being popularized for cultivation as an important inter-crop in arecanut gardens (Fig.5). The plant is propagated by stem cuttings which are taken from middle portions and are planted at an angle. Cuttings are planted in nursery beds or polythene bags. They are ready for transplantation in 8-10 weeks. Planting is done at a distance of 60 cms on raised beds and water-logging must be avoided. Fertilizer requirement is 150:50:50 kg NPK/ha/year with about 10-12 tons of organic manure. Harvesting is done after six months. Only half of the plant is harvested and subsequent harvests are done after 4-6 months depending upon the local conditions. The plants give good yields up to three years after planting. The harvested herb is dried in shade allowing free air circulation and marketed. The oil yield varies from 2.5 to 3.5 per cent on shade-dry basis of leaves and an average of 2.5 % may be considered commercially satisfactory. Patchouli oil is produced by steam distillation

Mixed Cropping With Pepper

Black pepper is an excellent crop for mixed cropping with arecanut and high economic returns can be expected (Abraham, 1974; Nair, 1982; Nayar, 1982). The arecanut stems are used as live standards for training black pepper (Fig. 6). An experiment was laid out in 1977 at Vittal to study the shade tolerance of four local pepper cultivars viz., Panniyur-I, Karimunda, Uddakere and Malligesara (Abdul Khader *et al.*, 1993). The pepper vines were trained on arecanut palms grown at different spacings. The performance of pepper cultivars, Panniyur-I and Karimunda, were better compared to others in all the spacing treatments (Table 2). The yield of arecanut was not affected by growing pepper. However, the fertilizer doses should be doubled in the mixed cropping to avoid any deleterious effects on the main crop. In an experiment in Karnataka, Black pepper cv. Panniyur-1 was trained on arecanut standards spaced at 2.0 x 2.7 m, showed that the yields were highest (7.2 and 36.52 q/ha, respectively) when 200 g N + 80 g P + 280 g K/arecanut palm were applied (Hegde *et al.*, 1997). The cultivation of black pepper in Konkan region of Maharashtra in are

Vanilla As Mixed Crop

Vanilla, *Vanilla planifolia* is a large green-stemmed climbing perennial plant of the orchid family. Vanilla is cultivated for its fragrant essence, vanillin. The vine has a fleshy, succulent stem; smooth, thick, oblong-lanceolate green leaves with numerous twining aerial roots by which it clings to its support. To obtain commercial production of vanilla beans it is essential to hand pollinate the flowers (Loewenhead and Back, 1974). Vanilla cultivation is one of the most attractive propositions as it fetches remunerative prices (George, 1984). The major countries producing vanilla are Indonesia, French Polynesia, Mexico, Tahiti,

Seychelles, Sri Lanka and West Indian Islands. Cultivation of vanilla is gaining importance especially as an intercrop of arecanut and coconut plantations in India (Madhusoodanan and Radhakrishnan, 2001).

Vanilla can be grown from sea level up to an altitude of 1500m, in a temperature range of 21-32^{0} C. It requires dry spells of 2-3 months for flowering. Usually, the plants are grown on supports. Some of the common living standards are Casuarina, Glyricidia, Mulberry and Erythrina trees. It can be successfully grown in arecanut gardens (Fig. 7). The rooted cuttings are planted during post monsoon period. Since it requires about 50 per cent shade arecanut gardens are very ideal. The plants require abundant organic manure and mulching. Foliar sprays of 17:17:17 NPK is recommended. Vines are allowed to grow to about 1.5m heights and subsequently coiled down the supports to induce flowering. It can also be twisted horizontally between the palms using PVC wires. The vines are given more bends, which can produce more flowers. The tender tips of matured plants should be cut off in advance to induce flowering.

Mixed Cropping With Cardamom

In Uttar Kannada district of Karnataka and Wynad district of Kerala, the cultivation of cardamom as a mixed crop with arecanut is a common practice (Korikanthimath *et al.*, 1994; Fig.8). The compact crowns of arecanut palms provided adequate shade to shade-loving cardamom. Dry yield of arecanut was higher in monoculture by 7% compared with the mixed cropping system. Dry yield of cardamom in the mixed cropping system varied with year, with highest yields in the second/third years after planting. The reduction in arecanut yield in mixed systems was amply compensated for by cardamom production (Korikanthimath *et al.*, 1997; 1998). Cardamom ('Malabar' type) is introduced between rows of arecanut as intercrops at spacing of 2.7 x 1.2m. The microclimatic variables of arecanut were higher than those of cardamom. Photosynthesis and transpiration rates were higher in arecanut compared to cardamom (Korikanthimath *et al.*, 2000).

Cocoa With Arecanut

Cocoa is believed to have been introduced into India more than 200 years ago (Ratnam, 1961). Small scale introductions have been made from Sri Lanka and Malaysia. The microclimate especially shade, soil moisture and temperature in the arecanut gardens were found to be ideal for cocoa (Shama Bhat and Leela, 1968; Shama Bhat and Bavappa, 1972). Further, detailed experiments with arecanut-cocoa mixed cropping were discussed (Shama Bhat, 1988; Fig. 9). The experiment was laid out in1970 with 6x2x4 confounded asymmetrical factorial design having six different spacings viz.,(S1) both arecanut and cocoa at 2.7 x 2.7 m; (S2) arecanut at 2.7 x 2.7 m and cocoa at 2.7 x 5.4 m; (S3) arecanut at 2.7 x 2.7 m and cocoa

at 5.4 x 5.4 m; (S4) both arecanut and cocoa at 3.9 x 3.9 m; (S5) both arecanut and cocoa at 3.3 x 3.3 m; (S6) arecanut at 1.8 x 5.4 m and cocoa at 3.6 x 5.4 m and two fertilizer levels viz., (M1) both arecanut and cocoa at 100 g N, 40 g P_2O_5 and 140 g K_2O; (M2) arecanut at 100 g N, 40 g P_2O_5 and 140 g K_2O and cocoa at 200 g N, 80 g P_2O_5 and 280 g K_2O per tree per year. The spacing had significant influence on the number and weight of cocoa pods (Table 3) in the normal spacing of arecanut it was indicated that either S1 or S2 combination could be safely followed although operational advantages are better in S2 spacing. However, the cocoa yields were maximum at S5 spacing and it is suggested that this can be followed if new plantings with mixed cropping in mind is desired (Shama Bhat, 1988).

Table 3. Mean annual yield of cocoa and arecanut

Treatment	Population ratio Cocoa:Arecanut	Cocoa pods (t/ha)	Arecanut chali (t/ha)
S_1	1:1	16.36	1.71
S_2	1:2	12.55	1.91
S_3	1:4	7.53	2.09
S_4	1:1	11.62	1.04
S_5	1:1	17.12	1.26
S_6	1:2	10.47	1.43

The season of harvest and density of plants (Shama Bhat, 1988) and genotypes (Subramonian and Balasimha, 1981) influenced the pod and bean characters. Significant decrease in pod-value factors for the latter half of harvesting season (May-June) were noticed. Another experiment at Kannara was laid out in 1969 with six cross combinations of cocoa, two levels of fertilizer application as described above and two methods of alignment viz., quincunx and square. There were no significant differences between these alignments. The arecanut yield was not affected by these cropping systems.

The effect of spacing on growth parameters was studied by Shama Bhat (1988). At the time of planting the differences in heights and girths are not significant. Significant differences were observed from fifth year onwards with closer spacing giving taller trees with compact canopy and wider spacing giving maximum canopy area. The relative heights of arecanut palms and cocoa trees were almost equal up to second year, thereafter the palms take a lead. Only the closest spacing (S1) showed significantly lower values in most of the growth and biomass parameters, canopy photosynthesis(Pn) and harvest index. Thus, the spacings do influence the growth and subsequent yields. Hence, optimum spacing for cocoa-arecanut mixed cropping have to be evolved keeping in view the agronomic advantages and economic returns expected.

The environmental factors especially photosynthetically active radiation have a profound influence on leaf function (Barnes *et al.*, 1969; Cooper and Qualls, 1967; Pearce *et*

Fig. 2. Ginger intercrop

Fig. 3. Turmeric intercrop

Fig. 4. Banana intercrop

Fig. 5. Patchouli intercrop

Fig. 6. Pepper mixed crop

Fig. 7. Vanilla in arecanut garden

Fig. 8. Cardamom in arecanut garden

Fig. 9. Cocoa mixed crop

Fig.10. High density cropping system

al., 1969). Since the light intensity transmission varies with spacing (Table 4), it can be expected that changes in leaf physiology exists. In the spacing trial it was found that specific leaf weight and nitrate reductase activity were higher in S5 and S6 coinciding with maximum photosynthetically active radiation (Balasimha and Subramonian, 1984; Table 5).

Table 4. PAR profile under arecanut canopy at different spacing

Spacing	PAR (μ E $m^{-2}s^{-1}$)		
	9.00	12.00	15.30 h
2.7 x 2.7 m	73	470	135
3.3 x 3.3 m	80	1410	307
3.9 x 3.9 m	43	950	600
1.8 x 5.4 m	650	1710	810

Table 5. Effect of spacing treatments on leaf characters

Treatment	SLW (mg cm^{-2})	NR activity (μmol g^{-1} FW)	Total chlorophyll (mg g^{-1}FW)
S1	4.70	0.59	2.01
S2	4.92	0.68	2.02
S3	6.75	0.87	1.99
S4	5.04	0.62	2.14
S5	6.08	0.80	1.82
S6	5.88	0.71	1.80

High Density Multispecies Cropping

High density multispecies cropping system in arecanut typically comprises of black pepper, cocoa/clove, pineapple/coffee and banana occupying different vertical airspaces. A model was laid out in 1983 with six crop species in a 17 year old arecanut garden and preliminary results were reported (Abdul Khader *et al.*, 1992; Bavappa *et al.*, 1986; Fig.10). There was steady increase in the yield of arecanut, and the intercrops started yielding after third year of planting (Table 6). The economic dry matter yield of intercrops accounts for aproximately 27% of total economic yield. This system can accommodate 1300 arecanut palms with 1300 pepper vines, 210 cocoa, 180 clove, 390 banana and 2400 pineapple plants in one ha of area. The arecanut yield was not affected negatively (Ravi Bhat *et al.*, 1999). Pepper was found to be good inter-crop during early years. Banana was alo economically profitable. Covariance analysis revealed that no significant difference among different crop combinations were found (Ravi Bhat et al., 2001). The study indicated that by growing cocoa and clove as mixed crops, arecanut yields were not affected. Cocoa and black pepper

or banana, betelvine and lemon crops are profitable mixed crops in Maidan parts of Karnataka (Sannamarappa, 1993). Mixed cropping with coffee has also been found to be profitable and also result in increase in arecanut yields.

Table 6. Yield of different crops (kg/ha)

Sl. No.	Crops	Year				
		1984	1985	1986	1987	1988
1.	Arecanut (Chali)	1582	2490	4130	3507	3832
2.	Banana (Fruit)	-	2650	2146	1421	390
3.	Pineapple (Fruit)	-	1263	419	244	427
4.	Pepper (Dry pepper)	-	-	45	319	1418
5.	Cocoa (Pods)	-	-	71	941	1084
6.	Coffee (Dry beans)	-	-	10	30	68
7.	Clove	-	-	-	-	-

The success of involving multispecies cropping system depends on the relative shade tolerance of component crops. The crop occupying higher air space under arecanut should have lower interception efficiency and higher photosynthesis. More shade tolerant species are desired at still lower vertical heights. Among the six crops studied, cocoa, clove, coffee, banana and pepper are suitable for multistoried cropping (Bavappa, *et al.*, 1986). The comparative dry matter partitioning and harvest index in pineapple and banana revealed higher harvest index in the latter.

The leaf area duration was maximum in cocoa and chlorophyll/leaf was highest in cocoa and pepper. The seasonal changes in specific leaf weight, chlorophylls and nitrate reductase activity was measured in these crops and compared to open condition (Balasimha, 1989). There were significant differences in seasons and growth conditions. The photosynthetic characteristics in these intercrops also revealed their shade tolerant ability (Table 7). Plants adapt to shade by modifications in leaf thickness and higher chlorophyll contents. The plants grown under light limiting conditions always recorded higher chlorophyll contents on weight/area basis demonstrating more energy investment in the synthesis of light - harvesting system.

Various cropping models for sub-Himalayan west Bengal region were tested at Mohitnagar (China Chenchaiah *et al.*, 2002; CPCRI, 2001). Arecanut based cropping systems with yam, pepper, lime, betel vine, cocoa, banana, turmeric, coffee and cinnamon have shown profitablilty of these models (Table 8). Among the crops studied black pepper, cocoa, coffee, banana were found to be most profitable. The yield of arecanut increased considerably in mixed crops as compared to monocrop. A huge quantity of biomass comprising grass, leaf and other plant parts varying from 14,154 to 25,797 kg/ha could be recycled in different models. In West Bengal multiple crop systems with banana, black pepper, cocoa, elephant

foot yam, acid lime, arrowroot, pineapple and elephant foot yam have been studied (Singh and Baranval, 1993; Singh *et al.*, 1982). In general, irrigation increased the yield of all crops compared with rainfed crops. Similar high density systems are also grown for profitable returns in Assam (Ray *et al.*, 2000). Several multistoreyed cropping systems in arecanut plantations have been tried in Assam (Kakaty *et al.*, 2002). Black pepper, Napier grass, pineapple, cowpea and French bean have been found to be effective in increasing yield and gross returns.

LIGHT PROFILES AND INTERCEPTION

Approximately 30-50% of photosynthetically active radiation is transmitted through the arecanut canopy (Balasimha, 1989; Balasimha and Subramonian, 1984). This varies with season and time of day. Under the arecanut canopy, the light environment is highly dynamic due to variation in cloud cover, solar angle and canopy. The pattern of light transmission varies with the spacing of arecanut palms also (Table 4). The mid-day light profile revealed that spacings of 3.3 x 3.3m and 1.8 x 5.4m allowed maximum transmission. However, in the afternoon 3.9 x 3.9m spacing showed maximum transmission. The arecanut canopy on an average intercepts 70% of incoming radiation. The interception of the remaining radiation depends on the nature of intercrop canopy and leaf area index. For example cocoa with compact canopy and high leaf area intercepts nearly 90% of available light. Pepper which is trained on arecanut stems receives differential light which is dependent on directional and diurnal effects (Table 9).

When intercropped in arecanut, the mixture components are distinct vertically and light measurements can be done by detectors placed above and below each of the canopies. To avoid sampling problem due to the shade and sunfleck areas, large number of measurements are needed (Balasimha, 1989; Charles-Edwards and Thorpe, 1976; Nair and Balakrishnan, 1976). Experimental designs for light measurements nevertheless have to be carefully made, because the mean values taken of such large number of measurements are often statistically meaningless due to non-random distribution (Anderson, 1987). However, if the nature of canopy and leaf areas are precisely known, the measurements can be taken systematically to avoid large errors.

Another useful method is to estimate light interception by different canopies of intercrops at different heights. The measurements of canopy structure in relation to light was studied in multistoreyed high density cropping. The stratified sampling gave a precise distribution of leaf area index at different heights and the levels of transmitted light. This also demonstrated the relative competition for light by component species. The crop species with leaf areas at higher strata is always at an advantage to larger radiation. When such canopies become large enough and intercept most of light, the component species at lower strata are at a disadvantage and are to be subsequently removed. By studying light conversion

Table 7. Photosynthetic characteristics of intercrops of arecanut

Species	Parameter					
	PAR μmol $m^{-2}s^{-1}$	Leaf temp ° C	Transp. mmol $m^{-2}s^{-1}$	Pn μmol $m^{-2}s^{-1}$	Inter. CO_2 ppm	Cond. $cm^{-1}s^{-1}$
Banana	508	32.3	3.01	6.38	236	0.63
Clove	613	31.7	1.72	4.01	237	0.24
Coffee	438	31.6	2.23	3.68	240	0.27
Cocoa	980	34.9	3.52	4.33	271	0.56
Pepper	352	31.9	2.02	4.98	253	0.34

Table. 8. Mean Yield of arecanut and component intercrops

Models	Produce/ha	Mean
Model I	Arecanut chali (kg)	1,617
	Dry pepper (kg)	309
	Banana fruit (kg)	699
	Cocoa pods (nos)	9,055
Model II	Arecanut chali (kg)	1,781
	Dry pepper (kg)	262
	Banana fruit (kg)	1,084
	Gandraj lime (nos)	6,983
	Banana suckers (nos)	223
Model III	Arecanut chali (kg)	1,770
	Betel leaf (nos)	1,62,711
	Turmeric fresh wt (kg)	1,966
	Banana suckers (nos)	249
Model IV	Arecanut chali (kg)	1,673
	pepper (kg)	55
	Banana fruit (kg)	2,059
	coffee (kg)	95
	Banana suckers (nos)	519
Model V	Arecanut chali (kg)	1,842
	Betel leaf (nos)	3,669
	Banana fruit (kg)	1,898
	Dry cinnamon (kg)	276
	suckers (nos)	65
	air layers (nos)	4,185
Control	Arecanut chali (kg)	1,313

efficiencies in terms of photosynthesis and Pn/Ii, models can be constructed to study Pn/Ii interactions and relative efficiencies of crop species. Among these banana appears to be suitable for upper canopy having higher conversion efficiency. Coffee and pepper show very low interception efficiencies.

MICROCLIMATE

The microclimate existing in the arecanut is expected to be milder as compared to the open condition because of the shade cast by the trees. First studies on the climatic variables in pure arecanut gardens were made by Abdul Khader (1983). The evaporation during January to May from the soil surface of the arecanut garden was lower than in the open surface. This is expected because of the lower evaporative demand in the arecanut garden. Lower radiation in cropping systems especially of poly culture nature reduces the evapotranspiration (Allen *et al.*, 1976). Consequently, the air temperatures were lowered and humidity was increased in the garden.

Detailed investigation on microclimate of arecanut-cocoa mixed cropping have been made (Shama Bhat, 1983). The variables studied were evaporation rate, wind velocity, soil temperature, relative humidtiy, vapour pressure and air temperature. The evaporation, air and soil temperature were lower in mixed cropping as compared to sole crop and open conditions. Another important feature to be noted here is least differences between morning and afternoon values in these factors within the mixed cropping. In general they reported that there was lower evaporative demand, higher soil moisture content and least diurnal variations in temperature in standing cocoa plantations. The mean wind velocity inside the sole crop of arecanut was 33% and inside the mixed crop 9% that of the velocity in the open. Thus, the arecanut palms provide excellent protection to the intercrops against wind.

SOIL NUTRIENTS AND RECYLCING

The availability of these nutrients depends on the biological processes in the soil and organic and inorganic inputs to the system. The nature of competition in the soils for water and nutrients are not well known. When more crops are intercropped there is an accumulation of litter enhancing the organic content of the soil (Hart, 1986). Another possibility is that the component species may occupy different soil profiles avoiding competition for nutrients.

In the arecanut-cocoa mixed cropping, the nutrient status of soils were profoundly influenced (Shama Bhat, 1983). The spacing and depth influenced the pH significantly. The organic carbon content were higher in mixed crops, and showed decreasing trend with depth of soil. The available P in sole arecanut basin showed higher concentration than sole arecanut. However, in mixed cropping bases of arecanut and cocoa had lower P content at lower depths. Available K was also higher in mixed crops. In a high density multispecies

Table 9. Directional PAR profile around pepper trained on arecanut palm

Time (h)	Canopy PAR (μ E $m^{-2}s^{-1}$)				PAR open
	East	West	North	South	
8.30	298	70	143	236	760
10.30	793	131	689	789	1500
12.00	1065	495	1196	1368	1680
14.30	105	553	543	150	1200
16.30	39	76	64	70	650

Table 10. Soil characteristics in HDMSCS and monocrop of arecanut

Crop	Soil depth	Soil characters				
		pH	Org C (%)	P_2O_5(ppm)	K_2O (ppm)	Ca (ppm)
Arecanut + Pepper	0-25	4.6	1.20	1852	421	191
	25-50	4.3	0.66	152	260	125
	50-75	4.7	0.42	48	221	148
Clove	0-25	4.9	1.02	1700	425	193
	25-50	4.7	0.74	339	289	180
	50-75	4.6	0.34	56	226	174
Coffee	0-25	5.1	1.09	532	108	156
	25-50	5.2	0.73	93	131	178
	50-75	5.5	0.54	24	147	162
Cocoa	0-25	4.5	0.90	498	382	98
	25-50	4.2	0.66	57	241	83
	50-75	5.2	0.37	19	189	131
Interspace of arecanut	0-25	5.3	0.80	127	101	152
	25-50	5.3	0.56	14	189	133
	50-75	5.3	0.34	9	166	305
Interspace of arecanut	0-25	5.7	0.92	11	46	176
	25-50	5.7	0.67	8	55	192
	50-75	5.9	0.37	6	45	174

Table 11. Microbial population and soil biomass in 0-25 cm soil layer

Cropping	Location of sampling	Total microbial population/ g soil (10^3)	Soil microbial biomass (μg g/g soil)
Arecanut monocrop	Arecanut basin	768	763
Arecanut monocrop	Arecanut interspace	126	616
Arecanut HDMS	Arecanut basin	819	788
Arecanut HDMS	Arecanut interspace	530	676

cropping system at Vittal, the nutrient status in the soil were investigated (Table 10). Where the soil nutrient factors are examined in soil depths of monocrop and HDMCS, the available P_2O_5 and K_2O content were higher in the latter. This is because the individual plants were manured at recommended doses resulting in gradual nutrient accumulation. This may also help in better root feeding of the nutrients. So, a reduction in the supply of these fertilizer inputs is indicated.

The nutrition added through rainfall, canopy leachates and soil depletion in run off was studied (CPCRI, 1988a; Mohapatra and Bhat, 1990). The rains during June added 3 kg N as NH_4, 4 kg N as NO_3, 37 kg Ca and and 11 kg Mg per ha. The washings from arecanut canopy supplied 4.5 kg K, 6.0 kg Ca per ha. The leaching losses of water soluble nutrients in HDMSC plot was 0.16 kg P, 1.5 kg K, 90 kg Ca and 31 kg Mg per ha and in fertilizer experiment of monocrop arecanut it was 15 kg P, 286 kg K, 225 kg Ca and 39 kg Mg per ha. This reveals that the leaching losses from the soil were substantially decreased due to intensive cropping. The increase in output/input ratio in the system shows its superiority over the monocrop, maximum being in arecanut-cocoa mixed cropping system. The flow of energy is through the capture of solar radiation and fossil fuels used in fertilizer manufacture. Usually, in the energy budget system the energy inputs from solar radiation is not included. In this system the energy through recycling of crop residues and organic matter is not also included as in most other studies (Hart, 1986) and should form a component while doing future research in the energy flows of multiple cropping systems. Such integrated systems approach involving nutrient recycles and energy flow can lead to the proper understanding and fertilizer scheduling in tree crop based intensive cropping models.

The concept of energy and nutrient cycling is important in multiple cropping system. There is greater scope for internal recycling due to higher production of crop residues. These are generally in the form of leaf fall, pod/nut husk and prunings. These can be used efficiently for both mulching and organic recycling. In fact from this system 17%N, 14% P_2O_5 and 23% K_2O were returned annually. Due to these favourable organic and microbiological conditions in the soil, there was a more than two fold yield increase in main crop of arecanut (Bavappa *et al.*, 1986; CPCRI, 1988b).

RHIZOSPHERE MICROORGANISMS AND SOIL BIOCHEMISTRY

The soil microflora and fauna vary according to the soil conditions, agronomic practices and cropping pattern. The microorganisms associated with the perennial tree crops are most likely to be constant in their quantitative nature and abundance (Nair, 1979). Initial work on the rhizosphere microflora were reported in coconut palms and cocoa in mixed cropping (Nair and Rao, 1977). The rhizosphere microflora have been studied in arecanut palms in relation to distribution (Bopaiah and Koti Reddy, 1982), application of manures and fertilizers (Bopaiah and Bhat 1981), mulches and irrigation levels (Abdul

Khader and Bopaiah, 1989). The soil microflora was found upto 60 cm lateral distance and 90cm depth. The application of organic matter increased the microbial populations. Similarly, mulching with organic matter and irrigations improved the microbial level significantly in the arecanut root regions. The qualitative fungal flora revealed the abundance of *Trichoderma sp., Aspergillus, Penicillium, Mucor* and *Rhizophus.* The bacteria found were *Bacillus, Arthrobactor, Micrococcus* and *Pseudomonas.* The actinomycetes consisted of *Septromyces, Nocardia, Micromonospora* and actinomycetes (Bopaiah and Bhat, 1981).

The rhizosphere microorganisms in high density multiple cropping and arecanut monocrop have been reported (Bopaiah, 1991) and presented in Table 11. The population of bacteria, fungi, actinomycetes, N_2-fixers and P-solubilizers were more in rhizophere of arecanut, cocoa and pinapple as compared to arecanut monocrop. The spore count, vesicular-arbuscular mycorhizae root infection and colonization was least in banana. The microbial biomass was also higher in multiple cropping system. The asymbiotic N_2 fixers isolated from arecanut based high density multiple cropping system had the N_2 fixing capacity in the range of 2.8 to 11.8 mg N/100 ml of medium (CPCRI ,1988b).

Root exudates from the component crop species may influence the soil composition microorganisms. The root exudates have been analysed for their biochemical constitution (Nagaraja *et al.*, 1986). They found that the optimum period for collection of root exudates was five days. Further, the root exudates contained sugars, amino acids and organic acids. Exudation of sugars was not significantly affected in the component crops investigated growing under different cropping systems; arecanut, 2.1 – 4.4; banana, 3.4 – 10.5; cocoa, 0.36 – 0.58; pepper 2.0 – 3.0 mg/g root day weight. However, mixed and high density cropping system significantly reduced the exudation of amino acids. Phenols were not detected in the root exudates. There were also no differences in the qualitative composition of sugars, organic acids and amino acids in relation to cropping system. The biochemical characterization of the soils in the above cropping systems have been attempted (Nagaraja, 1988).

The results showed that phenol content decreased in root region of arecanut, pepper, cocoa and banana growing under multiple cropping compared to monocrop. Sugar content of soils from areca, banana and cocoa were higher. Amino acid content of soils from cocoa soils under mixed cropping was significantly lower than cocoa monocrop. These beneficial changes in the rhizosphere of the main crop and intercrops not only improve soil microclimate, but result in enhancing yields of crops.

SOCIO-ECONOMIC CONSIDERATIONS

In the tropical countries the farm holdings are small, being less than two hectares in three-quarters of farmers. This applies to arecanut gardens as well. In perennial crops the

land is committed for several years. This has led to a widespread practice of multiple cropping among farmers who have evolved various systems by experience, tradition and socio-economic needs. Only in recent years that researchers and policy-makers have begun to realise the potential for maximizing productivity. More scientific approach and methods are being developed now.

Arecanut alone may not give sufficient economic stability for the large number of small farmers in India. To ensure yield stability and economic sustainability of small farm units, it is necessary to develop scientific multiple cropping systems. The farming systems will have to be developed keeping in view the social needs and food habits of a particular region. The systems approach and trials in farmers' fields will help in evolving the suitable technology.

Few studies on the economic advantage of perennial crop based multiple cropping have been made. Under irrigated conditions arecanut-cocoa mixed cropping gave a monetary advantage of Rs.19,163/ha/year with a land equivalent ratio of 2.18; arecanut-pepper cropping gave a monetary advantage of Rs.18,402/ha/year and LER 1.50 (Das and Vijaya Kumar,1991). There is always a difference in pricing of component crop products. In assessing the efficiency of multiple cropping, it is appropriate to follow a sliding price scale method when two or more crops are combined (Hilderand,1976). In the arecanut-cocoa spacing trial such a method was adopted and found that either a spacing of S1 or S2 was ideal (Shama Bhat,1988). The LER in this system ranged from 1.56 to 2.17 with a maximum value in S5 followed by S1 spacing treatments (Shama Bhat,1983). The net returns from the arecanut HDMS was also found to increase markedly as compared to the arecanut monocrop (CPCRI, 1988a).

Two other issues that are relevant here are the risk factors and employment generation. A small farmer cannot afford to lose the crop due to any of the climatic disasters or pest and disease attack as he is wholly subsistent on it. The multiple cropping system may protect the farmer from any eventual risks caused by non marketability or crop loss in any crop species. In most of the plantation crops farming is labour intensive. The introduction of multiple cropping increases the labour inputs. At Vittal in the arecanut based HDMS for example, a labour input of 900 mandays in HDMS and 405 mandays/ha/year in monocrop was required (CPCRI, 1988b). Thus, the employment opportunities are increased in the multiple cropping which is of significant importance in developing countries. Apart from these factors the ecological advantages are substantial due to the prevention of soil erosion and nutrient loss in multiple cropping as compared to monocrop systems.

YIELD GAP ANALYSIS

The difference between potential and actual yield is known as yield gap. The research gaps in such analysis will be generally with respect of photosynthetic efficiency, partitioning,

harvest index and agronomic and disease management practices. Even the average yields of experimental farms are not reached in the farmers' fields which is due to extension and developmental gaps. Arecanut as monocrop faces these constraints and it is even more intense when intensive cropping systems are introduced. Similar yield gaps exist in important intercrops like cocoa and pepper. By achieving the development cum extension gap alone several fold increase in the yields can be achieved.

It is not an easy proposition, however to achieve the research gaps. For this a deep understanding of various physiological, bio-climatic and agronomic factors are necessary. Some optimal factors are known to some extent atleast in some crops (eg., cocoa). Even though these help in sole cropping systems, it is not sufficient for increasing the biological efficiency of crop cultures as so many complex factors are involved. The shade cast by trees, canopy relationships, light quality and plant-plant interactions are so dynamic and diverse that a simplistic model cannot be constructed. The dry matter yield in a 2 crop combination (arecanut-pepper or arecanut-cocoa for example) is always greater than the yields of any single perennial crop as an unit area of land. The multistorey cropping may have other advantages, but do not reach such high levels, because the plant density of component crops are always lesser and resource limitations more. Hence, the maximization of yields cannot be achieved beyond certain levels.

PROBLEMS AND PROSPECTS

The production of arecanuts is now saturated because of the limited domestic use of the product and it has not much export potential. Despite efforts to develop some alternative uses for arecanut, so far no viable commercial exploitation has been possible. Instead of looking for only alternate possible uses of the product, the time has come that the policy makers and researchers should concentrate on the arecanut industry by intensifying the cropping patterns. The pressure on the land in India is very acute and it is possible to increase the productivity of important crops like pepper, cocoa and clove etc., which have great export potential. By and large the total area under arecanut is under-exploited in spite of the research efforts on intensive cropping systems. The beneficial effects of crop combinations, agrometeorology, fertility management, rhizosphere microorganisms, light use efficiency etc., should be employed to suitable crop combinations with arecanut.

Unlike the coconut based multiple cropping which is mainly grown on rainfed conditions (Nair, 1979), the potential for multiple cropping in arecanut palms are greater because arecanut is raised mainly as an irrigated crop. The introduction of intercrops however, will increase the demand for water. The research needs of the system then, has to be addressed for efficient water use by component crops besides the main crop. This can be achieved by proper micro-irrigation systems.

Plant breeding efforts also should be given a new dimension, since it involves growing plants under light and/or nutrient deficient conditions. Traditionally, evolving varieties

have been done in sole crops under most optimal conditions. The breeders should not only attempt to maximize yields under shade environments, but look in for resistances to stresses and pests. One should not confine to such cropping systems described in these sections, but look for broader horizons. For example, the combination of pastures and animals as 'mixed farming' has not been given sufficient attention. The use of modulating legumes in the basins of arecanut will enrich the fertility. Arecanut by-products like husk are degradable and can be utilized for cultivation of edible mushrooms in arecanut interspaces which is a novel proposition. This needs future trials to see its economic viability.

According to the Hildebrand (1976) the focus of any crop model should be on the farmers. For this the agro-socio-economic survey of the target groups is essential. The three characteristics of such models are: a rapid generation of technology, orientation for more research based feed back and creating multidisciplinary environment to evolve successful research in multiple cropping system. In arecanut the first two processes are available and results of the multidisciplinary research has started giving some results. There is still a need to get more precise and basic information. Then only it is feasible to refine the cropping systems in the field with long range extension action in mind. The programmes, resource use and technology development of multiple cropping with arecanuts is an example of how the biological efficiencies can be increased. This can be used as a model or reference for adopting other perennial crop based multiple cropping systems of the humid tropical countries.

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6. DISEASES AND DISORDERS

N. Saraswathy

INTRODUCTION

Arecanut palm (*Areca catechu*. L) is mainly cultivated in states of Karnataka, Kerala and Tamil Nadu. Plantation level cultivation is also seen in parts of Andhra Pradesh, Assam, Maharashtra, Meghalaya and West Bengal. The productivity of palm is affected by a number of diseases and disorders. Some of the diseases like, fruit rot, yellow leaf disease, basal stem rot and inflorescence dieback are economically important since they cause damage to the product as well as the crop. The other diseases of lesser importance are bud and crown rots, bacterial leaf stripe, stem bleeding, seedling diseases and the disorders like crown choke, nut splitting, sun scorch and stem breaking etc. The fungal diseases may cause partial or total loss of the crop depending upon the part, which is affected. The yellow leaf disease caused by Phytoplasma is a slow decline disease, which affect the productivity of the palm as well as the quality of nuts. Besides the diseases and disorders some fungi cause spoilage of harvested nuts during drying and storage leading to deterioration of the produce.

PHYTOPHTHORA DISEASES

The diseases caused by *Phytophthora* results in partial or total crop loss in individual palms or death of the palm itself. The fungus *Phytophthora* affects the seedlings in the nursery or the transplanted seedlings and the adult palms during southwest monsoon causing fruit rot (mahali or kole roga). The fungus also attacks the growing bud and the crown resulting in bud and crown rots respectively. The later two diseases are fatal if the diseases are not noticed and treated in time.

Fruit rot is weather dependent and seen during southwest monsoon season rains (May-August/ June-September), whereas bud/ crown rots are seen during monsoon season as well as in the cooler months (October-February). Fruit rot is first recorded from the erstwhile Mysore state (Butler, 1906) and later from the present Dakshina Kannada and Uttara Kannada Districts of Karnataka and parts of Malabar and Cochin in Kerala (Coleman, 1910).

The reported records on crop loss due to fruit rot varied from 10-90 per cent and due to bud rot about 15 per cent. The information on crop loss due to the above diseases is described by several authors (Table 1).

Anandaraj and Balakrishnan (1987) developed a sampling technique to assess the yield loss due to fruit rot. Chowdappa *et al.* (2000a) reported that the loss due to fruit rot vary according to locality and variety.

Fruit rot is characterised by rotting and heavy shedding of immature nuts (Butler, 1906). A detailed account of the disease with its causal organism is documented by Coleman

Arecanut (Balasimha, D. and Rajagopal, V., Eds), CPCRI, Kasaragod - 671 124

Table 1. Crop loss due to rot

Loss Percentage	Reported by
Fruit rot up to 75 or total destruction	Coleman (1910)
15-20 per cent	Anonymous (1960a); Coleman and Rao (1918); Kamath (1956); Nambiar (1956)
50-90 per cent	Koti Reddy and Anandaraj (1980)
72-350 kg nuts/acre	Sastry and Hegde (1985a)
BUD ROT	
. One percent of trees	Coleman (1910)
Heavy loss	Anonymous (1960b) Dorasami (1956)
15 per cent	Saraswathy (1994)
21-50 palms/ acre	Sastry and Hegde (1985a)

(1910) in his pioneering work on fruit rot. The occurrence of disease could be identified by the unusual shedding of fruits during South West monsoon season. The symptom appear as dark green water soaked lesions on the nut surface usually near the perianth. Fungus makes entry to the host tissue through the stomata or epidermis. The entry is aided by the mycelium or germ tube of the germinating sporangia (Coleman, 1910). Under the laboratory conditions the infection initiates within 18-19 hours on the wounded tissues or occur 4-5 days after inoculation on uninjured fruit surface (Saraswathy, 1994). Fruits loose their clear natural green colour due to infection. On the infected nuts the lesion spread gradually covering the fruit surface before or after shedding and on incubation under humid conditions develop white mycelial mat over the infected area and envelopes entire surface of the fruit (Fig. 1) (Coleman, 1910; Saraswathy, 2003). In severe case of infection fruit stalk and the axis of inflorescence are also affected (Marudarajan, 1950a ; Sundararaman and Ramakrishnan, 1928). Waterhouse (1974) described symptoms of fruit rot as development of chlorotic area with loose mycelium and luxuriant sporangia. The infected nuts showed discoloration of kernel, reduction in weight and large vacuole. The infection occurring towards the end of south west monsoon season may not develop the typical symptoms of fruit rot and dry up without shedding of nuts and remain mummified (Marudarajan, 1950a). Fruit rot leads to quantitative and qualitative loss to the crop and the infected nuts are not suitable for chewing.

Bud rot is another manifestation of fruit rot and this may occur independently or following severe fruit rot and the fungus can grow down the bunch stalk and from there to the tender portion of the stem or can enter directly through the outer leaf sheath in to the tender growing point (Coleman, 1910) leading to crown rot. Bud rot and crown rots can occur frequently in fruit rot affected palms (Sastry, 1982; Sastry and Hegde, 1987). The palm treetops were killed in Marthur experimental garden in the malnad area, adjoining the western ghats (Venkatarayan, 1932). Later, the occurrence of bud rot in a severe form from the heavy rainfall areas of Karnataka was reported (Nambiar, 1949). Bacterial rot of

spindle from many parts of Karnataka and severe rotting of young leaves by *Nigrospora sphaerica* were reported (Naidu, 1960; Naidu and Sampath Kumar, 1964). The disease occurs during South West monsoon season and fresh infection during Nvember onwards becomes severe during subsequent cooler months (Marudarajan, 1950a). Bud rot is characterized by rotting of growing bud and the surrounding tissues. The initial visible symptom is yellowing of the spindle leaf. The affected spindle looses its natural green colour and in the advanced stages turn to yellow and can be drawn out with a gentle pull (Fig. 2). As a result of rapid spread of infection to the base of adjacent leaves, these leaves also become yellow, droop and drop off ultimately leaving a bare stem. Colonization of the infected portion by secondary organisms converts it into a slimy mass, which would emit a disagreeable odour (Coleman, 1910). In the case of crown rot infection initiates from the base of outer most leaf sheath or from the stalk ends of infected areca bunches or developing inflorescence and slowly spread to the internal tissues of the stem. The first visible symptom is yellowing of the outermost leaf sheath (Fig. 3). Inner portion of affected sheath exhibit water soaked lesions and later the infection spread to the tender portion of the stem and the growing bud resulting in yellowing of the leaves, rotting of the internal tissues of the crown and finally death of the palm. Sarma and Murthy (1971) recorded the occurrence of crown rot caused by *Thielaviopsis paradoxa* (de Seynes) von Hohnel from united Khasi and Jayanthi hills of Assam.

The earliest description of the pathogen causing fruit rot is by Sydow and Butler (1907) who described the pathogen as *Phytophthora omnivora* de Bary. Coleman (1910) named it as *P. omnivora* var.*arecae*. Pethybridge (1913) observed that the fungus is quite different from de Barys *P. omnivora* and renamed it *as P.arecae* Peth. Later *P. palmivora* (Das and Cheeran, 1986) and *P. meadii* Mc Rae (Sastry and Hegde, 1985b; 1987) were reported to cause fruit rot in parts of Kerala, Siddapur, Sirsi, and Yellapur areas of North Kanara. Subsequently the occurrence of *P. meadii* was reported from different areca growing areas of Kerala and Karnataka (Dutta and Hegde, 1987; Santha Kumari and Hegde, 1987; Saraswathy, 1994). Identification of the pathogen collected from diseased areas of Dakshina Kannada is confirmed by CMI, England with IMI nos. 352313, IMI 352314 and 352316, isolated from fruit rot, budrot and leaf rot affected tissues (seedlings) respectively (Saraswathy, 1994). Chowdappa *et al.* (2002) recorded the occurrence of homothallic strain of *P. heveae* on fruit rot affected arecanut in addition to *P. meadii.*

Mycelium of the fungus is coenocytic in younger cultures and becomes septate on ageing. It is inter and intra cellular, occasionally branched with a diameter of 8-9 mm in *P. arecae* (Coleman, 1910). The fungus grows and sporulate better on steamed cornmeal agar (Tucker, 1931). The mycelium of *P.meadii* is copiously branched with a diameter ranging from 5-6 mm without distinct hyphal swelling (Saraswathy, 1994; Sastry and Hegde, 1987; Waterhouse, 1974). The cultural characters of *Phytophthora spp.* differ according to media used. In *P.arecae* aerial mycelium is luxurient, scanty or sometimes absent and in submerged cultures the hyphae are smooth, gnarled, even or uneven and on carrot agar medium the

fungus put forth fairly copious growth with slightly radiate pattern (Ramakrishnan and Seethalaxmi, 1956; Thomas *et al.*, 1947; Waterhouse, 1974).

The cultural characters of *P. meadii* are described differently by different workers. The fungus did not show any cultural pattern or growth was profuse in solid media with white fluffy mycelium with radial growth or fluffy with uniform growth in carrot agar and potato dextrose agar respectively (Santha Kumari, 1987; Waterhouse, 1974). Saraswathy (1994) studied the cultural variation of *P. meadii* on different synthetic and organic media and reported that the growth pattern varied from fairly striate or stellate or radial with fluffy mycelium either near the inoculum or the entire surface of the medium and colour of the colony varied from white to off white depending on the medium. Chowdappa *et al.* (2000a) described the colony characters as petalloid to radiate pattern with cotton wool like aerial mycelium on carrot agar medium.

Majority of the isolates are heterothallic but occurrence of homothallic isolates have also been recorded. The fungus reproduces asexually by means of sporangia and chlamydospores. Size and shape of sporangia vary according to the conditions in which it is grown. Sporangial characters of *P. arecae* and *P. meadii* shows wide variation. Sporangiophore in *P. arecae* is irregularly branched, sympodial or mostly sympodial without any hyphal swellings. The deciduous sporangia are ellipsoidal, obturbinate, nearly spherical, papillate without double apieces and not distorted and are borne laterally and intercallary. The sporangial measurements varied from 20.6 x 30.1 mm to 43.3 x 71 mm or 40 - 50 x 35 - 40mm and maximum 70 x 48 mm with an L:B ratio of 1.1 - 1.4 : 1.0 in *P. arecae* (Coleman, 1910; Ribeiro, 1978; Stamps *et al.*, 1990; Tucker, 1931; Waterhouse, 1963; 1974).

Sporangiophores in *P. meadii* are irregular with sparse branching and characterised by swelling at the nodes or else where. The sporangia (Fig. 4) are spherical or ellipsoidal, distorted or lobed and sometimes with more than one apex. They are laterally inserted with round base and hemispherical papilla. Sporangial diameter ranged from 25-72 x 15.0-40 mm with an L:B ration of 1.3 : 1.0 (Sastry and Hegde, 1987) or 45-75 (Stamps *et al.* 1990) or 40-55 x 22.5-37.5 to 45 – 52.5 x 22.5 –35.5 mm with an L:B ratio of 1.3-1.6 or 1.4 –1.7 mm in solid media and in water respectively (Saraswathy, 1994) or 41.09 to 50.85 x 27.84 to 33.30 mm with an L:B ratio of 1.43 to 1.74 (Chowdappa *et al.*, 2000a). The sporangia are caducous with a thin pedicel and the length varies from 11-16 mm (Sastry and Hegde, 1987) or 7.5 –21.0 mm (Saraswathy, 1994) or 21 –30.87 mm (Chowdappa *et al.*, 2000a).

Chlamydospores are not produced by all the isolates of the same species. But the rare occurrences of these spores are recorded in *P. arecae* and *P. meadii*. They are spherical, terminal or intercallery with the measurements ranging from 35-40 (maximum 60 mm) and wall thickness of 1.0 mm in *P. arecae* and 16-36 mm in *P. meadii* (Stamps *et al.*,1990; Tucker, 1931; Waterhouse, 1974). Chlamydospores are totally absent or seen in older cultures of certain isolates (Saraswathy, 1994; Sastry and Hegde, 1985a).

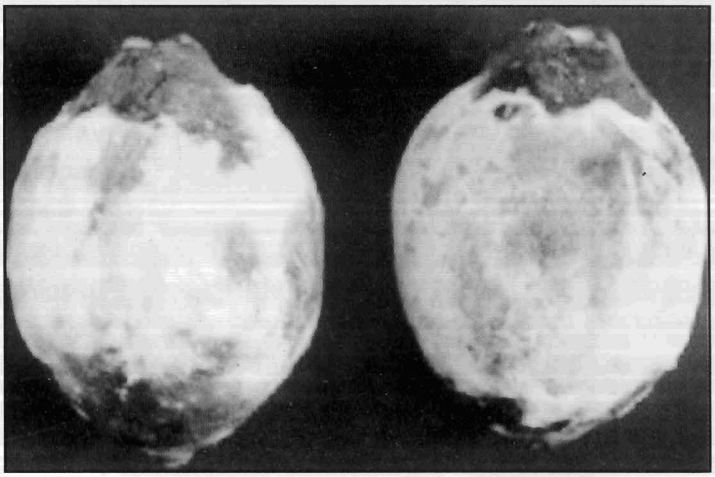

Fig.1. *Phytophthora meadii* mycelium on fruit rot affected areca nut

Fig.2. Bud rot affected spindle

Fig.3. Crown rot affected palm

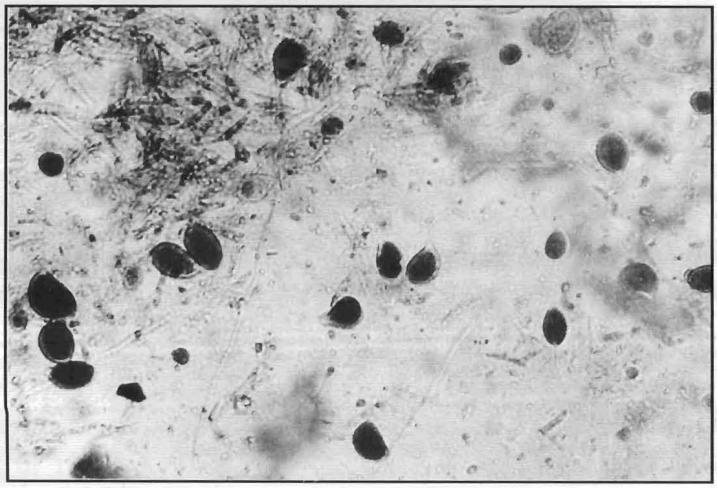

Fig.4. Sporangia of *P. meadii*

Phytophthora spp. affecting areca palm is mostly heterothallic. However formation of sex organs in single cultures and naturally infected nuts are observed both in *P. arecae* and in *P. meadii* (Coleman, 1910; Desai, 1950; Narasimhan, 1922; Ramakrishnan and Seethalakshmi,1956; Saraswathy, 1994). Sundaraman and Ramakrishnan (1928) could not observe oospores in nature and this character was attributed to the presence of '+' and '– ' strains in nature (Uppal and Desai, 1939). Desai (1950) could observe oospore production on fresh bean agar. Heterothallic nature of the above isolates was studied by several workers and recorded oospore formation in paired cultures of *P. arecae* x *P. meadii*; *P. arecae* x *P. infestans* and *P. meadii* x Compatible A_2 mating types (Ashby, 1929; Gallegly, 1964; Marudarajan, 1941; Narasimhan, 1930; Sastry and Hegde, 1987; Venkatarayan, 1932). Chowdappa *et al.*, (2000a) reported the existence of A1 and A2 mating types within *P. meadii*.

Oogonial diameter of *P. arecae* varied from < 30 or 30-40 mm and in *P. meadii* < 30 or 30-40 or 40-50 mm. Oospores nearly fill the oogonium and wall thickness varied 2-4 mm and is related to diameter. Oospore measurements recorded are 20-30 mm or 30-40 mm in *P. arecae* and <20 or 20-30 or 30-40 mm in *P. meadii* (Sastry and Hegde, 1987; Stamps *et al.*, 1990).

Antheridia are always amphygynous and are usually broader than its length. The measurements recorded ranged 14 x 15 mm; or 12 x 13 mm (Sastry and Hegde, 1987; Waterhouse, 1963).

Information on the nutritional requirements of *Phytophthora* spp. affecting arecanut is scanty. In general the different species of the fungus *Phytophthora* vary greatly in their nutritional requirement and different isolates within the species vary in their response to nutrient or environmental factors (Zentmyer *et al.*, 1976). *P. meadii*, the fruit and bud rot pathogen of arecanut put forth good growth in sucrose and fructose as sources of carbon:sodium and potassium nitrates as nitrogen and riboflavin as vitamin source (Saraswathy, 1994).

Temperature plays an important role in the growth and sporangial formation of *P.* spp. The minimum, optimum and maximum temperatures favoured the growth and sporulation of *P. arecae* is 10-12; 27-30 and 35°C and >5; 25-30 and >30°C for *P. meadii* (Ribeiro, 1978; Sastry and Hegde, 1987). Saraswathy (1994) observed good growth and sporangial formation of *P. meadii* at 24-30°C and 27-30°C respectively.

Southwest monsoon plays a key role in the occurrence, persistence and spread of fruit rot. Continuous heavy rainfall with intermittent bright sunshine hours, low temperature (20-23°C) and high relative humidity *i.e.* more than 90 per cent are factors congenial for disease development (Coleman, 1910; Kamath, 1956; Narasimhan, 1922). The disease intensity is high in gardens with high relative humidity (Kamath, 1953). Koti Reddy and Anandaraj (1980) attempted to correlate the intensity and spread of the disease in relation to the rainfall and temperature for a period of nine years (1970-1978) and reported maximum

crop loss in 1978 when the rainfall was as high as 5088.6 mm. The fungus requires bright sunlight for a short while for the formation of sporangia and liberation of zoospores (Anandaraj, 1985a). The disease occurs usually 15-20 days after the onset of monsoon (May-June) and continues till the end of rainy season (August-September). Rarely a wide gap of 40-50 days also has been recorded between first monsoon rain and initial incidence of fruit rot in the season wherein the rainy days were scattered and discontinuous (Anandaraj and Saraswathy, 1985; Marudarajan, 1950b; Saraswathy, 1994). This observations clearly indicated that the occurrence and persistence of the disease is mainly depended on the onset and pattern of rain. Spread of the disease is favoured by heavy wind and to a certain extent by small insects and rainsplashes. Under favourable conditions the zoospores released from the sporangia germinate in the films of water and penetrate the nut surface through the stomata. The incidence and spread of the disease did not show any particular pattern (Anandaraj, 1985a; Anandaraj and Saraswathy, 1985; Coleman, 1910; Kamath, 1956; Narasimhan, 1922; Saraswathy, 1994). Anandaraj *et al.* (1992) studied the weather parameters viz., maximum/ minimum and ambient temperature, amount of rainfall in 'mm' relative humidity and sunshine hours in relation to disease incidence and worked out a linear model to predict the disease four days in advance.

Though the reports revealed the existence of bud rot disease since early 1900's the epidemiology of this disease is not studied in a systematic way. The disease is seen during the monsoon especially in the later part of rainy season. Fresh infection initiating in the fag end of monsoon slowly develop from October onwards and become severe in subsequent cooler months. This may be due to lower temperature, the occasional rains, cool nights with dew formation prevailing during these months will help the pathogen to remain active during the off season.

The pathogen survives in the form of dormant mycelium in the tree top either on the infected dried bunches or bud rot affected dead palm or upper layers of soil or in the form of oospores on fruit rot affected nuts under natural condition (Coleman, 1910; Kamath, 1956; Saraswathy, 1994; Sastry and Hegde, 1985a; 1989; Uppal and Desai, 1939). The existence of alternative host plants namely sandalwood and Jatropha is reported earlier (Venkatarayan, 1944).

Anandaraj (1985a) could collect sporangia of the pathogen using bi-directional and multidirectional traps kept at a height of 7.5 mts at the crown level (Table 2).

Covering of areca bunches with 'Kotta' or 'Karada' was in practice to control the fruit rot disease in Uttara Kannada areas of Karnataka in the early years of this century (Coleman, 1910). Later, the effectiveness of Bordeaux mixture alone or in combination with resin or washing soda, adhesives and spreaders, potash alum casein, vegetable oil etc was studied by different workers. During this period a spraying campaign undertaken in Karnataka on payment basis and am improved sprayer called 'Primus' was developed for the purpose

Table 2. Number of sporangia caught in the splash traps during south west monsoon

Sl No.	Height of observation (m)	Quantity of water collected	Sporangia present per mm^3
1	3.0	-	-
2	4.5	-	-
3	6.0	52	20
4	7.5	50	140

Sl. No. 1-3 bi-directional splash traps
4 multidirectional splash traps
(Source: Anandaraj, 1985a)

(Anonymous 1938a). These studies revealed that prophylactic spray of 1 per cent Bordeaux mixture alone is equally effective as Bordeaux mixture with any sticker or spreader (Anandaraj, 1985b; Coleman, 1910; Marudarajan, 1951; Marudarajan and Subramanyan, 1948; Narasimhan, 1923; 1924; 1928a; 1928b; Thomas and Marudarajan, 1938; 1952; Rao, 1960) and Bordeaux mixture spray do not cause any adverse effect on areca palms (Krishnamurthy, 1955). In the studies carried out with copper oxy chlorides and proprietary fungicides like fycol-8, fycol-8E and Oleocop revealed that copper oxy chlorides were toxic even at 0.5 per cent concentration and proprietary fungicides were not effective in controlling the disease. Venkatrayan (1943) recommended spraying with two application of Bordeaux mixture with spreader such as rosin paste or potash soap, one before the onset of southwest monsoon the seconds after six weeks or two months. Tenacity of Bordeaux mixture was studied and it was observed that the spray deposit was retained on the nut surface up to 40-45 days and accordingly the spray schedule was recommended (Table 3; Anonymous, 1969; Anandaraj, 1985b; Rao, 1962a). Control studies against fruit rot was continued with new contact and systemic fungicides. Though the contact fungicides Blitox, Captafol, Dithane M_{45} and Ovis–20 (a natural citronellel) were effective against the pathogen in the laboratory studies (Saraswathy, 1999), these fungicides were not recommended for field application due to poor retention capacity especially during the monsoon season. Among the systemic fungicides tested aliette and metalaxyl at 0.5 per cent or aliette at 0.15 per cent as spray gave good control of fruit rot (Anandaraj and Saraswathy, 1986; Sastry and Hegde, 1985a). In a mutlilocational trial on management of fruit rot using different fungicides revealed that Boredaux mixture 1 per cent spray still holds good in controlling fruit rot as it is seen from the result where the disease incidence was 3.8 per cent and 8.6 per cent in Bordeaux mixture and 0.3 per cent akomin sprayed palms respectively (Chowdappa *et al.*, 2000b). In the field control trial different methods of application of fungicides was studied and it was found that stem injection of akomin at 3.3 ml and 5.6 ml per palm and stem injection and root feeding with 4.2 ml of tridemorph/ palm was promising as evidenced by the less number of nuts affected by fruit rot. For stem injection a simpler but efficient stem injection unit was made by replacing the PVC container of existing unit with the glucose bottle (Fig. 5)

The advantage of this unit is that the flow of fungicides could be seen as well as the flow time could be calculated (Saraswathy, 2000a).

Table 3. Copper deposit on nuts sprayed with different fungicides

Fungicides	Type of spray	Infection (%)	Copper deposit in μg/ml of washed nut (mean value)	
			1 day after spraying	40 days after spraying
Fycol 8E in water	Low volume	68	7.34	5.59
Fycol 8E in oil	Low volume	21	5.28	4.8
Oleocap in oil	Low volume	29	7.48	4.11
Fycol 8 in oil	Low volume	28	7.36	4.35
Bordeaux mixture	High volume	8	15.52	7.63

Though the above fungicides were effective in combating the disease the repeated climbing and spraying during rainy season poses difficulties in carrying out the spray operations. To overcome these difficulties field trials were conducted on mechanical method i.e., covering the bunches (Fig. 6) prior to regular monsoon rains. The data collected revealed that cent percent control of fruit rot could be achieved by this method (Chowdappa *et al.*, 2002; Saraswathy, 1994; Sastry and Hegde, 1985a). The cost of covering varied from 5.29 to 8.6 per palm whereas the cost of Bordeaux mixture spray varied 6.34 to 7.42 per palm. This operation is costlier compared to Bordeaux mixture spray but the overall benefits accrued from preventing the loss due to the disease, this method is feasible in the long run. Besides, by covering the bunches environmental pollution and health hazards which can occur by spraying various fungicides can be avoided.

The recent trend is to minimise the use of fungicides for disease management. On this line studies were carried out with various bioagents including fungi and bacteria and also plant extract. The laboratory study indicated that *Trichoderma viride T. harzianum* p. *Myrothecium verrucaria; Aspergillus terreus, Pseudomonas fluorescence* etc. are potential bioagents against *P. meadii* (Saraswathy, 2000b). Among the various plant extract tested 10 per cent aqueous extract of leaves of henna (*Lawsonia inermis*) and sacred basil (*Ocimum sanctum*) were very effective in checking the growth of *P. meadii* (Saraswathy, 2002). The above studies clearly indicated that the bioagent/ source plant of extracts can be used for soil suppression of *Phytophthora* population to below the level of infection especially in areca plantations where black pepper and cocoa are grown as mixed crops.

Bud rot/ crown rot can be controlled if the affected palms are treated in the initial stages of infection. The earlier recommendation against these diseases included drenching the crowns with mercuric compounds like wet cerason 0.2 per cent or leytosol or Bordeaux mixture 1 per cent (Anonymous, 1960a; 1963a; 1969; Lingaraj, 1969; Naidu, 1960; Nambiar, 1956). Smearing with 10 per cent Bordeaux paste after removal of affected tissues and drenching the crowns of the surrounding palms with Bordeaux mixture 1 per cent quite

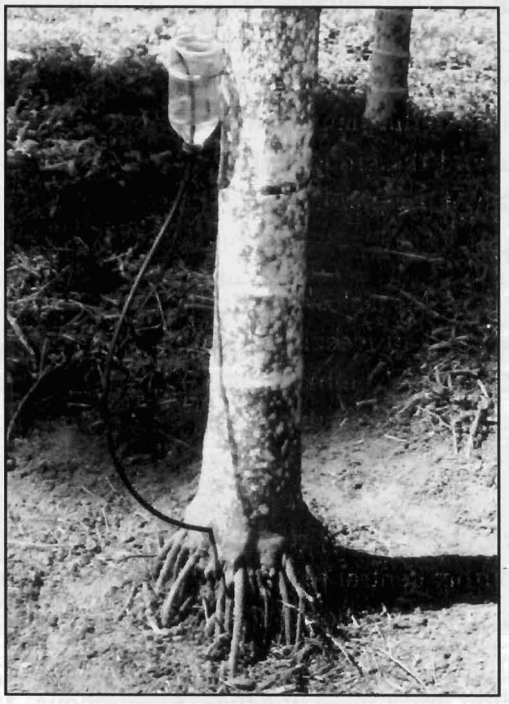

Fig.5. Stem injection

Fig.6. Polythene covering

effective in saving bud rot affected palms as well as in reducing the incidence. The crown areas of the palms have to be well protected *i.e.*, through mist spraying to check the occurrence of the both bud and crown rots. Phytosanitation is also equally important to minimize the inoculums load in the plantation. Removal and destruction of fruit rot affected dried bunches, shed nuts and the crowns of the palms affected by bud/ crown rots may help to maintain the health of the plantations.

YELLOW LEAF DISEASE

Yellow leaf disease (YLD) is a slow decline disease affecting the productivity of the palm. The disease is known as 'kattuveezhcha' in Malayalam and 'chandiroga/ arasina roga' in Kannada (Dastagir, 1963; 1965; Nambiar, 1949). The earliest mention of YLD is found in the publication on diseases of coconut palm (Varghese, 1934). The disease was first observed succeeding a heavy flood in 1914 from Muvattupuzha (Ernakualm district), Meeanchil (Kottayam district) and Chalakudy (Trissur district) areas of Kerala State (Nambiar and Srinivasan 1951). Dastagir (1963; 1965) reported it from Malnad areas of Karnataka. The disease was also reported from central regions of Maharashtra and parts of Karnataka and Tamil Nadu (Anonymous, 1963b; Menon, 1963a).

The preliminary surveys conducted in Kerala during 1959-60 indicated that 90 per cent of the palms in Quilon areas were affected (Anonymous, 1960b). A comprehensive survey conducted during 1976 in Kerala showed that 233 million palms are diseased. About 36 per cent of the palms are affected in the state with maximum incidence in Idukki (97 per cent) followed by Kottayam 94.3 per cent and 28.4 per cent percent area in Koppa and Sringeri taluks of Karnataka is affected. (Anonymous, 1977; Rawther *et al.*, 1982). Further, the garden to garden survey conducted in Karnataka during 1989 and 1990 revealed that the disease is present in all the six areca growing districts of Karnataka (Rawther, 2000). The yield loss is as high as 50 per cent within a short span of three years after the contraction of the disease and an average of 4 per cent reduction in leaf fall during the three year period is recorded (Anonymous, 1976).

The disease affects palms of all age groups. Thorough and systematic observation was made to understand the pattern of spread of the disease at the erstwhile Research Centre of CPCRI, Palode, a predominantly disease affected area. The seedlings planted in 1961 in virgin forest cleared soils manifested the symptom after seventh year in 1968 and thereafter within a period of four years 80 per cent of the palms contracted the disease (Rawther and Abraham, 1972). Though the spread was rapid it did not show any definite pattern

Symptoms of YLD are well pronounced immediately after the cessation of South West monsoon rains. Characteristic yellowing starts at the tip of the leaflets of two or three fronds of the outer most whorls (Rawther, 1976). This yellowing gradually extends to the middle of the lamina showing a clear-cut demarcation of yellow and green parallel bands on both sides of the midrib of leaflets and this is the first visible symptom of YLD (Fig. 7). These symptoms are expressed maximum in August, and minimum in May (Nayar, 1976).

In palms with the early stages of infection, the yellowing symptoms begin to disappear well before the start of dry period. YLD yellowing is distinct from all other yellowing due to pathological, entomological and nutritional reasons (Saraswathy and Ravi Bhat, 2001). The symptoms are very clear in seedlings and young palms. As the disease progresses, the yellowing extends to the whole lamina, leaving only the leaf stalk green. Earlier workers described the symptoms as yellowing of leaves and shedding of both immature and mature fruits (Nambiar, 1949). Menon (1963a) reported translucent spots on the spindle as the first visible sign of the disease and as the spindle unfolds yellowing starts from tips of leaflet and this chlorosis could be distinguished from the physiological yellowing by the abrupt demarcation between the green and yellow regions of the diseased leaf.

As the disease advances, the whole crown size gets reduced. The leaves become stiff and pointed, closely bunched and abnormally puckered. The leaf tips become necrotic and dry up during summer. Other symptoms are reduction in internodal length, tapering of stem and non-production of inflorescence. Ultimately the palms may die or crown falls off leaving a bare trunk (Nayar and Seliskar, 1978).

The root system also exhibits varying degrees of rotting. The lateral roots are not produced as profusely as in healthy palms and tips of absorbing regions of young roots turn black and gradually rot. However, no correlation could be made between root rot and foliar yellowing during different seasons (Rawther, 1976). This root decay is aggravated in waterlogged plantations (Fig. 8) and the disease incidence is more in gardens with higher water table (Chandramohanan and Nair, 1985). The developing fruits of diseased palms exhibit kernel (endosperm) discolouration and it becomes blackish and soft which render them unsuitable for processing and consumption. All the fruits produced in a bunch of diseased palm may not show kernel discoloration (Rawther, 1976). Palms without foliar symptoms in the diseased gardens also produce nuts with discoloured kernels. The disease results in quantitative and qualitative loss to the crop. To quantify the disease intensity by visual observation alone is very difficult and to solve this, George *et al.* (1980) studied the symptoms in more than 2000 palms and developed a formula to assess the disease intensity more accurately. The formula is:

$$I \text{ (intensity)} = \frac{Y + N + R}{L} \times 10$$

Where

Y= total scoring for yellowing of the leaves (0-7)

N= scoring for the necrosis of the leaves (0-2)

R = Scoring for reduction in size of the crown (0-1)

L = Half the number of leaves in the crown

The affected palms show anatomical changes like plugging of vascular elements, degeneration and disorganization of various cells of the leaves, inflorescence, nut, stem and root. Nayar (1968) observed multinucleate cells derranged tissue differentiation, blocking

and pigmentation of the palisade tissues of the leaves. The degeneration, underdevelopment of the endosperm sac and blackening and softening of endosperm were observed on fruits of different stages of development (Nair, 1969; Pillai, 2000). Anatomical changes include lateral and linear proliferation of phloem tubes of roots, the presence of spherical or sub spherical in growth within the xylem vessels and blocking of xylem vessels (Fig. 9) of older leaves and roots and an overall changes in the palm characters as well as profound changes in pollen sterility (Nair, 1976; Nair and Aravindakhan, 1970a; 1970b; 1971a; 1971b; 1972). Unusual deposition of callus was recorded in sieve pores of roots and rachillae of diseased palms. Besides, the protophloem tissues were found crushed and necrotic and occuluded with electron dense contents. These changes might adversely affect the functional property of phloem in the transport of synthesized food material from the source to the "sink region"(Pillai, 2000).

Leaves of diseased palms showed impaired stomatal regulation (Chowdappa *et al.*, 1993) irrespective of the age. These palms showed higher stomatal resistance (rs) and lower transpiration (E) than in apparently healthy palms in the wet season. (Chowdappa *et al.*, 1995). They observed higher water and turgor potentials and low osmotic potential in leaves of diseased palms. The epicuticular wax (ECW) content of the leaves was significantly higher resulting in low transpiration and accumulation of high water content. The affected palms also exhibited reduced photosynthetic activity, decrease in fluorescence indices and reduction in carotenoid and chlorophyll pigments (Chowdappa and Balasimha, 1992; 1994; Chowdappa *et al.*, 1993). The reduction in chlorophyll content in diseased palms is apparently related to the expression of diagnostic symptoms of the disease (Srinivasan, 1982, 1985). The leaf tissues of diseased palms showed low Mg and this is attributed to high CaO/MgO ratio (Anonymous, 1967). Diseased palms exhibited accumulation of carbohydrate in the leaf tissues (Yadava *et al.*, 1972a). Phloem necrosis was observed in diseased palms (Nair, 1976) and this damage might have disrupted the translocation of sugar resulting in accumulation of sugars and starch in diseased palms (Chowdappa *et. al.*, 1993). A significant reduction in sterol content was observed in the leaves of diseased palms and this decrease is attributed to the utilization of this by phytoplasmas for growth and multiplication (Chowdappa *et al.*, 2000c). Affected palms also undergo a number of changes in amino acid metabolism due to disease (Nair and Aravindakshan, 1971a). A significant increase in cystine and methionine, sharp reduction in threonine and less phenyl alanine and alanine, progressive increase in lysine and argenine contents of leaves with the advancement of the disease, absence of amino acids like serine and glutamic acid in the leaf tissues, presence of these in larger quantities in the tissues of inflorescence and total disappearance of proline, cystine and histidine from the roots on infection, serine, arginine and threonine declined in the stem tissue. No significant differences in protein content and electrophorectic protein banding pattern, leaf DNA, RNA and DNA:RNA ratio and isozyme pattern were found between healthy and diseased palms (Chowdappa *et al.*, 2000c). Srinivasan (1984) reported changes in poly phenol oxidase, peroxidase, catalase, ascorbic acid and ascorbic acid oxidase activity and these changes were comparable with severity of disease.

Fig.7. Areca seedling with foliar symptoms of yellow leaf disease

Fig.8. Root rotting due to water logging

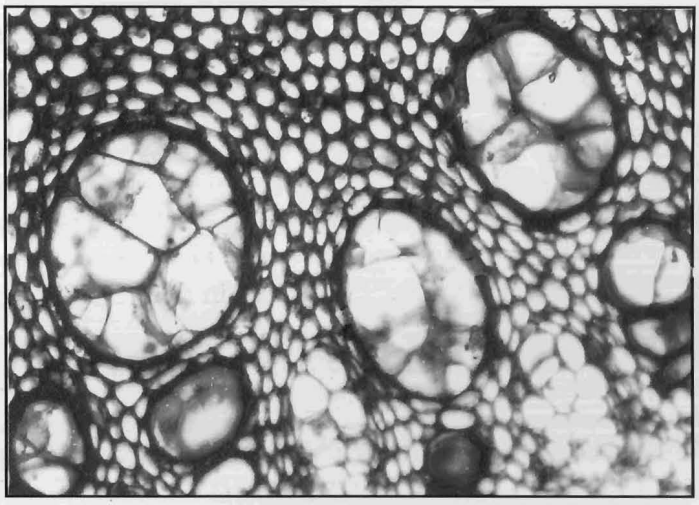

Fig.9. Blocking of xylem

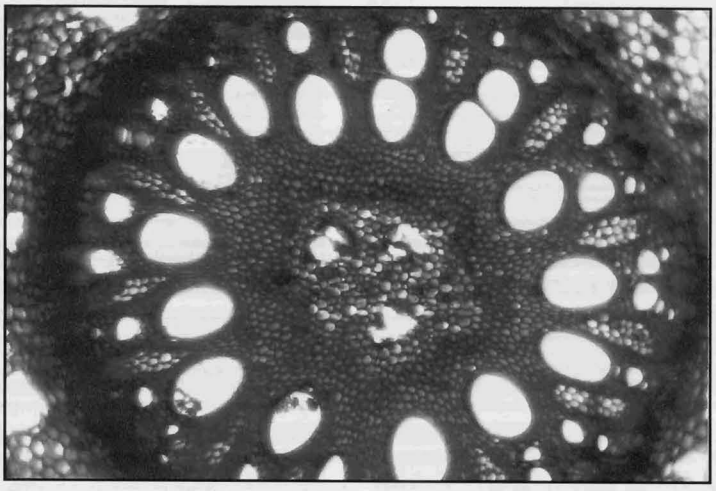

Fig.10. T. S of Areca root- phloem tissues stained with Dienes stain

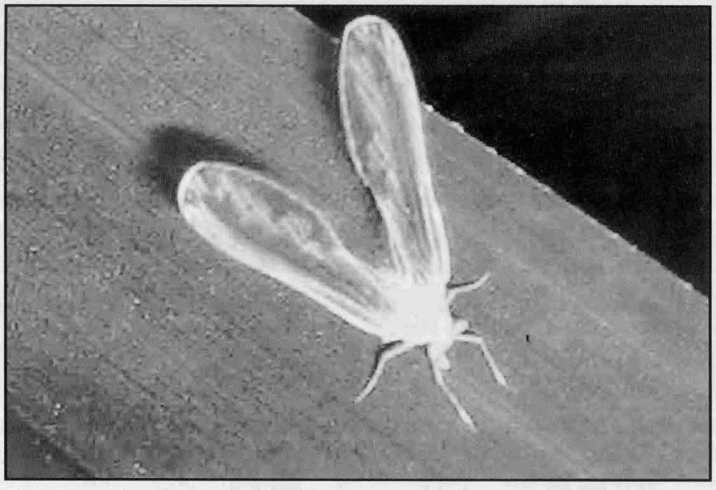

Fig.11. *Proutista moesta*

Among the different factors associated with YLD, soil health and nutritional factors influence the disease incidence either directly or indirectly. Lack of balanced nutrition and improper cultivation practices makes the palm susceptible (Menon, 1961a) and application of fertilizers showed improvement in condition of the palm (Anonymous, 1967). Water logging also influences the intensity of the disease. Studies conducted during 1959-62 in YLD belt of Kerala indicated that soils are highly acidic with pH of 3.8 and deficient in all three major nutrients (Anonymous, 1960b). Soils of diseased gardens showed low pH, organic carbon, available phosphorous and magnesium (Velappan, 1969). It is also reported that soils of diseased gardens were deficient in manganese (Anonymous, 1960b) phosphorous (Anonymous, 1976) and hire in iron and aluminum (Anonymous, 1970; 1973). Yadava *et al.* (1971) observed deficiency of N, P and Mg in diseased palm and normal quantities of pottassium and calcium were present in palms at the beginning of expression of foliar symptoms. Guruswamy and Krishnamurthy (1994) reported soils of diseased gardens were acidic with low levels of soluble salts and low in boron, low to medium in available P, K and S whereas organic carbon, calcium and magnesium were seen in adquate quantities. The experiments conducted to study the role of major nutrient deficiencies in symptom expression did not produce any typical symptoms of YLD (Yadava *et al.*, 1972b). Tissues of diseased palms showed low levels of nutrients and these deficiencies are attributed to impaired protein synthesis and amino acid metabolism (Yadava *et al.*, 1973) and low levels of nitrogen, phosphorous, magnesium and zinc were noticed in the leaf tissues of diseased palms. Analysis of the leaves and roots of diseased palms revealed high levels of aluminium. Soils of the diseased tracts of Kerala and Karnataka also showed higher contents of exchangeable aluminium and iron, but these elements when root fed did not produce any symptoms of YLD (Mathai, 1976; Mohapatra and Bhat, 1975; Mohapatra *et al.*, 1975; 1976).

The etiology of YLD was a matter of dispute as in the case of other diseases of unknown etiology. The microbiological and biochemical study did not give any indication on etiology, management, mechanism of the metabolic alterations leading to the manifestations of symptoms (Jayashankar, 1976). A number of fungal and bacterial species were isolated from the soil as well as different parts of the diseased palm. *Cercospora arecae*, *Exosporium arecae*, *Leptosphaeria* sp, *Diplodia* sp, *Phyllosticta* sp, *Dimerosporina* sp and *Trametes corrugata* were isolated from the leaves of diseased palms (Anonymous, 1963c; Menon, 1959a). Out of these, *C. arecae* and *Phyllosticta* sp. are known to cause leaf spot disease in seedlings and young palms. Roots of diseased palms yielded fungal species, including *Acremonium* sp, *Aspergillus* spp, *Botryodiplodia theobromae*, *Chaetomium* spp, *Colletotrichum* sp. *Cylindrocladium* sp, *Fusarium* spp, *Gliomastix* sp. *Goagronella sp*, *Pestalotia* sp. *Penicillium* spp, *Phytophthora* sp, *Pythium* spp, *Rhizoctonia* sp, *Rhizopus* sp. and *Trichoderma* spp. (Radhakrishnan Nair, 1994) *Gloeosporium* sp and *Glomerella cingulata* were isolated from the fruit tissue (Anonymous, 1960b). Inoculation studies with pathognic species of these organisms did not yield any positive results (Anonymous, 1977). Extensive rotting of roots of diseased palm was observed but there was no qualitative difference between healthy

and diseased palm or any seasonal variation (Rawther, 1976). Alice *et al.* (1985) reported seasonal variation in microflora of soils. High bacterial population was observed in the rhizosphere of the diseased palms was noticed and this character is attributed to the presence of root secretions (Bopaiah, 1979). Similarly the studies with bacteria *viz., Pseudomonas* (Srivastava *et al.,* 1970) *Bacillus, Xanthomonas* and *Serratia* (Anonymous, 1963a; Bopaiah, 1979) also yielded negative results only. Though difference was noticed quantitively no qualitative difference was noticed between healthy and diseased palms (Bopaiah, 1985; Bopaiah and Koti Reddy, 1982)) and the role of bacteria in the development of YLD is ruled out in further studies (Bopaiah, 1983).

Menon (1960; 1961a) observed some forms of proteins and subunits in the sap of affected palms. Serological studies indicated antibody formation, indicating the possibility of involvement of virus or virus like organisms in the development of YLD. The disease could be transmitted to indicator plants like *Jatropha curcas*; *Canavalia ensiformis* and *Vinca rosea (Cantharanthus roseus)* using partially purified sap by carborundum technique. Under specific conditions the transmission of the pathogen from areca palm to coconut was possible indicating that the organism involved in coconut root (wilt) and YLD are identical or related (Menon, 1963a). Nayar (1971) cultured mycoplasma like organisms from the leaf tissues of affected palm. Numerous umboid colonies were produced in solid plates and these colonies showed similarities to those of other Phytoplasma colonies. However, the cultures have neither been deposited with the American Type Culture Collection Centre (ATCCC) nor with any other repository for confirmation. Inoculation studies with this organism on arecanut seedlings grown under glasshouse conditions produced some yellowing but these data were too meager to confirm the association of Phytoplasma with YLD. Studies were continued to identify the etiological agent of the disease. Electron microscopic studies revealed the presence of Phytoplasma in the young sieve elements of tissues of the affected palms collected from Kerala and Karnataka and these structures were totally absent in healthy palms (Anonymous, 1985; Nayar and Seliskar, 1978; Seliskar and Wilson, 1981). These organisms are pleomorphic, often assumed sites close to the wall of sieve tubes and also found traversing the sieve pores. Root tips and rachillae of juvenile inflorescence were the ideal plant part for locating Phytoplasma (Ponnamma and Solomon, 2000). The diseased palms continue to have the organisms irrespective of the symptoms and the expression of the foliar symptoms may be influenced to a greater extent by certain environmental factors (Solomon, 1991). The foliar symptom is maximum soon after the rains but gets reduced with rise in temperature indicating the heat sensitivity of the pathogen associated (Nayar, 1976). Phytoplasmal association was further confirmed by Dienes' staining technique (Fig. 10; Deelay *et al.,* 1979). The transmission studies using the plant hopper *Proutista moesta* (Fig. 11) and dodder laurel (*Cassytha filiformis*) indicated involvement of Phytoplasma (Ponnamma, 1994). The transmission by insect was

evident from an experiment in which areca seedlings were protected from the aerial vectors and also grown in insect proof cages. The seedlings kept in insect proof cages did not contract the disease as against seedlings grown in open field. Electron Microscopic examination of the ultra thin sections of salivary glands of *P. moesta* which were offered acquisition and incubation period of over 30 days on the foliage of YLD affected palms revealed the presence of Phytoplasma (Ponnamma and Solomon, 1998). The organisms were confined to the acini of the salivary glands. However, such bodies were neither observed in the salivary glands of laboratory-reared insects nor in insects with acquisition and incubation period of less than 30 days. This observation indicated the capability of this insect to acquire the organism, sustain its multiplication and act as vector in transmitting the disease (Ponnamma *et al.*, 1991). The inoculated seedlings developed characterstic foliar symptoms of YLD with an incubation period of 21-32 months. Root sections of these seedlings showed positive reaction to Diene's staining and ultra thin sections of root apices showed the presence of Phytoplasma in the sieve tube. These observations are the direct evidence to establish the role of *P. moesta* as a vector of YLD (Ponnamma, 1994; Ponnamma *et al.*, 1997). The affected palms exhibited remission of symptoms when treated with antibiotics like oxytetracycline, hostacycline, ledermycin and neomycin where as palms given penicillin, gentamycin and distilled water did not show any remission of symptoms. This reaction also proved the assosciation of phytoplasma with YLD. Since the visual observation is not reliable a rapid serodiognostic method was standardized but this method give only a faint reaction. So an immuno-osmophoresis was attempted on microscopic slide using extracts of YLD affected palms and this produced a single precipitation line midway between antigen and antisera belt. Tissue extracts from healthy palms did not show any such precipitation line (Solomon, 1991).

The diseases caused by Phytoplasma are not curable by the application of conventional plant protection chemicals. It is useful to adopt proper management practices to get additional income from affected gardens (Koti Reddy *et al.*, 1978). Foliar application of salts of magnesium and manganese reduced the foliar yellowing (Menon and Kalyanikutty, 1961). Soil application of NPK and lime with or without zinc sulphate significantly reduced foliar yellowing (Dastagir, 1963). Samraj and Paily (1965) could induce yellowing by soil application of boron but further studies proved that yellowing due to boron application is different from yellowing due to YLD. A comprehensive trial using macro and micronutrients was laid out at Koothattukulam, Annamanada and Punalur (Pathanamthitta district) in Kerala and Jayapura (Chikmagalur district) in Karnataka in the sixties (1965-69). But these trials did not yield any tangible improvement in the foliar yellowing and discolouration of the kernel (Nagaraj *et al.*, 1976). Palms treated with different fungicides (Chandramohanan, 1979) and auriofungin sol (Rawther, 1976) did not produce any positive results. A similar trial done at Palode, in Southern Kerala along with irrigation was not effective in controlling the disease (Rawther and Abraham, 1972). Trials with regular recycling of cowpea and Guinea grass as organic matter in a 15 year old diseased garden indicated a general

improvement in yield but did not show any ameliorative effect on the foliar symptoms (Rawther *et al.*, 1979). Since deficiency of phosphorous was observed in diseased gardens, application of additional dose of one kg of super phosphate was applied to the affected palms and palms given additional dose of 'P' delayed the symptom expression on areca seedlings (Anonymous, 1983). In an integrated management trial conducted at Sagar with the following treatments i.e., insecticide, fungicide, drainage and nutrients, root drenching of emissan (5 li/ palm), pauchamycin (5 li/ palm) NPK (140:500:150) + zinc (8.5 g/ palm), NPK + zinc + lime (85 g/ palm) and neem cake (5.0 kg/ palm) improvement of disease condition was observed (Ramanandan and Abraham, 2000). In another field trail carried out in farmers field at Sampaje (Dakshina Kannada) increased the yield by 20 per cent and reduced the disease intensity (Anonymous, 1983). Soil application of higher dose of phosphorous over the normal package increased the yield in the released variety and soil application of Mg was found effective in containing the disease (Anonymous, 1982). The results of the nutrient management trials thus indicated that though the disease cannot be cured, the general health of the affected palm and the economic yield could be improved in a diseased garden.

As the disease is not amenable to chemical control measure studies were focused on locating the resistant/tolerant lines. The multilocation trial carried out in 1970's indicated that all the four released varieties *viz.*, Mangala, Sumangala, Sreemangala and Mohitnagar are susceptible. The screening trials with Saigon x Mangala exhibited high level of tolerance. Further studies with different cross combinations revealed that none of the combinations was resistant (Ravindran *et al.*, 2000).

Since none of the available germplasm collections, hybrids and diallel crosses are resistant/ tolerant to YLD, efforts are made to identify elite disease free palms or disease escapes in the endemic areas for breeding/ multiplication of progenies from selfed elite palms for field planting.

BASAL STEM ROT (FOOT ROT)

The basal stem rot is a slow decline disease with a history of more than 100 years. Buchanan recorded the disease from Karnataka (Rawther *et al.*, 1982). The disease was mentioned as 'betel nut plague' from Silhat (Butler, 1906). It is also known as anabe roga in Kannada language which means a disease caused by a mushroom. The occurrence of the disease is reported from Kerala, Assam, West Bengal (Sharples, 1928), Nicobar Islands (Sangal *et al.*, 1961), the present Karnataka (Coleman, 1911) and from Mettupalayam areas of Tamil Nadu (Aonymous, 1960b). The disease is severe in neglected, illdrained and overcrowded gardens (Venkatarayan, 1936). Lalithakumari (1969) observed the disease incidence more in hard, black loamy acid soils of higher iron and calcium contents. Palms in the age group of 5 – 10 years are more susceptible to the disease (Coleman and Rao, 1918). The disease is soil borne, but secondary spread through air borne spores is also reported (Venkatarayan, 1936).

Crop loss due to the disease is not documented systematically. Mortality of palms is reported as 94 per cent in neglected gardens (Butler, 1906). Later researchers reported the death rate as five per cent (Venkatarayan, 1936) or as eight per cent in neglected and waterlogged gardens (Naidu *et al.*, 1966). Salvi *et al.* (1985a) conducted a survey in diseased gardens in Diveagar areas of Maharashtra and reported a loss ranging from 0 to 11.72 with an average mortality of 2.21 per cent. A disease incidence ranging from 0.05 to 5.1 per cent is reported from Mettupalayam area of Tamil Nadu (Anonymous, 1971). In endemic areas the disease incidence is as high as 20-25 per cent (Sampath Kumar and Nambiar, 1990).

The palms cannot be identified in the initial stage of the disease. The visual symptom of the disease is yellowing of the outer whorl of the leaves, which gradually spreads to the inner whorl of leaves. As the disease progresses, the entire crown becomes yellow, leaving only the spear leaf green. In the advanced stages spindle also gets dried up and finally the crown topples down leaving the bare stem.

The palms in the advanced stage of infection express symptoms on the crown, stem and root system. On the crown the predominant symptom is wilting of leaves, which resembles to severe drought. The development of inflorescence also is arrested. Tapering of stem and reduction in internodal length are the other symptoms exhibited on the crown. Simultaneously, symptoms are seen on the basal portion of the stem as small dull brown spots. These spots later coalesce to form bigger discoloured patches. In the acute stage of the disease a brown gummy liquid oozes out through this patches. These patches may extend half to one meter height on the trunk from the ground level. The bracket shaped fruiting bodies (basidiocarp) of the fungus are formed at the base of the trunk usually after the death of the palm or on the stump or rarely on the live palm (Fig. 12). The internal tissues of the stem, mainly xylem and xylem parenchyma are damaged completely. Tyloses like outgrowths are seen inside xylem vessels (Anonymous, 1973).

Root system also exhibits varying degrees of discoloration and rotting. The roots of affected palms are brittle, dry and have a musty smell (Naidu *et al.*, 1966). The uptake of nutrients and water are interrupted due to rotting of tissues of root and stem, leading to the situation of pathological drought (Venkatarayan, 1936) which is similar to pronounced drought condition. Such palms may not respond even to the best management measures. The infection is mainly through the roots and secondary spread is by spores borne on the fruiting bodies, irrigation water, repeated ploughing and other cultural operations in the garden.

The pathogen causing basal stem rot (foot rot) is a bracket forming polyporus fungus *Ganoderma*. The fungus is cosmopoliton and cause white rot of woody plants by decomposing lignin, cellulose and other polysaccharides. The earlier workers reported *Fomes lucidus* as the disease causing fungus (Butler, 1906; Coleman, 1911; Rao, 1917). Later, *Ganoderma lucidum* (Leys) Karst was reported as the causal organism of the disease (Venkatarayan, 1936). Sampath Kumar and Nambiar (1993) reported the association of

G. applanatum with the disease. Though *G. lucidum* is reported as the primary pathogen, its pathogenisity could not be established in the earlier studies (Venkatarayan, 1936). The efforts to reproduce the symptoms on living palms was continued by later researchers and Sampath Kumar and Nambiar (1990; 1996a) succeeded in inducing the symptoms on the live palms. The inoculated palms took fairly longer incubation period *i.e.*, 8 to 9 months to express the symptoms of disease.

The fungus is heterothallic and tetra polar. The hyphae are hyaline, 1-2 μ in diameter and have a deposit of calcium oxalate crystals. The older hyphae produce clamp connections. Under laboratory conditions the hyaline hyphae becomes dotted with colourless fluid containing round, white thin walled conidia measuring 14 x 20 μ, 40 days after growth in the medium. Patches of the mycelium turn pale yellow with a russet tint, typical of mature sporophores of *Ganoderma* found in nature. The basidiocarp turn to reddish brown, smooth, shiny and centraly or laterally stalked. The size of the fruiting body varies 4-12 x 10-12 x 1.4 cm. It is hard and the hymenial surface becomes light brown on drying. It produces three types of spores in addition to basdiospores (Banerjee and Sarkar, 1958; 1959). Chlamydospores are terminal inter- callary granular and golden yellow in colour (Menon,1963b). Basidiospores are light brown; yellowish brown or brown and thick walled and measures 8.3-10 x 5.4 –6.7 μ (Sampath Kumar and Nambiar, 1993). The fungus grows well in Waksman's medium but luxurient growth was noticed in malt extract agar. The optimum pH for growth was 5.5-6.5 but it can grow well in a wide range of 3-7 pH (Nambiar and Radhakrishnan Nair, 1974) or fungus could grow in acidic or in alkaline soils (Venkatarayan, 1936).

Sporophores are formed on wood pieces of *Mangifera indica* (Bose, 1930). In *in vitro* conditions sporophores were formed on sawdust medium enriched with 10 per cent malt extract and 15 ml of 5 ppm biotine.

The moisture requirement of the fungus in the soil vary from 40-80 per cent but 100 per cent moisture did not cause any mortality of the fungus (Koti Reddy and Saraswathy, 1976). Studies on the physiology of the fungus revealed that the fungus could utilize a wide range of carbohydrates. Among the different sources, maltose was the best carbon. Carbohydrates were better utilized than organic acids or carbonates. Peptone and glycine served as the best sources of nitrogen and amino acid respectively (Nambiar and Radhakrishnan Nair, 1974). The fungus produces many hydrolytic enzymes in cultures (Venkatarayan, 1936). Lalitha Kumari (1969) isolated enzymes like endopolygalactrunase and laccase. Later, Koti Reddy *et al.* (1981) studied the phenol and its oxidase in root tissues of healthy and diseased palms and reported that root tissues of the healthy palm contained higher amount of total phenols and phenoloxidase than the diseased tissues.

The fungus has a wide host range (Naidu *et al.*, 1966). The most commonly affcted plants other than arecanut palm are *Cocos nucifera* (Butler, 1906); oil palm (Sharples, 1928),

Delonix regia, *Pongamia glabra* Vent, *Casuarina equisitifolia* Forst. (Bose, 1930; 1931; Venkatarayan, 1936); *Eucalyptus citriodora* Hook (Bagachee, 1953; Bakshi, 1974) mango (*Mangifera indica* L.) *Cassia siamia* Linn.; tamarind (Anonymous, 1971); *Artocarpus heterophyllus*; *Citrus* spp. and grape vine. Since the primary source of inoculam is from soil, repeated ploughing and digging in the diseased garden may enhance the spread of incoulum from the diseased to healthy areas. Fungus cannot survive and grow in soil independently and the spread of the fungus is through root contact (Sulladmath, 1995). Hence the practice of repeated ploughing and digging to be avoided in diseased tracts. Dense planting is not advisable. Fruiting bodies of the fungus and stumps of diseased palms are to be removed along with root system and distroyed by burning (Venkatarayan, 1935; Venkatakrishnaiah, 1956). Fresh planting in these pits are to be done after burning the pits and after a gap of about six months. In areas where the disease is sporadic, affected palms are to be isolated by digging isolation trenches of 30 cm wide and 60 cm deep, which will reduce the disease incidence from 17.6 to 2.4 per cent (Sampath Kumar and Nambiar, 1990). Planting of *Delonix regia* Rafin, *Pongamia glabra* Vent. *Cassia siamea*. Linn.etc. near areca plantations is discouraged since they act as alternate hosts for the fungus.

A number of microorganisms viz., *Trichoderma* spp., *Bacillus coagulans* Hammer, *Bacillus* spp. *Streptomyces* sp. and *Mucor* spp. posessing antagonistic effect against the fungus have been recorded (Anonymous, 1963b; 1967; Menon, 1963b; Sulladmath and Yaraguntaiah, 1979). In a recent study on the management of the disease Rohini Iyer *et al.* (2004) suggested the possibility of using plant extracts and antagonistic organisms as compatible component in an IDM package.

Many fungicides like sulphur (Anonymous, 1941; Narasimhan, 1940; Venkatarayan, 1949), mercurised copper oxychlorides (Nair and Rao, 1965), cycloheximide (Lalitha Kumari, 1969), captan, mercuric chloride, thiram, difolatan, Vitavax and aureofungin sol (Anonymous, 1973; Nambiar and Radhakrishna Nair, 1974; Sulladmath and Hiremath, 1978) were reported as effective against *G. lucidum in vitro*. The available soil moisture also plays a key role in the effectivity of fungicides applied to the soil. Koti Reddy and Saraswathy (1976) studied the activity of different fungicides in soil using soil columns provided with different moisture levels. They have reported the fungicide thiram, difolatan, benomyl, plantavax, vitavax and aureofungin–sol + copper sulphate was inhibitory to *G. lucidum* at 100 and 150 per cent available soil moisture.

The earlier recommendation to manage the diseased garden included soil drenching with 2 per cent Bordeaux mixture at monthly intervals throughout the monsoon (Singh, 1985) or captan or bavistin at 0.3 per cent (Sampath Kumar and Nambiar, 1990). Further studies carried out with different fungicides including systemics revealed that the root feeding of palms (Fig. 13) with 125 ml of 1.5 per cent calixin in the early stage of infection is very effective in checking the disease. To minimise the disease incidence the adjacent palms have to be given soil drenching with 1.5 per cent calixin at quarterly intervals

(Sampath Kumar and Nambiar, 1996b) and the diseased palms are to be isolated (Anonymous, 1941; 1956b) by taking trenches of 30 cm wide and 60 cm deep around the affected the palm to avoid root contact of healthy and diseased palms. In a field study conducted in Karnataka for a period of 4-5 years show that the infection could be reduced from 17.6 to 2.4 percent by isolating the disease palms (Sampath Kumar and Saraswathy, 1994). The affected palms take long incubation period to express the visual symptoms. So identification of diseased palm in the early stage of the disease is very difficult. To overcome this problem a fluorescent antibody technique was developed, which is much useful in the early detection of *G. lucidum* infection and timely treatment of palms (Sampath Kumar and Saraswathy, 1994). Soil drenching with captan or bavisitn @ 0.3 per cent also will help in reducing the spread of the disease. Besides, the fungicidal treatment the soil fertility and root formation can be improved by application of FYM 15-20 kg, green leaf 15-20 kg and 2-2.5 kg of neem cake in addition to the recommended dose of NPK (100:40:140) fertilizers. Dead and dying palms should be dug out and since the infected roots and stems remain as source of inoculum for fresh infection and spread, phytosanitary measures are to be adopted by removing and destroying the stumps along with roots.

INFLORESCENCE DIE-BACK AND BUTTON SHEDDING

Dieback of inflorescence and button shedding is one of the reasons for low fruit set in areca palms (Anonymous, 1971). Studies carried out in the mid seventies revealed that up to 60 per cent of palms are affected by this disease (Saraswathy *et al.*, 1977). However systematic survey reports are lacking to assess the actual crop loss caused by the disease. The disease is seen through out the year but becomes severe during summer months *i.e.*, February to May. Yellowing, browning and shedding of buttons are accelerated by water stress and high temperature prevailing during summer (Chandramohanan and Kaveriappa, 1985).

Yellowing of the rachillae of male flowers is the initial symptom. The yellowing progresses from the tip of the rachillae towards the main rachis and as this spreads downwards, the rachillae turn dark brown followed by drying, a condition known as die-back (Rao, 1965). Subsequent spread of yellowing and discolouration induces shedding of female flowers (Fig. 14). When the infection occurs directly on the stigmatic end of the female flowers, they shed without the typical symptoms of die-back. Infection on female flowers causes discolouration and shriveling of the developing embryos. The infected rachis exhibit concentric rings of conidial mass of the fungus that is pink in colour (Anonymous, 1961) and the stigmatic end of the female flowers shows the presence of fungal mycelia. The pathogen gains entry into the host tissue either through the scar of shed male flowers or through the stigmatic end of female flowers.

In the earlier studies it was assumed that shedding of female flowers and die-back of inflorescences are due to nutritional imbalance and physiological reasons. Lack of pollination and subsequent failure of fertilization were also attributed as reasons for flower shedding

Fig.12. *Ganoderma lucidum* - fruiting body on live palm

Fig.13. Root feeding

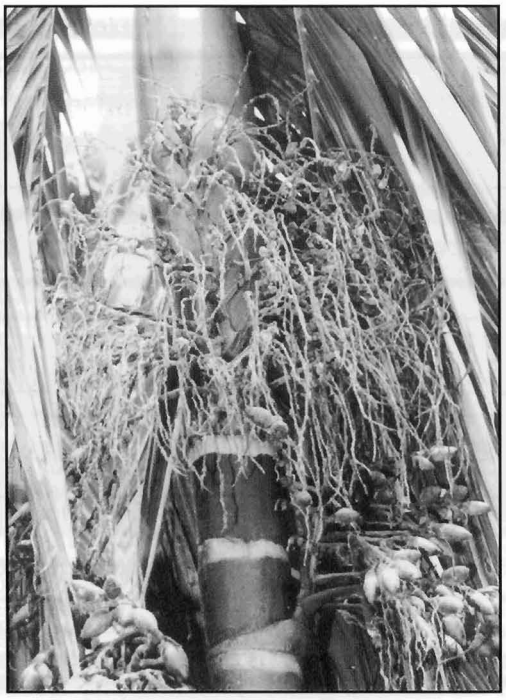

Fig.14. Inflorescence showing dieback symptoms

Fig.15. Young palm with crown choking symptoms

(Raghavan and Baruah, 1956). The presence of the fungus *Gloeosporium* in the shed nuts and inflorescence was reported (Anonymous, 1938b). Menon (1961a) considered that shedding of buttons and die-back and discoloration are due to the effect of toxin produced by the fungus. Saraswathy *et al.* (1977) observed the constant association of the fungus *Colletotrichum gloeosporioides* Penz, the conidial state of *Glomerulla cingulata* (Ston.) Spauld and Schrenk with more than 70 per cent of the shed female flowers and infected inflorescence. They could establish the primary pathogenic nature of the fungus through Koch's postulate. *C. gloeosporioides* Penz., and Sacc. is reported to cause anthracnose in arecanut and the fungus could survive in the debris of previous year's infected bunches for eight months (Yashoda and Hegde, 1986; Yashoda *et al.*, 1988a; 1988b and 1989). They studied the physiological and nutritional requirement of the fungus and reported that the optimum pH and temperature for growth ranged from 5.0 to 6.5 and 25-30°C respectively. The fungus utilized dextrose, peptone, tyrosine and magnesium sulphate as carbon, nitogen and sulphur sources (Yashoda *et al.*, 1990; 1993; 1994).

Considering the complex nature of the disease, management trials were carried out from different angles. Since a portion of the shed female flowers are unfertilized assisted pollination was tried to correct this, and an increased fruit set from 12-26.4 per cent could be achieved through this method (Shama Bhat, 1963). Yadava *et al.* (1974) studied the effect of growth regulators like GA and 2,4-D and reported increased fruit set. The beneficial effect of application of wood ash in reducing flower shedding is reported (Saidalikutty, 1951).

The above methods failed to give satisfactory control of shedding and dieback. Hence, management trials were focused on fungicidal control measures, as fungal pathogens were consistantly observed in the shed female flowers and infected inflorescence. In early sixties, copper fungicide alone and in combination with insecticide were tested. High retention of tender nuts was reported when a combination of shell copper and endrex (Anonymous, 1960a) or one per cent Bordeaux mixture alone or in combination with endrex was sprayed (Anonymous, 1963b). Later, different fungicides were tested *in vitro* against *C. gloeosporioides* and found that the fungicides benomyl 0.1 per cent, captan 0.25 per cent, thiram 0.25 per cent and phenyl mercury urea 0.1 per cent were effective in inhibiting the radial growth of the fungus (Saraswathy *et al.*, 1975). Yashoda *et al.* (1992) reported *in vitro* inhibition of the fungus by the fungicides blitox, zineb, cuman-2 and mancozeb. Under field trials spraying the inflorescence with dithane Z78 and heptane antibiotic or DMOC 0.1 per cent, heptane antibiotic + copper sulphate (each at 50 ppm) and zineb 0.4 per cent (Saraswathy *et al.*, 1975) were found effective in reducing the disease incidence. Two sprayings at an interval of 20- 25 days are recommended. Initial spraying has to be given during the female phase.

Phytosanitation is as important as fungicidal control. Removal and destruction of completely dried inflorescence will reduce the inoculum potential of the pathogen and further spread. Since *C. gloeosporioides* is pathogenic on cocoa causing pod rot and leaf

blight diseases any negligence in carrying out phytosanitation and crop protection measures can cause economic loss to both the crops.

STEM BLEEDING

The disease was first reported from isolated pockets of Mettupalayam areas of Tamil Nadu (Nambiar, 1949). It closely resembles the stem bleeding disease of coconut (Anonymous, 1953; Sundararaman *et al.*, 1928). The disease incidence is very less in older palms. Younger palms are more susceptible (Patel and Rao, 1958). Incidence of the disease is very rare on arecanut palms.

Symptom of the disease appear as small discoloured depressions on the basal portion of the trunk. As the infection progresses these spots coalesce to form larger patches followed by formation of cracks. Subsequent rotting leads to disintegration of fibrous layers of the stem. This portion hollows up to varying depths all along the infected area. Gummy exudates ooze out from these patches in the acute stage of the disease. Tapering of the stem near the crown, reduction in crown size and yield are noticed in badly affected palms. The pathogen is identified as *Thielaviopsis paradoxa* von. Hon (*Cerotostomella paradoxa*) (Sundararaman *et al.*, 1928).

The affected portion of tissue are to be scraped off and smeared with hot coal tar or Bordeaux paste (1:1:10) are the remedial measures suggested (Nambiar, 1949; Patel and Rao, 1958; Seshadri and Rawther, 1968; Sundararaman *et al.*, 1928). Since the disease is reported to be severe in gardens with high water table and poor drainage (Varadarajan, 1958) improving the drainage may minimise the disease incidence. Swabing of 5 per cent calixin after removal of infected portion and soil drenching with calixin may also reduce the occurrence of the disease as in the case of coconut stem bleeding disease (Ramakrishnan, 1990).

BACTERIAL LEAF STRIPE

The earliest reference on the bacterial disease of arecanut caused by *Xanthomonas vasculorum* (Cobb) Dowson dates back to 1947 (Orion, 1948).) The occurrence of *X. vasculorum* causing yellowing, brown linear lesions and gum exudation was reported from Mauritius (Anonymous, 1948). An endemic nature of this disease was noticed in Tumkur areas of Karnataka (Rao and Mohan, 1970) and it is not reported from any other areca growing areas of India.

The disease symptoms are seen anywhere on the lamina of the leaf as dark green water soaked lesions of different shapes. The initial characteristic symptoms are the appearance of one to four mm wide dark green, water soaked, translucent linear lesions or stripes alongside and parallel to the midrib of the leaf let and its main veins. The margin of the lesions is usually straight and well defined but at times becomes wavy due to lateral spread. Profuse bacterial exudate is seen on the corresponding lower side of the lesion and this is a striking feature of the disease. This exudate is creamy white and slimy when wet,

but becomes waxy film or creamy white to yellowish flakes or fine granules or irregular mass on drying. The severe infection may cause partial or complete blighting of the leaf and the entire crown may be affected especially in the seedlings. The affected seedlings may succumb to the infection (Rao and Mohan, 1970; Sampath Kumar, 1981). Variation in susceptibility was noticed with age of the palm and the part, which is affected (Sampath Kumar, 1985a).

Profuse bacterial streaming through the cut ends of the infected leaves indicate the parenchymatous nature of the disease. The bacterium was identified as *X. compestris* pv *arecae* based on the cultural and morphological characters and reproducibility of the disease was established by artificial inoculation on to young areca palms. This bacterium could infect coconut and other ornamental palms also (Rao and Mohan, 1976; Sampath Kumar, 1981).

The bacterium produces large quantities of extra cellular toxic polysaccharides and this ability is associated with the virulence of the pathogen. In highly susceptible areca cultivars the proliferation of the bacterium results in copious amounts of gummy exudates, chlorosis and localized water soaking. The purified toxin produced characteristic symptoms on detached fronds of the palm. The toxin is a heteropolymer of glucose, galactose, mannose and small amounts of glucuronic acid. Most of the phenolic compounds produced were common to both healthy and diseased leaf tissues but an extra phenolic compound was observed in diseased leaf tissues (Sampath Kumar, 1981).

The disease is very severe during rainy months i.e. from July to October, when the average monthly rainfall is 130 mm or above with more than ten rainy days/month. Temperature above 30°C and below 17°C will slacken the disease spread. The bacterium does not remain in the soil for more than 75 days indicating that soil is not the primary source of inoculum. The bacterium survives on the blighted leaves and leaflets remaining on the palm. The pathogen was found to confine to the green or yellowish areas adjacent to the blighted portions and remain viable in such conditions during the off season, thus acting as source of inoculum for epidemics during conducive periods (Sampath Kumar, 1981; 1983; 1993).

Phytosanitation followed by spraying with tetracycline and its formulations at 500 ppm concentration showed prophylactic and curative effects. Stem injection with the antibiotics gave longer protection than foliar spray (Sampath Kumar, 1981). Closer spacing, frequent irrigation and intercropping with banana plants will aggravate the disease incidence in disease endemic areas (Sampath Kumar, 1985b).

CROWN CHOKE

Crown choke is a disorder rather than a disease, which occurs during some stage of development of the palm. Prevalence of this disorder was first noticed in 1889 -1890 period from Konkan coast of Maharashtra (Joshi and Joshi, 1952). The word 'band' in Marathi language means barren since the palms ceases to bear fruits. In Kannada language the

disorder is known as 'hidimundige' *i.e.* a sort of constriction at the crown region. Rawther *et al.* (1982) reported the occurrence of similar type of disorders *viz.*, "pencil point" and "rosette" on palm species in Sri Lanka and Australia respectively.

The report on loss due to this disorder is scanty. Joshi and Joshi (1952) reported 5 to 25 per cent loss from parts of Maharashtra. Incidence of the disorder varies with locality and plantations in the plains are affected more than those situated in the hill tops (Kibe *et al.*, 1956). Salvi *et al.* (1985a) reported 0 to 16.66 per cent incidence from Konkan regions of Maharashtra.

The symptoms of the disorder are exhibited on the leaves as well as the stem near the crown. The leaves become shorter than normal size and are distinctly dark green in colour. The leaflets are characteristically brittle and crinkled with wavy margin. As the disease progresses the other symptoms like reduction in internodal length, tapering of the stem (Patel and Rao, 1958) and failure of production of inflorescence of normal size are expressed by the palm (Fig. 15). Sometimes when the inflorescences are produced they are small and malformed. In the acute stage, as a result of failure of natural opening of the leaves, which remain tightly binding the top portion of the stem and the crown exhibit rosette shape. This condition prevents the normal growth of the bud. Sometimes multiple shoots are developed or the newly formed shoots may emerge through the sides of the tightly folded lower leaves (Joshi and Joshi, 1949). Roots are poorly developed, brittle and crinkled. This disorder is not contagious and is not spread through any other means than the natural occurrence.

The earlier workers suggested the possible reasons for development of this disorder as due environmental factors or infestation by nematodes (Thirumalachar, 1946). However, further studies proved that the nematodes are not involved in the development of this disorder (Venkatarayan, 1946). The studies conducted in 1950's ruled out the association of biotic agents in this disorder (Anonymous, 1951). The prevalence of the disease is more in gardens with poor drainage and low soil fertility (Daji, 1948; Gokhale *et al.*,1916; Nambiar, 1951). Though the nutritional imbalance is attributed as the cause of the disease (Daji, 1948; Joshi and Joshi, 1952), soil nutrient status of the healthy and affected palms did not show any significant difference except for zinc which was low in diseased soils where as no change in boron and magnesium contents was noticed. (Joshi and Joshi, 1952) The presence of lateritic soil, prolonged water stagnation below the root zone or gardens with poor crop management and situated on flat land and closed to the sea or hard clayey soils is contributory factors in the incidence of the disorder (Patel and Rao, 1958; Salvi *et al.*,1985b).

The palms with crown choke symptoms may not respond to any treatment with plant protection chemicals. The only way to manage the problem is better soil management and improvement of drainage (Kibe *et al.*, 1956). The affected palms may remain unproductive

for a long timé or regain the normal growth without any treatment. The affected palm may not respond to any fungicidal/ pesticidal treatment since biotic agents are not assosciated with the disorder. The palms in well-managed gardens respond more to manural treatments than the palms in the neglected gardens (Kibe *et al.*, 1956). Soil aeration can be improved by removing the hard pan of sub soil and application of organic matter, this in turn improve better formation of root system. Crown choke condition of the affected palms can be improved by foliar application of micronutrients or correction of soil acidity and incorporation of a mixture of equal quantities of copper sulphate and lime (Joshi and Joshi, 1954; Nambiar, 1971; Patel and Rao, 1958; Rao, 1960). Salvi *et al.* (1985b) reported application of nitrogen @ 0.15 kg + provision of drainage proved to be the best treatment in respect of percentage recovery of band affected palms. Soil application of borax @ 25 gm/ palm may also improve the condition of the palm.

SUN SCORCH AND STEM BREAKING

The constant exposure of the stem of border palms, which are exposed to solar radiation are exhibiting this disorder (Ramakrishnan, 1956). This was observed decades ago from different parts of Dakshina Kannada. The badly damaged palms break away due to heavy wind during South West monsoon season resulting in loss of both the produce and the palm. Prior to understanding the reasons for this condition a small unit was established at the erstwhile CARS, Vittal (the present CPCRI, Regional Station, Vittal) to investigate the cause and control aspect of this disorder. The team studied the different aspects of the disorder and suggested the control measures (Anonymous 1956a).

The symptoms are seen on the stem exposed to sun's radiation. The initial visual symptom is the development of golden yellow patches all along the exposed portion of the stem (Fig. 16). Colour of these patches turn to dark brown followed by development of longitudinal fissures of 1.0 to 3.0cm deep. Once the fissures are formed, further deterioration is accelerated by the saprophytic microorganisms and small insects. Severly affected stem break away during heavy wind (Seshadri and Rawther, 1968).

A number of pathogenic fungi have been isolated from rotten stem tissues. Among the various organisms observed fungi *viz.*, *Ganoderma lucidum, Ceratostomella paradoxa, Lenzitus* and *Polyporus* could cause infection on young palms when inoculated through wounds caused by sun scorch (Coleman and Rao, 1918; Patel and Rao, 1958)

Since the primary cause of the disorder is radiation effect from sun, the exposed palms can be protected by trailing pepper vines or raising shade trees on the South Western side of the garden (Kurup, 1955; Ramakrishnan, 1956) or tying with dried palm leaves (Fig. 17) or lime washing on the exposed portion of the stem of the border palms (Fig. 18) and weak portions of the stem can be reinforced by tying with split areca stem (Anonymous, 1956b; Shama Bhat *et al.*, 1956). Aligning the rows of palms in north-south direction reduces the incidence of sunscorch (Ishwara Bhat, 1965).

NUT SPLITTING

Areca palms in the age group of 10-25 years are more prone to this disorder. The occurrence of nut splitting was first reported from Karnataka by Nambiar (1949). The disease is prevalent in paddy field converted areca gardens as well as gardens with high water table and seen during rainy season.

The characteristic symptom is premature yellowing of the nuts (Fig. 19) when they are half to three forth mature. Splitting may occur from the perianth or distal end or from both ends of the fruit or may be restricted to only one side of the nut (Iswara Bhat, 1961). Sometimes kernel may also get split and exposed. All the nuts in a bunch may get split or rearly splitting of tender kernel may occur without external symptoms (Bavappa and Sahadevan, 1952).

Sudden flush of water after a long period of drought is attributed as the cause of the disorder. Sometimes water stress in the soil may also disturb the normal development of pericarp and kernel. Ishwara Bhat (1961) reported potash deficiency as the probable cause since reduction in splitting was noticed in palms applied with potash fertilizers.

The earlier recommendation to reduce the incidence of the disorder was to check the excess flow of water to the developing nuts by making longitudinal side slit at the base of the spadix, when the nuts are half mature (Bavappa and Sahadevan, 1952; Patel and Rao, 1958). Application of potash fertilizers (Ishwara Bhat, 1961) and spraying of sodium borate (Borax) @ 2.0 g/ lit. of water before the expression of symptoms were also found effective and are still practiced. Improvement of drainage in gardens with high water table may also help to minimize the occurrence of this disorder.

DISEASES OF SEEDLINGS

Seedlings in the primary and secondary nurseries as well as those transplanted in the field are affected by various fungal and bacterial pathogens. Among the diseases collar rot, leaf blight and leaf spots are important since these diseases can cause stunted growth or mortality of seedlings.

Collar rot

This disease is common in secondary nurseries and field planted seedlings. Poor drainage predisposes the seedlings to infection. The major fungal pathogens associated with this disease are *Fusarium sp. Rhizoctonia sp.* (Rao and Bavappa, 1961) and *Phytophthora sp.* Infection is mainly through roots or collar region. Aderungboye (1974) reported *Pythium* and *Rhizoctonia* from root portion of *Areca catechu* causing 96-100 per cent loss of seedlings in Nigeria. Other than the above fungi, a bacterium (unidentified) is also reported as the causal organism of collar rot. Infection of roots leads to seedling wilt while infection at collar region results in rotting of the young bud. Disease incidence can be reduced by providing proper drainage and soil drenching with 1 per cent Bordeaux mixture.

Fig.16. Sun scorch symptom on adult palm

Fig.17. Tying of stem with dried areca leaves

Fig.18. Lime wash against sun scorch

Fig.19. Nut splitting with premature yellowing

Fig.20. Leaf spot

Fig.21. Post harvest spoilage of nuts- healthy and infected

Leaf blight

Symptoms are seen on the leaf lamina as characteristic reddish brown spots and severe blighting results in stunted growth. The fungi *Phomopsis palmicola* (Wint.) *Sacc. arecae* (Roy, 1965) and *Pestalotia palmarum* Cooke were consistantly associated with blight. A pycnidial fungus was also reported to cause leaf blight (Menon, 1959b). Hossain *et al.* (1992) reported a new disease by *Phomopsis palmicola* causing leaf blight of arecanut in Bangladesh. They reported fungicides carbendazim 50 per cent WP, iprodione and propiconazole 250 EC reduce the colony growth of *P. palmicola in vitro* Ramesh Bhat *et al.* (1992a) reported the occurrence of *Phyllosticta arecae* causing leaf blight in Uttara Kannada. Seedlings at the all the age group are susceptible. The fungus enters the host tissue through the stomata or wounded tissues by germtubes of the germinating conidia. The fungus grew well in Sabouraud's liquid medium added with fructose as carbon source and dry weight of mycelium increased with increase in concentration but beyond a conc. of 9 per cent growth was declined. Studies on vitamin requirement indicated that the vitamin deficiency was only partial (Ramesh Bhat *et al.*, 1992b; 1993a; 1993b). Bharati and Anahosur (1994a; 1994b) studied the variability in virulence, nutritional and physiological requirement of *P. arecae* and reported that mannitol followed by maltose and glucose as best sources of carbon and these sources supported maximum production of toxic metabolites.

Providing proper shade followed by spraying with copper fungicides can minimize the blight caused by the pycnidial fungus and application of nitrogen and potash fertilizers followed by spraying with Dithane Z_{78} also reduces the blight caused by other fungi (Menon, 1959b; Menon *et al.*,1962).

Leaf spot

Leaf spot in arecanut seedlings and young palms is observed in different seasons *i.e.*, during summer and South West monsoon period. Young seedlings at the age of 1 to 2 1/2 years old are seen infected during summer. The symptoms appear as yellow specks of 3.0 to 10 mm diameter on the leaf lamina. These spots later coalesce to form bigger lesions with typical yellow halo around. Severe infection cause stunted growth or death of the seedlings. The fungi isolated from such lesions include *Curvularia sp.* (Menon, 1962), *Colletotrichum sp. Phyllosticta sp. Helminthosporium sp.* (Rao, 1966; Rao and Bavappa, 1961) and *Alternaria tenuis* Nees ex. Pers (Agnihotri, 1963).

The second type of leaf spot occurs during South West monsoon season. Intensity of disease is more on young palms of less than 10 years. This leaf spot is reported in a severe form from several areca gardens in Uttara and Dakshina Kannada districts of Karnataka and parts of Kasaragod district of Kerala. The infection is restricted to three to four leaves of the outer whorl. The symptoms develop as small brown to dark brown or black round spots with varied sizes (Fig. 20). The spots are characterized by yellow halo around and in

advanced stages they form blighted patches. Severe infection cause drying, drooping and shredding of leaves. *Phyllosticta* sp. (Rao, 1966) and *Colletotrichum gloeosprioides* are the most frequently isolated fungi and their pathogencity has been established (Padalkar *et al.*, 1996; Ramanujam *et al.*, 1993).

Leaf spots seen during summer can be minimized by providing proper shade and spraying with Dithane Z_{78} or 1 per cent Bordeaux mixture (Menon, 1962; Rao, 1962b). Fungicides viz., ziram, mercurized copper oxy chlorides were also have been recommended earlier (Rawther *et al.*, 1982). Field fungicide trial conducted at Sirsi and Yellapura areas of North Canara and Kavu and Halenarangi areas of Dakshina Kannada district against the leaf spot seen during South West monsoon season revealed that disease could be controlled effectively by spraying the leaves with Dithane M-45 @ 0.3 per cent or Foltaf @ 0.2 per cent concentration (Ramanujam *et al.*, 1993). The inoculum load inside the areca gardens can be reduced by collection and destruction of infected leaves by burning.

Red rust

In addition to the diseases by fungal/ bacterial and phytoplasmal origin a rust disease caused by algal parasite *Cephaluros* sp. has been reported on arecanut (Paily and Menon, 1960). The above parasite cause circular, sunken spots on the stem and foliage. The irregular spots are characterized by the presence of yellow halo around. The infected epidermal cells get destroyed. Providing shade followed by spraying with 1 per cent Bordeaux mixture could control infection (Westcott, 1966).

Rao (1988) reported a new but similar disease on arecanut from Andaman and Nicobar Islands. The pathogen assosciated with the disease was reported as *Cladosporium spongiosom*. Seedlings at the age group of 4 to 6 years are affected. Symptoms develop as light brown spot on the stem at 2-3 cm from the base. The spots measure 2 to 6 cm long and 1.0 to 3.0 cm wide with irregular dark zonation. On ageing these portions, become dark olivaceous brown with slightly raised light yellow margin with variable width.

POST HARVEST SPOILAGE OF ARECANUT

The harvested fruits during drying and storage are subjected to attack by a number of fungi. Infection during storage can be due to many factors like improper drying and exposure to unexpected rains. Fungal infection can occur both on the husk and kernel of the fruits. This affects the quality of the kernel and is not good for chewing.

A number of fungi mainly the hyphomycetes are reported on harvested nuts during drying and storage. Infection is seen on husk, endosperm and kernel. Initial infection on husk occurs during early period of drying. Infected nuts exhibit discoloration and disintegration of the white core and exhibit a hollow cavity. The colour of the infected nuts

varied according to microorganisms résponsible for the spoilage (Fig. 21). The invading fungi first attack the embryo spread to the central white core of the endosperm and cause disintegration and then attack the adjacent lamella of the rumination. (Jaleel and Govindarajan, 1969; Nambiar *et al.*, 1971).

Table 4. Infection percentage by different fungi of stored nuts

Fungi	Colour of infected kernel	Infection (per cent)
Aspergillus niger	Black	6.4
A.chivalieri	Yellow	6.4
A.flavus	Yellowish green	6.4
A.fumigatus	Velvetty green	6.4
Penicillium sp.	Felty olive green	1.3
Botryodiplodia theobromae	Grey to greyish black	19.3
Rhizopus sp.	Grey	1.8
Mucor sp.	Yellowish grey	0.7
Thielaviopsis paradoxa	Black	0.2

While harvesting, by dropping the fruit bunches on the ground, fruit surface gets mechanical injury by abrasion and these points serve as foci of entry to the microorganisms (Nambiar and Radhakrishnan Nair, 1970) and infection percentage was upto 54.7. *Aspergillus niger, A. flavus, Botryopiplodia theobromae* and *Rhizopus* were reported from such infected nuts (Nambiar and Koti Reddy, 1979). Saraswathy (1981) reported a new fungus namely *Cylindrocarpon tonkinense* Bugnv from decaying husk. Among the fungi reported maximum spoilage was by *B. theobromae* (19.3 per cent) and *Aspergillus* spp. (6.4 per cent). The fungi infecting stored arecanuts are listed in Table 4. The infection is more in the initial days of drying and maximum moisture loss takes place during the first 5-10 days and slow process of drying coupled with high nutrient content of the kernel favour the infection by fungi (Nambiar *et al.*, 1971).

The extent of damage depends upon the condition of the drying yard, season and prevailing temperature and humidity. Intensity of infection varied according to season and longer the time taken for drying the greater will be the chances of infection. The percentage of infection varied from 21 and 62 per cent when dried in February and October respectively. The higher infection in October is attributed to low temperature, high humidity and unusual rains.

A number of fungi were reported by different authors Table 5. The highest kernel infection was reported on 'sweet areca' (Nambiar *et. al.*, 1971). Muralimohan and Reddy (1995) observed *A. flavus* as the predominant fungus on marketed arecanut and this fungus produced aflotoxin and toxins were identified as Af B2 and AfG1.

Control

Different methods of harvesting and drying were tested to assess the intensity of damage. Since soil is the primary source of infection, eliminating soil contact after harvesting might minimize the infection. No infection was recorded on nuts harvested without soil contact and dried in hot air oven at 65° C for 63 hr, whereas in the conventional method of harvest followed by drying in mechanical drier at 62° C for 72 hr, 3.6 per cent of the nuts contracted the infection (Nambiar *et al.*, 1971; Namboodiri *et al.*, 1963). Treatment of nuts with fungicides such as blitox (Anonymous, 1962a) or Bordeaux mixture followed by drying on cement floor significantly reduced the percentage infection. Time required for drying on cement floor was less (Anonymous, 1973). Studies on methods of storage indicated that spoilage was less in nuts stored in airtight bins and also in polythene lined gunny bags compared to that stored in ordinary gunny bags (Nambiar and Koti Reddy, 1979; Nambiar and Radhakrishnan Nair, 1970).

Table 5. Fungi associated with stored arecanuts

Fungi	References
Apergillus niger	Lal and Chandra, 1953 Nambiar et al., 1971; Rao, 1986
A.chevalieri	Anonymous, 1971
A.flavus	Anonymous, 1971 Muralimohan and Reddy, 1995
A.fumigatus	Anonymous, 1971
Aspergillus spp	Anonymous, 1961; 1962b
Botryodiplodia theobromae	Nambiar *et al.*, 1971
Cladosporium sp	Anonymous, 1970
Colletotrichum gloeosporiodes	Saraswathy *et al.*, 1977
Cylindrocarpon tonkinense Bugn.	Saraswathy,1981
Diplodia sp	Anonymous,1961; 1962b
Fusarium sp	Anonymous, 1970
Mucor sp	Nambiar *et al.*, 1971
Penicillium sp	Anonymous,1961; 1962b
Phomopsis heteronema	Butler and Bisby, 1931
Rhizopus sp	Nambiar *et al.*, 1971
Subramanella arecae	Srivastava *et al.*, 1962
Thielaviopsis sp	Anonymous, 1961; 1962b

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7. PESTS

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INTRODUCTION

Arecanut palm, *Areca catechu* L. is attacked by an array of insect and non-insect pests. The pest infests all parts of the palm *viz.*, stem, leaves, inflorescence, roots and nuts. Brown bug, *Saissetia hemisphaericum* Targ. was the first record as a pest of arecanut by Coleman and Rao (1918). Since then about 102 insect and non-insect pests have been reported to be associated with arecanut palm (Table 1; Nair and Daniel, 1982). Among these, mites, spindle bug, inflorescence caterpillar, root grubs and pentatomid bug cause considerable economic loss to the crop. They are either seasonal or persistent on the crop. Theiur habits and control have been described briefly (Devasahayam and Nair, 1982). Though not highly host specific, they infest the crop in serious proportions.

INSECTS INFESTING THE LEAVES

Spindle bug, *Carvalhoia arecae* Miller and China (Heteroptera: Miridae)

The capsid (Mirid) bug was first reported as a pest of arecanut palm from Dakshina Kannada (Karnataka) by Khandige (1955). The taxonomic identity of *Carvalhoia arecae* was confirmed by Miller and China (1957). The bionomics was studied by Nair and Das (1962). The bugs colonized in the upper most leaf axils of the arecanut palm. Observations from gardens in Southern Kerala and parts of Dakshina Kannada revealed that feeding by these bugs caused 80 per cent damage to the spindle (Nair, 1964a; Abraham, 1976).

The bug completes its lifecycle in 24 - 33 days (Nair and Das, 1962). The eggs were thrust singly into the tender tissues of spindle. The site of egg laying becomes dark in colour. Freshly laid eggs are milky white and oval in shape and measures 1.36 mm x 0.34 mm. The anterior end is distinctly demarcated into a short neck, bearing at its tip thick and rigid convex oval operculum. The chorion is smooth and leathery. Two bristle (unequal in size) like chorionic processes arise from the operculum. One of them is long and the other is short and slightly curved. During the course of development the egg turns to pink and then red and hatches out in a period of ten days.

There are five nymphal instars, which extends for 15-24 days. On hatching the first instar nymph measures 1.07 mm long. The head is triangular with a pair of four segmented antennae. Three-segmented rostrum reached up to hind coxa. The thoracic segments are equal in size. The six-segmented legs bear a two-segmented tarsus. The abdomen is oval with nine visible segments. The antennae, legs and rostrum are deep violet brown; thorax

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Table 1. List of pests infesting arecanut palms

Name of the pest	Plant parts infested	Reference
INSECTS		
Acanthopsycheplagiophelphs Hampson	Leaf	Anonymous, 1969a
Acicnemis praembulans Fst.	Inflorescence	Murthy *et al.*, 1965
Anomala varians	Roots and leaf	Nair, 1975
Anomelochela sp.	Roots	Murthy *et al.*, 1965
Aonidiella orientalis (Newst.)	Leaf	Puttarudriah andChannabasavanna, 1956; Nair and Menon 1963; Nair, 1975
Aspidiotus destructor Sign.	Leaf	Nair and Menon, 1963; Nair, 1975
Aspidiotus ficus Ash	Leaf	Ayyar, 1940
Aulacophora sp.	Leaf	Murthy *et al.*, 1965
Aularches miliaris Linn.	Inflorescence	Jones, 1954; Nair and Menon, 1963; Kumar and Naidu, 1965; Nair, 1975; Pillai *et al.*, 1976
Batrachedra sp.	Floral parts	Nair and Menon, 1963
Brontispa mariana	Leaf	Bryan, 1949
Brontispa longissima	Leaf	O'Connor, 1940
Bruchus sp.	Floral parts	Murthy *et al.*, 1965
Carpophilus sp.	Floral parts	Murthy *et al.*, 1965
Carvalhoia arecae Miller and China	Spindle	Khandige, 1955; Nair and Das, 1962
Cerataphis lataniae (Boisd)	Inflorescence	Pillai and Kurian, 1959a; Nair and Menon, 1963
Cerataphis variabilis.	Inflorescence	Nair and Menon, 1963.
Chionaspis dilatata Gr.	Leaf	Ayyar, 1940; Ramachandran, 1951; Nair, 1975
Coccus acutissimum Gr.	Leaf	Nair and Menon, 1963; Nair, 1975
Coccus hesperidum Linn.	Leaf	Puttarudriah and Channabasavanna, 1956; Nair and Menon 1963; Nair, 1975
Contheyla rotunda H.	Leaf	Sathiamma and Bhat, 1972
Cryptothelia sp.	Foliage	Nair and Menon, 1963
Ceroplastus actiniformis	Leaf	Ponnamma and Sasidharan, 1989
Cletus sp.	Leaf	Ponnamma and Sasidharan, 1989
Chrysomphals aonidum	Leaf	Ponnamma and Sasidharan, 1989
Dasychira mendosa Hubner	Spindle and leaf	Ponnamma, 1989
Diocalandra frumenti F.	Stem and Inflorescence	Murthy *et al.*, 1965; Nair and Menon, 1963
Diocalandra stigmaticollis Gyll.	Stem and Inflorescence	Murthy *et al.*, 1965; Pillai and Kurian 1959a
Dioryctus sp.	Inflorescence	Nair and Menon, 1963; Nair, 1975
Diostombus carnosa(Westwood)	Leaf	Murthy *et al.*, 1965
Dysmicoccus brevipes (Ckll.)	Collar of seedlings	Ponnamma and Sasidharan, 1989
Elymnias caudata Butl.	Seedlings	Rao and Bavappa, 1961; Nair, 1975
Exitianus sp.	Leaf	Nair, 1964b; Nair, 1975

Euproctis semisignata Walk.	Leaf and Inflorescence	Ponnamma and Sasidharan, 1989 Nair, 1975
Gossyparia sp.	Inflorescence	Nair and Menon, 1963;Nair, 1975
Halyomorpha marmorea	Tender nut	Vidyasagar and Shama bhat, 1986
Hemerocampa sp.	Leaf	Nair and Menon, 1963;Nair, 1975
Icerya aegyptiaca (Doug).	Leaf and Inflorescence	Puttarudriah and Channabasavanna, 1957a, Nair and Menon, 1963; Nair, 1975
Lepidiata sp.	Roots	Rao *et al.*, 1961; Murthy *et al.*, 1965
Lepidasaphes sp.	Leaf	Nair and Menon, 1963;Nair, 1975
Leptocorisa sp.	Leaf	Ponnamma and Sasidharan,1989
Leucohimatum sp.	Inflorescence	Murthy *et al.*, 1965
Leucopholis burmeisteri Brenske	Roots	Anonymous, 1967
Leucopholis lepidophora Blanchard	Roots	Puttarudriah and Channabasavanna, 1957a; Murthy *et al.*, 1965
Limnogonus nitidus(Mayr)	leaf	Ponnamma and Sasidharan,1989
Mahasena corbetti Tams.	Leaf	Anonymous, 1929
Manatha albipes Moore	Foliage	Pillai and Kurian, 1959a; Nair, 1975
Melanaplus sp.	Foliage	Nair and Menon, 1963
Monomarium gracillimum Sm.	Foliage and inflorescence	Anonymous, 1962; Nair and Menon, 1963
Morismus carinatus Walk.	Young palms	Kumar and Naidu, 1965; Anonymous, 1969
Nephantis serinopa Meyrick	Leaf	Valsala, 1958
Nilaparvata lugens (Stal.)	Leaf	Ponnamma and Sasidharan, 1989
Nephotettix virescens (Distant)	Leaf	Ponnamma and Sasidharan, 1989
Nirvana(Sophonia)greeni	Leaf	Ponnamma and Sasidharan, 1989
Nisia nervosa (Motschulsky)	Leaf	Ponnamma and Sasidharan, 1989
Nygmia	Inflorescence	Nair and Menon, 1963
Odontotermes obesus (Ramb)	Seed nuts and seedlings	Pillai and Kurian, 1959a; Nair, 1975
Oecophylla smaragdina F.	Inflorescence	Anonymous, 1962; Nair and Menon, 1963
Oryctes rhinoceros Linn.	Leaf and spindle	Nambiar, 1949; Valsala, 1965; Murthy *et al.*, 1965; Kumar *et al.*, 1967
Oliarus sp.	Leaf	Ponnamma and Sasidharan, 1989
Parlatoria mytilaspiformis Gr.	Leaf and	Puttarudriah and Channabasavanna, 1956;
Pamendanga punctativentris(Kirby)	inflorescence	Nair and Menon, 1963; Nair, 1975
Phenacaspis cockerelli (Cooley)	Leaf	Ponnamma and Sasidharan, 1989
Phenacaspis dilatata (Green)	Leaf	Nair, 1975
Phyllophaga fissa	Leaf	Nair and Menon, 1963
	Roots	Anonymous, 1971a
Pinnaspis aspidistrae Sign.	Leaf and Inflorescence	Ayyar, 1940; Pillai and Kurian, 1969a; Nair and Menon, 1963; Nair, 1976; Nair, 1975

Pinnaspis buzi (Bouche)	Leaf	Nair, 1975
Pinnaspis dracoenae (Cooley)	Leaf	Nair, 1975
Pinnaspis strachani (Cooley)	Leaf and inflorescence	Nair and Menon, 1963; Nair, 1975
Porthesia sp.	Leaf	Nair and Menon, 1963
Promecotheca cumingi Baly	Leaf	Lever, 1951
Prautista moesta Westwood	Leaf	Nair and Menon, 1963
Proutista sp.	Leaf	Ponnamma and Sasidharan, 1989
Pseudococcus citriculus (Green)	Leaf and inflorescence	Nair, 1975
Pyroderces sp	Floral parts	Nair and Menon, 1963; Nair, 1975
Pyrilla sp.	Leaf	Ponnamma and Sasidharan,1989
Ouadraspidiotus sp.	Leaf	Nair, 1975
Ricania speculum Wlk	Leaf	Ponnamma and Sasidharan,1989
Rostrococcus iceryoides (Green)	Leaf and Inflorescence	Nair, 1975
Rhipiphorothrips cruentatus (Hood)	Leaf	Puttarudriah and Channabasavanna, 1956; Pillai and Kurian, 1959a; Nair, 1975
Rhynchophorus ferrugineus	Stem	Pillai and Kurian 1959a; Murthy, *et al.*, 1965
Rhynchophorus sp.	Leaf	Murthy *et al.*, 1965
Saissetia hemisphaericum	Leaf	Coleman and Rao, 1918
Saissetia sp.	Leaf	Nair and Menon, 1965; Nair, 1975
Spatulifimbria gresia Hering	Inflorescence	Anonymous, 1969a
Scaphoideus sp *sensulato.*	Leaf	Ponnamma and Sasidharan, 1989
Sophonia greeni	Leaf	Ponnamma and Sasidharan, 1989
Scophana spectra	Leaf	Ponnamma and Sasidharan, 1989
Telingana sp.	Leaf	Ponnamma and Sasidharan, 1989
Thyridopteryx sp.	Leaf	Nair and Menon, 1963, Nair, 1975
Tirathaba mundella Walk.	Inflorescence	Anonymous, 1962; Nair and Menon, 1963; Nair and Rawther, 1969
Tirathaba rufivena Walk	Inflorescence	Lever, 1937
Varma sp.	Leaf	Ponnamma and Sasidharan, 1989
Wallacea palmarum Gestro	Leaf	Anonymous, 1929
Xylocoris sp.	Leaf	Ponnamma and Sasidharan, 1989
Xyleborus habercorni Egg.	Stem	Murthy *et al.*, 1965
Xyleborus perforans Woll.	Stem	Seshadri, 1968
Xylotrupes gideon Linn.	Fronds	Anonymous, 1970
MITES		
Dolichotetranychus sp.	Tendernut	Sadanandan and Antony, 1973
Lasioseius sp.	Inflorescence	Nair and Rao, 1964
Neocypholaelaps stridulans Evans	Inflorescence	Nair and Rao, 1964
Oligonychus biharensis Hirst	Leaf	Puttarudriah and Channabasavanna, 1956
Oligonychus indicus Hirst	Leaf	Puttarudriah and Channabasavanna, 1956

Raoiella indica Hirst	Leaf	Puttarudriah & Channabasavanna, 1956
Tetranychus fijiensis Hirst	Leaf	Daniel, 1977
Amblyseius ovalis Evans	Leaf	Prasad, 1974
VERTEBRATE PESTS		
Squirrels	Tendernuts	Ramachandran, 1951; Pillai and Kurian,1959a; Naidu,1962
Rats	Tendernuts	Coleman and Rao, 1918, Pillai and Kurian,1959a; Nair and Menon, 1963
Bats	Fruits	Pillai and Kurian, 1959a; Daniel and Kumar, 1976
Monkeys	Fruits	Nambiar, 1949; Pillai and Kurian, 1959a; Daniel and Kumar, 1976
Woodpecker	Stem	Nair and Menon, 1963

and border of abdomen light violet brown, remaining part of abdomen greenish yellow. The head is light yellow with scarlet red eyes. The fifth instar nymphs are 4.43 mm long and 2.15 mm broad. Wing pads are well developed reaching up to the third abdominal segment in the fifth instar nymph (Fig. 1).

The adult bugs are black in colour and measure 6.0 mm long and 2.8 mm broad (Fig. 2). The females are bigger than the males. The female bug has broad and stout abdomen. They could be easily sexed based on the presence of black colour on the ventral side of abdominal tip. In the male, this color is confined to the lateral border of the sixth, seventh and whole of the eighth abdominal segments. In females the black coloration extends medially up to the fourth abdominal segment.

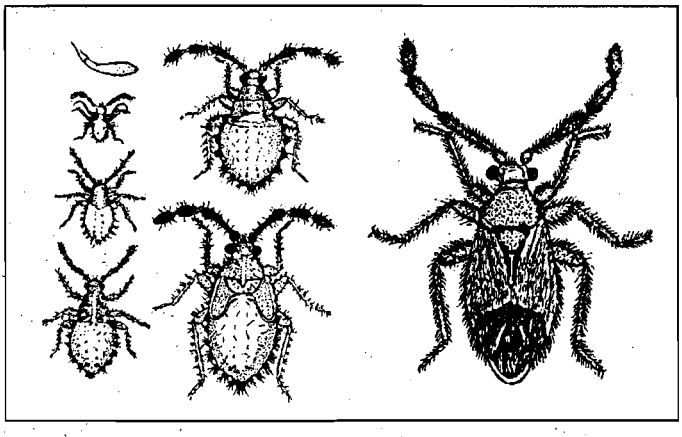

Fig.1. Different developmental stages of spindle bug

Nature of feeding and symptoms of infestation

Both the nymphs and adults suck the sap from the tender spindle and leaves. The bug pierce the stylet into the tissues by bending the rostrum and starts feeding. They are

satiated in 20 minutes of feeding. A longitudinal narrow discolored zone is formed on the site of the feeding (Fig. 3). As a part of pre oral digestion the bug-injects saliva with digestive enzymes into the tissues, which liquefies the cell contents before feeding (Nair and Das, 1962). The infested portions develops necrotic patches, which subsequently turn brown and dries up. The spindle infested by the bug shows typical linear brown lesions. Severely infested spindles fails to open fully. Portions of the necrotic patches after turning brown drop off forming holes on the leaves. In severe case of infestation the leaves are shredded and the palms become stunted.

The alternate hosts include *A. lutescens* L., *Loxococcus* sp. (Nair and Das, 1962) *Chrysalidocarpus madagascariensis, Pinanga* sp., *A. triandra* Roxb. and *A. concinna* Thw. (Nair, 1964b).

Population dynamics

The peak incidence of the pest in Kerala is from June to October with maximum population in August and September (Nair, 1964a). A peak in population density was noticed during December, January and July (Anonymous, 1972). According to Koya *et al.* (1979) the pest population was high during the monsoon and post-monsoon periods and low during summer months. There was a positive correlation between the rainfall and population of *C. arecae* and peak period of abundance varied at different places (Sathiamma *et al.*, 1980;1985a).

At Palode, monthly rainfall had positive correlation with the nymphs and adult population of *C. arecae*. Number of rainy days during the period of observations had no significant correlation with the population of *C. arecae* at different locations except at Neyyatinkara in Trivandrum district where a significant negative correlation with the adult population was observed. Maximum temperature had highly significant negative correlation with adult and nymphal population of insect. Minimum temperature had a negative correlation with the pest population (Jacob, 1980).

Control

Studies conducted for the past four decades revealed that chemical control measures were found to keep the pest at bay. Majority of the pesticides evaluated and found to be effective, are now banned for use in plant protection. Menon *et al.* (1962) suggested spraying of DDT, endrin, folidol 605 (ethyl parathion) and wettable BHC to control the spindle bug. Palms treated with BHC 0. 2% and endrin 0.025% were completely free from damage (Nair and Das, 1962). Spraying Fish Oil Rosin Soap (FORS) (1 kg in 80 litres of water), quinalphos (Ekatin) (1 ml in one litre of water) or endrin (Endrex) (1 kg in 700-900 litres of water) could control the pest (Anonymous, 1964).

Filling the innermost two leaf axils around the spindle with granular systemic insecticides like phorate l0G (Thimet 10G) or carbaryl 4 G (Sevin) or methyl 'o' demeton (Solvirex 5G) at the rate of l0 g/palm at an interval of three months was suggested (Abraham

et al., 1976). A granule applicator for facilitating the leaf axil filling of arecanut palm was also devised (Abraham, 1975). Granular formulations of lindane and phorate applied to innermost two or three leaves @ 10 g per palm at quarterly intervals effectively controlled the spindle bug population (Sathiamma *et al.*, 1985b). The abundance of these insects during rainy season and the vertically slanting position of leaves did not aid in the effectiveness of insecticide application in the form of spray or leaf axil filling of granular insecticides. Placement method of application of phorate granules in polythene sachets was effective. The fumigating and repelling fumes of the insecticide released from the sachets had insecticidal and repellent action to bugs. In the sachet method of insecticide application, 3 cm wide polythene tubes were cut into 5 cm length and filled with 2 g phorate 10G granules and heat-sealed. A few pinhole perforations were made on the topside of sachet. One such sachet each was placed in each of the topmost two leaf axils before the premonsoon showers. The sachets were transferred to the youngest leaf axils as and when new spindles emerge. The same pair of sachets was repeatedly used for five to eight months. Plantations with initial infestation may be sprayed with dimethoate 0.05 per cent (15 ml in ten litres of water) in and around the spindle and inner whorls of leaves in the morning or evening hours of the day.

Mites

The mites are widely distributed in all areca-growing tracts of India. As they are polyphagous and found to occur on other palms also. The two major species of foliage mites are the cholam mite, *Oligonychus indicus* Hirst and the palm mite, *Raoiella indica* Hirst. (Fig. 4). Three species of mites have been identified to attack arecanut in Tamil Nadu viz., *Dolichotetranychus*, *R. indica* and *O. indicus* (Loganathan *et al.*, 2000).

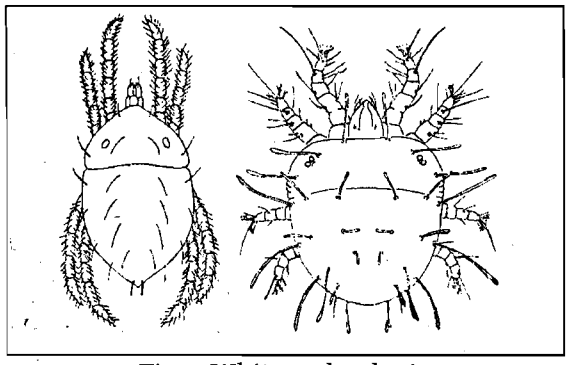

Fig.4. White and red mites

Oligonychus indicus Hirst. ((Acarina: Tetranychidae)

Puttarudriah and Channabasavanna (1956) first reported spider mite on arecanut seedlings near Bangalore (Karnataka). Both adults and nymphs colonized under webs on the lower surface of leaves, which is characteristic of the species. The incubation period varies from 72 to 95 hr. The larval, proto-nymphal and deuto-nymphal periods lasted for

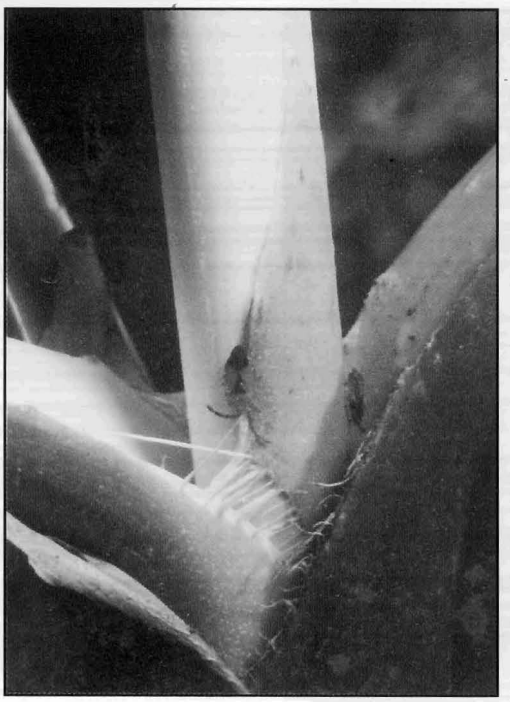

Fig.2. Adult of spindle bug

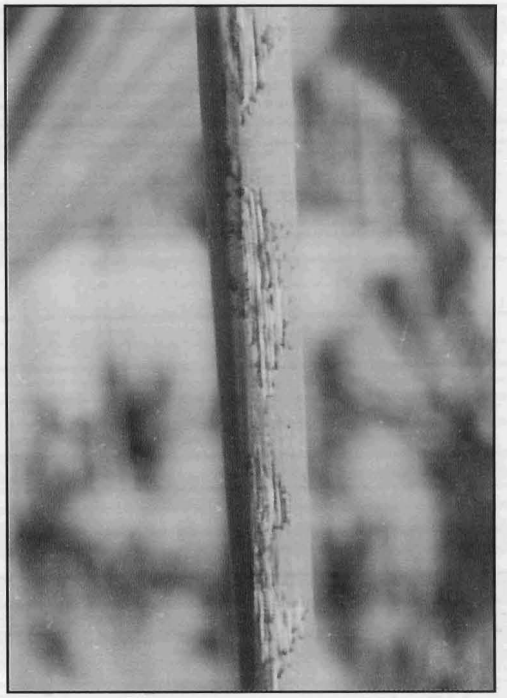

Fig.3. Damage of spindle by spindle bug

Fig.5. Symptoms of mite infestation

Fig.6. Yellowing of seedlings due to mite attack

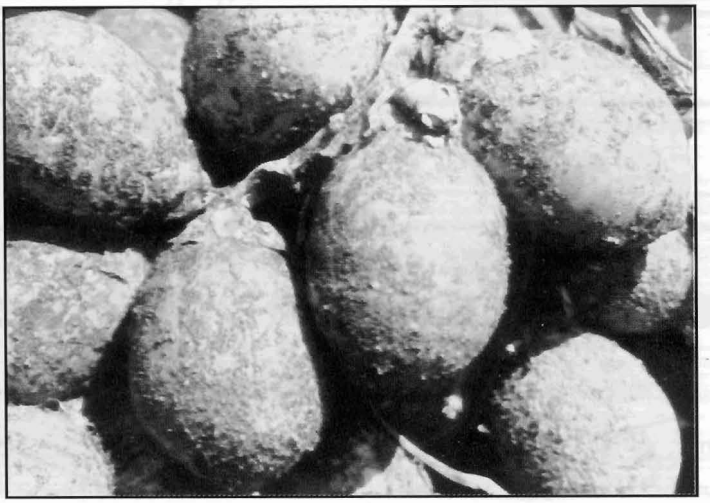

Fig.7. Infestation of scales on areca bunches

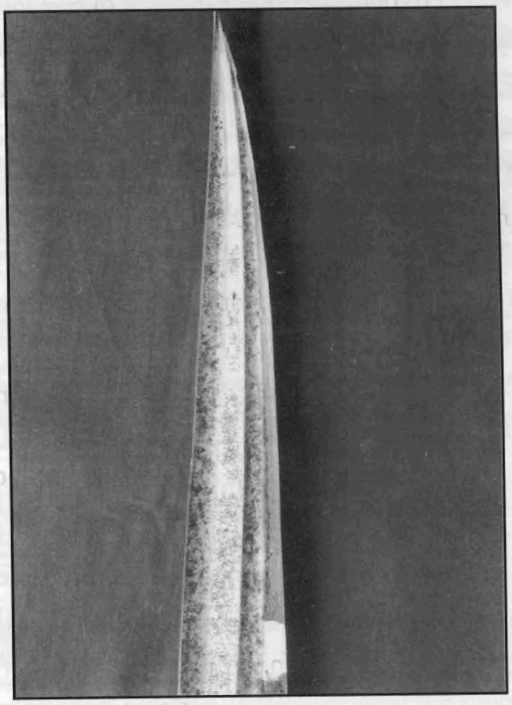

Fig.8. Nature of damage by thrips

Fig.9. Damage of inflorescence by *Tirathaba mundella*

26.6, 30.8, and 44.0 hr respectively. The total duration of the immature stages varied from 6.5 to 9.0 days with an average of 7.5 days. The female mite lays on an average 3-4 eggs per day and the average oviposition period lasted for 10 days (Anonymous, 1970).

Raoiella indica Hirst (Acarina: Tenuipalpidae)

Puttarudriah and Channabasavanna (1956) first recorded *R. indica* on arecanut seedlings at Hebbal, Bangalore. The palm mite *R. indica* commonly known as red mite is active during summer months. Both the adults and nymphs are seen in large numbers on the ventral surface of arecanut leaves. In severe case of infestation they were seen on the upper surface of leaves and on the spindle.

The life cycle of the female and male mites is completed in 12.9 days and 11.2 days respectively, during April-May (Anonymous, 1977). In addition to arecanut, *R. indica* is also observed on coconut, date palms, *Areca macrocalyx* and on the ornamental palm, *Livistona chinensis.*

Symptoms of infestation

Colonies of *O. indicus* and *R. indica* coexist on the same leaf. They suck the sap from the green portion of the plant. Feeding by the mites lead to formation of yellowish speckles on the lamina. These speckles later coalesce, become bronze coloured (Fig. 5) and the leaves wither away. The growth of the fungi *Meliola* sp. and *Capnodium* sp. on the leaves associated with mite infestation interfered with the normal photosynthesis of the affected leaves (Menon, 1960). In the case of infestation all the leaves in the seedlings are affected causing yellowing (Fig. 6) and often death of the seedling. In older palms infestation starts in the lower whorl of leaves and as the population increases, it spreads to the inner whorl.

Seasonal abundance

Population builds up immediately after the monsoon. With onset of hot weather from April-May and become more active and virulent form (Patel and Rao, 1958). The gardens under drought stress and nurseries are more prone to mite infestation. The pest incidence is at a lower level under well-irrigated and partially shaded conditions. The mite population declined with the onset of monsoon.

Control

Heavily infested and dried leaves are cut and burnt to check the spread of mites. Bhat *et al.* (1957) suggested spraying wettable sulphur, Folidol or dusting with lime and sulphur at 2:1 ratio for control of mites. Puttarudriah and Channabasavanna (1957a) suggested soil application of Systox, Solbar and Pestox 3H besides wettable sulphur for the control of areca mites. Patel and Rao (1958) reported that spraying of Folidol E 605, Systox or Ekatin was effective in control of foliage mites. Ponnuswamy (1966) suggested spraying of 0.03% parathion or malathion and 2% parathion dust and sulphur dust for control of *R. indica* on arecanut. It

was found that *R. indica* could be controlled by spraying dicofol (0.05 %), dimethoate (0.05%), formothion (0.025%) or phosphamidon (0.05%) (Devasahayam and Nair, 1985).

O. indicus, and *R. indica* were controlled by spraying with dicofol (Kelthane 1.86 ml/ litre of water), carbophenothion (Trithion 1.26 ml/litre of water) or chlorobenzilate (Akar 338 one ml/litre of water) (Anonymous, 1967). Maximum ovicidal effect on *O. indicus* was shown by dicofol 1.86 ml/litre of water (Anonymous, !969a; 1969b). Kantha *et al.* (1963) reported ovicidal action of Kelthane resulting in 23% reduction in hatching of eggs at 0.1% concentration.

Puttarudriah and Channabasavanna (1956) reported many coleopterous predators chiefly coccinellids of the palm mites. They included *Aspectes indicus* Arrow (Dermestidae), *Cybocephalus semipictis* (Nitidulidae), *Stethorus parcepunctatus* Kapur. *S.tetranychi* Kapur. *Juaravia soror,* (Wse.) and *Spilocaria bisselata* Muls. (Coccinellidae). Among the predators the species of *Stethorus* kept the mite population in check during summer months. *Stethorus keralicus* Kapur (Coccinellidae) as a predator on *R. indica* was recorded by Kapur (1961). This ladybird beetle was one of the major predators of the mite and it took 12- 14 days to complete its life cycle (Daniel, 1976). Daniel (1979) recorded a number of indigenous predators. Among them two species of *Stethorus* and a staphylinid beetle were the major predators of *O. indicus.* The coccinellid, *S. keralicus* and the phytoseiid, *Amblyseius channabasavanni* Gupta and Daniel are the key predators of the palm mite, *R. indica.* The females of predacious mite *A. channabasavanni* requires an average of 98 hrs and males an average of 93.3 hrs to complete the developmental period on the eggs of *R. indica.* A total of 15-38 host eggs were consumed during this period by female and 14-19 eggs by males (Daniel, 1981). Attempts to introduce the predacious mite, *Phytoseiulus persimilis* for the control of *O. indicus* and *R. indica* were not successful, as the predator could not acclimatize itself to the local conditions at Vittal in Dakshina Kannada district of Karnataka (Daniel and Seshadri, 1976).

Bagworms (Lepidoptera: Psychidae)

Pillai and Kurian (1959a) reported *Manatha albipes* Moore on arecanut. Other two species *viz., Cryptolhelia* sp. and *Thyridopleryx* sp. had also been reported from Kerala (Nair and Menon, 1963). They are found in large numbers feeding on the lower side of leaves. The attacked leaves shows numerous small holes.

Incorporation of soil insecticides like BHC, aldrin or chlordane to the nursery soils before sowing of nuts and removal of decaying organic debris from the soil are some of the preventive measures. Covering the nuts with a layer of river sand are also recommended for avoiding termite infestation (Pillai and Kurian, 1959a).

Grasshoppers (Orthoptera: Acridiidae)

Aularches miliaris was first reported in arecanut by Jones (1954). In addition to this *Melanoplus* sp. was reported to cause leaf damage to arecanut seedlings (Nair, 1975; Nair

and Menon, 1963). They eat portions of the lamina causing holes of vaying sizes. An epidemic outbreak of *A. miliaris* during June 1975 in Malappuram district of Kerala was reported on coconut, arecanut, coffee, teak and *Erythrina* (Pillai *et al.*, 1976).

Nymphalid caterpillar, *Elymnias caudata* Butl. (Lepidoptera: Nymphalidae)

Feeding by the caterpillar on the leaves lead to reduction in photosynthetic area. The pest incidence is high from September to December. The spherical and white colored eggs were laid on the ventral surface of the leaf. Incubation period lasted for 5-7 days. The caterpillars are pale yellowish in the early instars and when fully grown they are green in colour. Full-grown caterpillar measures about 35 mm. The larval period is about 21-25 days. Pupa is green in colour with yellow and red markings on the body and is about 25 mm long. Pupal period is 8-9 days. The adult butterfly is brown with patches of white, yellow and violet colouration (Nair, 1964b). The larvae are naturally kept under check by *Brachymeria* sp (Nair, 1975).

Scales and mealy bugs

Many species of scale insects and mealy bugs infest the areca leaves. They colonise on the lower leaf surface and in severe cases even the tender nuts also are affected. The feeding results in the production of yellow patches on the leaves, which under severe infestation cover the entire leaf.

Many species of mealy bugs are found to colonize almost all parts of areca palm *viz.*, spadices, inflorescence, developing fruit bunches, leaves and leaf sheaths. Infestation by most of the mealy bugs do not cause an economic loss to plantations. The following mealy bugs are associated with the leaves and leaf sheath.

Icerya seychellarum Westwood (Margarodidae)

These giant mealy bugs are polyphagus in nature. In addition to outer surface of the leaf sheaths they infest developing bunches and spadices (Daniel, 2003).

Pseudococcus cryptus Hempel (Pseudococcidae).

They were polyphagous and are found to infest leaves, inflorescence and developing fruit bunches (Daniel, 2003).

Pseudococcidae

The common pineapple mealy bug is seen colonizing mainly the spindle leaf of the palm and the inner basal portion of the inflorescence. Ants are associated with these mealy bugs and they protect them by the mud nests. Nair (1975) gave a list of coccids affecting leaves of arecanut palm. The scales, *Coccus hesperidum* Linn., *C. acutissimum* Gr. and *Saissetia* sp. also infested the leaves. Rao and Bavappa (1961) reported the mealy bug, *Dysmicoccus brevipes* Ckll. (Homoptera: Pseudococcidae) and the scale insect, *Aonidiella orientalis* Newst. on arecanut seedlings. These insects infested the lamina and collar regions

of the seedlings, causing yellowish patches. Treatment with contact insecticides like malathion or parathion was suggested by Rao and Bavappa (1961).

In addition to the above two species of coccids, Nair (1975) reported the hard scale, *Aspidiotus destructor* Sign., *A. ficus* Ash., *Chionaspis dilatata* Gr., *Phenacaspis cockerelli* Cooley, *Pinnaspis buzi* Bouche, *P. dracoenae* Cooley, *Lepidosaphes* sp., *Parlatoria mytilaspiformis* Gr. and *Quadraspidiotus* sp. on arecanut seedlings.

A survey in 1992 in Dakshinna Kannada district of Karnataka and Kasaragod district of Kerala revealed the presence of two species of scales, *A.orientalis* and *Chinapssiis.* Both were found to colonize the bunches (Fig. 7). *A. orientalis* was a polyphagous species feeding on a wide variety of plants except the conifers. *A. orientalis,* known to be distributed in 24 countries across 4 continents had assumed a serious pest status on coconut and arecanut in South India (Rajagopal and Krishnamurthy, 1996).

Ponnamma and Sasidharan (1989) monitored a total 300 arecanut seedlings in the age group three to ten years at weekly intervals for a period of one year. Twenty-one species of hemipteran insects were newly recorded on the areca palm. Daniel (2003) surveyed arecanut gardens in Dakshina Kannada District, Sringeri area of Chickmangalur district and Kundapura area of Udupi district in an attempt to collect and document the homopteran insects infesting the areca palms. Oriental scale, *A.orientalis* (Newst), the mussel scale, *Lepidosaphes karicaria* and Pandanus scale, *Pinnaspis buxi* were those, which assumed a serious pest status in areca ecosystem.

Though synthetic insecticides could effectively check the scales their sedentary nature make them an ideal candidate for management by the release of bio agents. Observation revealed that cocinellid beetle, *Chilochorus circumdatus* (Gyll.) and the predatory thrips, *Aleurodothrips fasciapennis* Franklin and *Podothrips* sp. are found to occur in scale infested bunches. Two species of predatory mites and a lacewing bug was found to feed on scale insects (Anonymous, 1992). Considering the potential by these bio agents, it was essential to conserve and augment them.

Mass rearing techniques of natural enemies

Areca bunches infested with the scale, *A. orientalis* were collected from field and the infested nuts were kept along with pumpkins and potatoes for propagation of scale colonies on the artificial host. The scale crawlers appeared on the pumpkins within a span of one week and maximum colonization was obtained in a period of two months. The nucleus culture of predators, *Chilocorus nigrita* was released on the pumpkin harboring the scales for mass multiplication of the predators (Daniel, 2003).

White flies / Black flies (Aleyrodidae)

Aleurocanthus sp.

This aleyrodid is closely related to the citrus black fly, *A. woglumi*, and they infest only the leaflets of areca palm. Their population is high on young areca plantations in parts

of Dakshina Kannada. The honeydew secreted by this insect invited colonization of sooty mould, which interfered with the photosynthesis of the palm. The colonization can be severe in young seedlings, which resulted in severe botching and drying of leaves (Daniel, 2003). Neem formulations (Nimbicidine and Mulineem) were evaluated at 0.2, 0.4 and 0.6% on areca palms of four years of age. Both the formulations were effective at 0.6 % concentration (Daniel, 2003).

Palm aphid, *Cerataphis brasiliensis* (Aphididae)

This is commonly known as palm aphid and they colonized the leaves, spindle leaves and inflorescence (Daniel, 2003). Natural enemies like *Paragnus yerbuiensis*, *Pseudaspidimerus* sp. and *A. octopunctata* werte recorded.

Grapevine thrips, *Rhipiphorothrips cruentatus* Hood (Thysanoptera: Thripidae)

They are widely distributed in India. They feed on a variety of host plants *viz.*, grapevine, pomegranate, crotons, rose, cashew, etc. Its incidence on arecanut is scattered. Puttarudriah and Channabasavanna (1956) reported the pest on arecanut in Tarikere and Bangalore (Karnataka) and Pillai and Kurian (1959b) recorded it in Ochira in Quilon district (Kerala). The dark brown adults and pinkish nymphs of the thrips occurred in groups in the lower surface of arecanut leaves and sucked the sap. Feeding marks appeared as silvery blotches (Fig. 8). Attacked portions of leaves turns brownish yellow and witheres away. Areca palms of all ages are infested by thrips and often the pest assumes serious proportions during summer in certain localized tracts.

Biology of the pest on arecanut was studied by Pillai and Kurian (1959b). The egg period varied from 3 to 8 days. The duration of the immature stages varies from 11 to 24 days. Total duration of life cycle ranged from 14 to 33 days. Spraying with malathion could successfully controlled the pest. An endoparasite, *Thripoctenus maculatus* Waterston (Hymenoptera: Eulophidae) attacked this pest.

Rhinoceros beetle, *Oryctes rhinoceros* L. (Coleoptera: Scarabaeidae)

This black beetle occasionally infests arecanut palms besides its normal host, coconut palm. Nambiar (1949) and Valsala (1958) found this beetle damaging the fronds of arecanut palms in West Bengal. In some cases, the adult beetles bore into the stem up to 60-90 cm below the crown exposing inner fibrous tissues (Kumar *et al.*, 1967). These beetles can be better managed by placing the pheromone trap @ one per two ha. These pheromone lures are available commercially. In addition to the exploitation of behavioral approach to manage the pest microbial pathogens were available to keep this pest under check. They are *Metarhizium anisopliae* and *Oryctes baculovirus*. The former was applied in the breeding ground and in case of *Oryctes* baculovirus the beetles can be inoculated with virus and

then released to perpetuate the infection among the beetles in the filed.

Other foliage feeders include the spider mite, *Tetranychus fijiensis* Hirst (Daniel, 1977), the caseworm larvae (Venugopal and Venugopal, 1961) and hairy caterpillar, *Euproctis semisignata* Walk (Nair, 1975).

Hairy caterpillar, *Dasychira mendosa* (Hubner) (Lymantridae : Lepidoptera):

This hairy caterpillar infests the leaves, spindle and inflorescence of areca palms. This pest attack both the seedlings and the grown up palms. Ponnama (1989) surveyed 889 areca palms in Palode and observed that, this pest infested 19.5 per cent of the palms. Of this 14.6 per cent infestation was on spindle and 4.9 per cent on leaves. Incidence of the pest was found round the year with a peak in rainy season. The caterpillar scrapes the tender tissue in the lower portion of the spindle and the spindle drops down. They remain on the ventral surface of the leaves and feed voraciously on the unopened leaves, leaving behind only the midrib. Cotton, guava, pear, Chinese potato and cinnamom are the alternate hosts (Ponnamma, 1989). These caterpillars are managed by spraying carbaryl 50 % WP @ 0.01 per cent after cutting and burning the badly infested leaves.

INSECTS INFESTING INFLORESCENCE

Inflorescence caterpillar, *Tirathaba mundella* Walker (Lepidoptera: Pyralidae)

This lepidopteron caterpillar cause damage to areca inflorescence in pockets of Dakshina Kannada district (Karnataka) and Trichur district (Kerala) (Anonymous, 1962; Nair and Rawther, 1969).

Nature of damage

The female moth deposits eggs into the spadix through punctures made on the spathe by slugs or snails. The caterpillars on emergence bore into the spathe. They move towards the tip of the inflorescence and commence feeding on the tender rachillae and male flowers. In case of severe infestation the caterpillars bore into the tender buttons as well. They are very sensitive to light and they web together the terminal portions of the inflorescences with silken threads and throw out large wet masses of frass. As a result of the webbing, the inflorescence fails to exert natural pressure on the spathe and eventually the opening of the spathe is delayed (Fig. 9; Nair and Rawther, 1969).

Biology

The eggs are deposited on the under surface of the spathe. The egg period is 5 days. The full-grown larvae is greyish brown with a reddish brown head and measures 23-25 mm in length. The larval period lasts for about 26 days covering five instars. Pupation is in silken cocoons with a wet mass of frass inside the spathe. Pupal period lasts for 9-11 days (Fig. 10; Nair and Rawther, 1969).

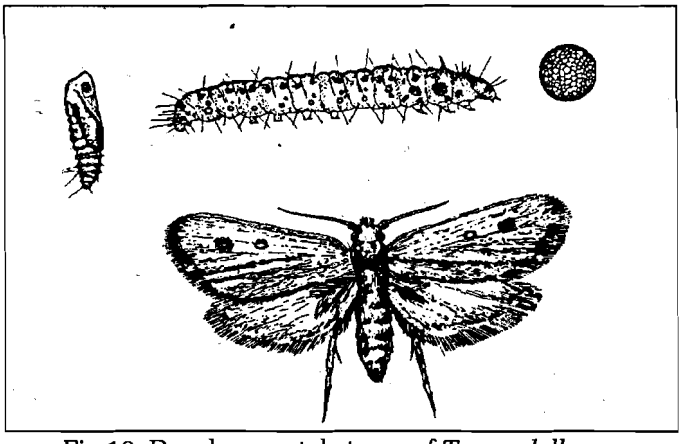

Fig.10. Developmental stages of *T. mundella*

Control

Spadices showing external indication of damage by slugs or traces of oozing out of brownish sap or fluid may be force-opened and if all the female flowers has been damaged, the inflorescence is removed and burnt. If the damage is only partial, the affected portions are removed and the inflorescence sprayed with 0.125% Endrex 20 EC (Anonymous, 1962) or 0.125% malathion (Anonymous, 1971a). Since injuries made by the slugs on unopened inflorescence act as a pre disposing factor for infestation of inflorescence caterpillar, control measures are to be taken against the slugs.

A new pest causing significant economic loss was noticed in Southern plains of Karnataka, which was identified as *Batrachedra arenosella* (Gowda *et al.*, 1999). These caterpillars feed on inflorescences. Removal and burning affected inflorescences and one or two sprays of insecticides like endosulfan (0.07%), quinalphos (0.05%), chlorpyriphos (0.04%), monocrotophos (0.05%) or phosphamidon (0.05%) can control the pest.

The slug causing damage to the arecanut inflorescence has been identified as *Mariaella dussumieri* Gray. There is a highly significant positive correlation between the slug damage and the caterpillar incidence on areca spathes (Anonymous, 1981) The slugs are controlled by either hand picking or poison baiting with a mixture of bran. Molasses or jaggery, lead arsenate and water (Anonymous,1962). The poison bait containing a mixture of bran and cement in the ratio 13:2 with a part of metaldehyde had been suggested (Anonymous, 1971b).

The red ant, *Monomonum graclilimum* Sm. feed on the young caterpillar of *T. mundella* (Anonymous, 1962). Lever (1937) noted the occurrence of *T. rufivena* Walk. on areca palm in the British Solomon Islands.

Pentatomid bug, *Halyomorpha marmoreal* (F.) (Pentatomidae: Hemiptera)

Tender nut drop considered a serious problem in some parts of Karnataka and Kerala, generally occurs during April- July (Chandramohanan and Shantaram, 1986). *Halyomorpha*

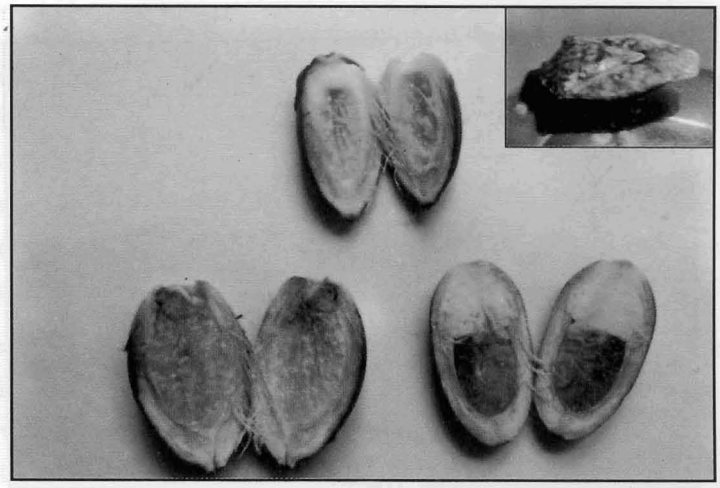

Fig.11. Pentatomid bug and nature of damage to tender nut

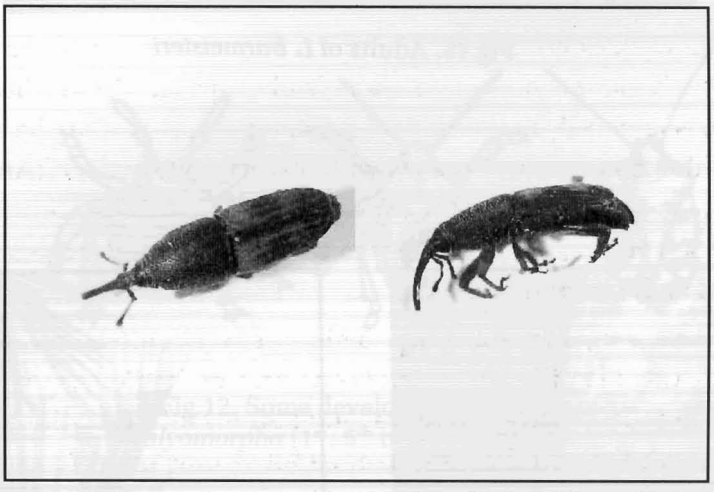

Fig.13. Adult weevil of *Diacalandra* dorsal (a) and lateral (b) views

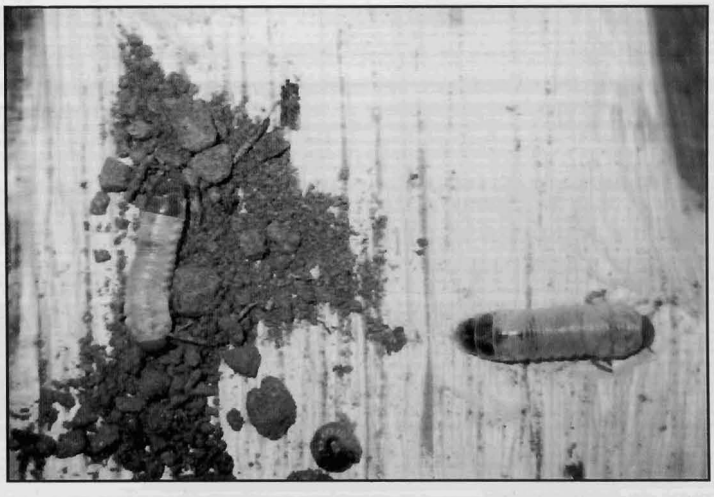

Fig.14. Larva of *L. burmeisteri*

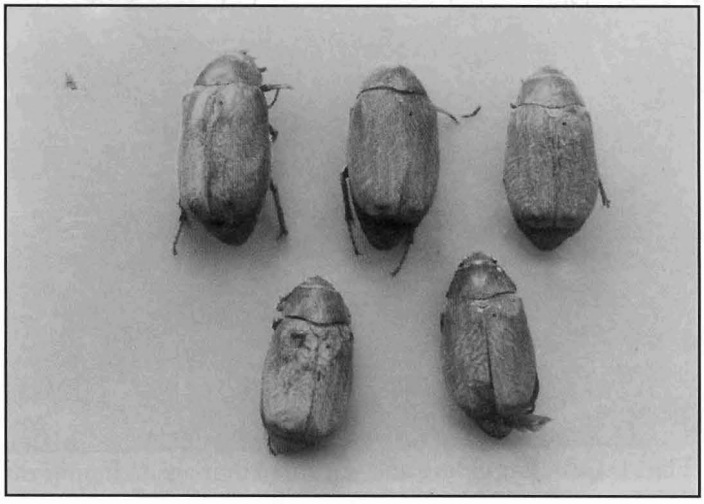

Fig.15. Adults of *L. burmeisteri*

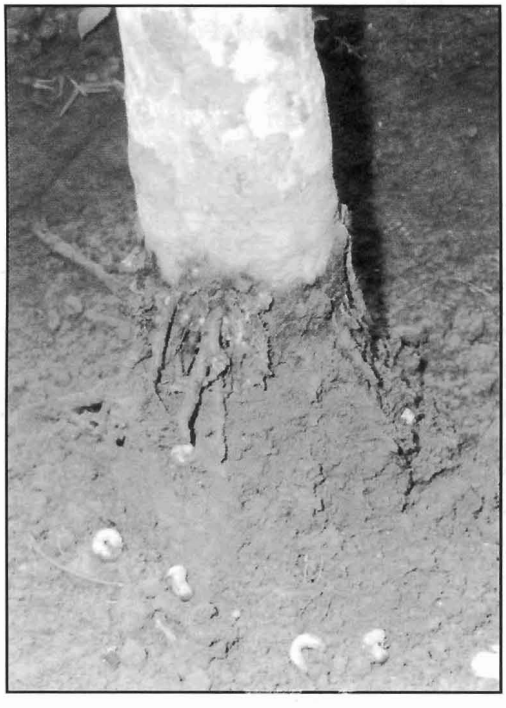

Fig.17. Damaged roots with grubs of *L. burmeisteri*

Fig.18. Root grub affected palm showing stem thinning and leaf yellowing

marmorea (F.) was observed to be responsible for tender nut drop in arecanut. This bug was observed to pierce tender nuts and suck the sap producing characteristic pinprick marks on the pericarp. Adult bug could feed on the sap of a single nut in a day, which causes drop in two days (Anonymous, 1985; 1990; Vidyasagar and Shama Bhat, 1986; Fig. 11). The biology of the bug has been studied (Vidyasagar, 1991). There were five nymphal instars with an average duration of 3.7, 6.1, 5.1, 6.5 and 9.3 days respectively (Fig. 12). The nature and extent of damage to arecanut and host range of this bug are also described (Vidyasagar, 1991).

The first incidence of the pentatomid bug on arecanut occurrs in March. The percentage of shed nuts showing *H. marmorea* infestation was maximum during June (29.1 per cent) followed by July, August and October (Anonymous, 1988). The incidence of the bug is found to become very serious during some years making it a major pest causing considerable loss to arecanut production.

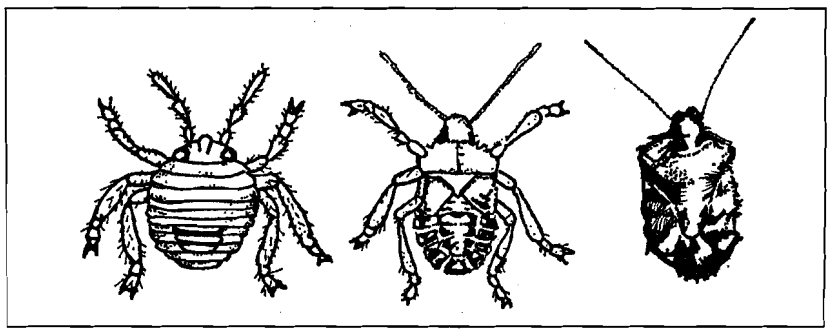

Fig.12. Some developmental stages of *Halyomorpha* (1st, 5th instars and adult bug)

Control

Spraying with fenvalerate, monocrotophos, dimethoate, endosulfan and methyl parathion was carried out. When the cost factor of three promising chemicals used in the field control trials was analyzed, endosulfan 0.05% was found to be the cheapest followed by methyl parathion 0.05% and fenvalerate 0.02% (Anonymous, 1990). The bugs were collected and destroyed from alternate host plants such as chillies, lady's finger and bittergourd. In case of severe infestation it was observed that spraying two rounds of endosulfan 0.05% during April – May and the second round after an interval of 45 days was effective.

Mealy bugs

The mealy bug, *Icerya aegyptiaca* Dougl. was noted by Puttarudriah and Channabasavanna (1957b) on arecanut from Karwar in Karnataka. Heavy infestation was noticed in isolated tracts. The stalks and basal parts of fruits in various stages of development are completely covered by mealy bugs. Infestation during the tender nut stage cause

immature nut fall. Natural enemies such as the adults and grubs of the coccinellid, *Rodolia* sp. and the Pteromalid parasite *Pachycrepoides coorgensis* kept the pest under check. Nair (1975) also reported the occurrence of *Pseudococcus citriculus* (Green) and *Rostrococcus iceryoides* (Green) in addition to *I. aegyptiaca* infesting arecanut inflorescence as well as leaves.

Perianth mite, *Dolichotetranychus* sp. (Acarina: Tenuipalpidae)

Perianth mite infestation results in severe tender nut fall in affected palms. The infestation is noticed extensively in areas around Trichur in Central Kerala. The mites are slender, orange coloured and seen colonized inside the perianth of tender nuts. As a result of the feeding activity, the nuts shrivells and later on fall off resulting up to 10% crop loss. The period of infestation is during November-May. Sadanandan and Antony (1973) suggested spraying of bunches with dimethoate and formothion @ 1 ml and 2 ml / litre of water respectively.

Scale insects

Three species of scale insects on arecanut inflorescence *viz., Gossyparia* sp., *Pinnaspis aspidistrae* Sign. and *P. strachani* Cooley have been reported (Nair, 1975; Nair and Menon, 1963). Adults and nymphs of *Ossyparia* sp. sucked the sap from inflorescence. They sometimes prevent pollination by covering the female flowers. *Pinnaspis aspidistrae* Sign. and *P. strachani* Cooley feed on the tender floral parts and cause premature flower and button shedding. Severe infestation resulted in complete drying of inflorescence.

Nut borer

Appanna (1959) mentioned about a lepidopteran borer of tender nuts of areca palm near Koppa, Chickamagalur district (Karnataka). The caterpillar is dark slate in color and the attacked nuts show webbed brownish excreta and smaller circular holes on the surface.

Red ants, *Oecophylla smaragdina* F. and ***Monomorium gracillimum Sm.*** (Hymenoptera: Formicidae)

These ants feed on the honeydew secreted by the coccids and aphids on the inflorescence. They checked the development of the spathe and such spathes do not open completely. The rachillae are netted together with the silken strands, for their harboring along with coccids. Ultimately the female flowers fall off and the inflorescence dries up. Nair and Menon (1963) reported them to be very serious on arecanut.

INSECTS INFESTING STEM

Stem weevil, *Diocalandra stigmaticollis* Gyll. (Coleoptera : Curculionidae)

This weevil was reported from certain pockets of Kerala and Mettupalayam, Tamil Nadu (Pillai and Kurian, 1959a; Anonymous, 1963; Naidu and Kumar, 1963). It infests

tender portions of the stem covered by the leaf sheath. When the leaves dropp off, the damage could be noticed on or above the nodes. The feeding of grub produced characteristic dents on the stem. The damage can be seen on the successive internodes. As the development of leaves is adversely affected, quite often leaves fail to develop further and the stem get weakened and is broken easily.

The larval development is spread over a period of 8 – 10 weeks and the pupal period was 10 – 12 days. The whole life cycle from egg to adult covered three months. The adult weevil is dark in color with faint blank patches on the pro thoracic region. The snout was long and pointed with a gentle inward curve. It was about 6.5 – 7.0 mm in length and 1.5 – 2.0 mm in width (Fig. 13). The grub is dull white in color and apodous.

The weevils gain entry through the tender leaf sheaths and lay eggs on the stem surface. Sunscorched or mechanically injured stem is more prone to infestation. Murthy and Hanumanthappa (1965) recommended spraying or dusting with contact insecticides like DDT or BHC for the control of this weevil. Murthy *et al.* (1965) recorded *D. frumentii* on the stem of arecanut from Mysore. Nair (1975) reported *D. stigmaticollis* on areca inflorescence in some parts of Kerala.

Shot-hole borer, *Xyleborus perforans* Woll. (Coleoptera: Scolytidae)

Seshadri (1968) recorded this polyphagous pest on arecanut and coconut from different parts of Dakshina Kannada. After entering through the basal portion of the stem, the pest bore upwards gradually. A large number of circular holes with extruding frass can be seen on the stem. When the damage is severe, the leaves turn yellow and the palm dries up. Maximum damage is seen during October-November. Painting of infested stem with contact insecticides like BHC or dieldrin checked the incidence of the beetle. *X. habercorni* was reported on arecanut from Mysore (Murthy *et al.*, 1965).

Redpalm weevil, *Rhynchophorus ferrugineus* F. (Coleoptera: Curculionidae)

The grubs of this weevil tunnel through the soft and exposed portions of the stem and crown. The incidence is more in neglected young palms. Pillai and Kurian (1959b) suggested injection of I per cent pyrocone-E for the control of the pest. This weevil can be managed by mass trapping using pheromone lure in bucket traps with food baits.

INSECTS INFESTING ROOTS

Root grub, *Leucopholis burmeisteri* Brenske and *Leucopholis lepidophora* Blanch (Coleoptera: Melolonthidae)

The root infesting scarabaeid white grub, *L. burmestrii* (Anonymous, 1967) and *L. lepidophora* (Puttarudriah and Channabasavanna, 1956) are the major pests on arecanut and are widely distributed in Kerala and the western ghat areas of Karnataka (Veeresh *et al.*, 1982). In addition to arecanut they feed on intercrops such as banana, yams, tuber crops, coconut (Veeresh *et al.*, 1982), sugarcane (Patil and Adusule, 1991a), rice (Patil *et al.*, 1986)

and groundnut (Patil and Adusule, 1991b). *L. burmeisteri* is the most common species infesting arecanut in Dakshina Kannada district.

A survey of the scarabaeids, *Leucopholis* spp. in arecanut plantations in Karnataka, India, was conducted in 1988. The results indicated that the pests were first noticed in 1964 and 47.12% of plantations were affected by 1988. The reduction in average yield was estimated to be 101.12 kg/acre. Control measures were being adopted by only 20.68% of growers (Gowda *et al.*, 1990).

Bionomics

L. burmeisteri has an annual life cycle. Emergence of adult beetles takes place during the premonsoon showers in May-June. On emergence they mate and the female beetles lay eggs in the loose soil around the root zones. The eggs are smooth, round and creamy white. Incubation period last for more than a month. During June-July large number of early instar grubs are seen on the top layers of soil. The larval period lasts for a few months. The larvae has a characteristic "U" shaped soft body with brown head (Fig. 14). The hind part of the body is smooth and shining and the dark body contents could be seen through the thin cuticle. The grubs when fully grown measure 50-60 mm in length. The pupation takes place in deep layers of soil and was completed in 35-40 days. The adult is a medium sized beetle having a chestnut brown colour (Fig. 15, 16).

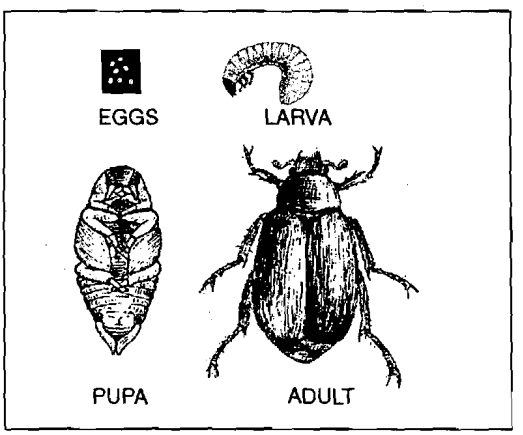

Fig.16. Developmental stages of *L. burmeisteri*

Population of the grub is seen in the moist soil from May-June till February-March. As many as 40-50 grubs are collected from the base of severely infested palms (Rao *et al.*, 1961). The water table in the garden determines the strata in which the grubs are found. In infested gardens with higher water table the grubs are seen in the top layers of soil. The incidence of the pest is more in ill-drained and low-lying clayey soils.

The root grubs feed on young roots of arecanut palm round the year and continuous feeding results in yellowing of leaves, tapering of stem and reduction in number of bunches.

The roots are damaged near the bole either by feeding on the tender roots from the tip or cutting them across at various points (Fig. 17). In severe cases of infestation the grubs feed on the entire bole region. When the grubs feed all the roots, the palm tends form pencil like stem below the crown with leaves turning yellow (Fig. 18), loses its grip on the soil and ultimately topples down. In the Maidan tracts of Karnataka, the white grubs are reported to be serious on nursery seedlings and young palms (Rao *et al.*, 1961). The visual symptoms of infestation in the nursery are the drooping and complete drying of the leaves within two to three days. The affected seedlings could be pulled out easily as they had an entirely damaged root system. Older palms continue to survive for a longer duration. Due to feeding of roots the leaves turn to a sickly pale yellow. Tapering of stem, reduction in leaf production, reduced yield, nut fall and production of less number of bunches are other symptoms of white grub infestation.

Control

Soil insecticides control white grubs effectively. Chlordane and heptachlor are recommended for the control of white grubs on arecanut (Anonymous, 1961; Rao *et al.*, 1961). In an insecticidal trial, application of Intox-'S' liquid (Chlordane) at the rate of 50 ml in 100 liters of water around the root zone was found effective in controlling arecanut white grubs (Rao *et al.*,1961). Heptachlor 20 EC at 6.3 ml per 10 litre water, BHC 5% dust @ 63 .0 kg per ha. (Rao, 1963) and phorate 10 G (Thimet) at the rate of 8g per palm was recommended (Anonymous, 1972). Dimethoate 5G (Rogor) granules at the rate of 30 kg per ha (Kumar, 1974) gave good control of grubs.

Results of field trials using systemic granular insecticides, soil amendments and contact insecticides showed that application of dimethoate (Rogor 5G) @ 30 kg per ha, *Pongamia* oil cake @ 2000 kg per ha, chlordane 5% dust @ 90 and 120 per ha, BHC 5% dust @ 120 kg per ha and quinalphos (Ekalux 1.5%) dust @ 90 and 120 kg per ha. twice in an year (May and November), for three years was effective in giving significant control of the grubs (Kumar and Daniel, 1981).

The commercially available oil cakes neem, karanj and mahua were evaluated, @ equivalent to 1000, 1500, 2000 and 2500 kg/ha. In addition 250 ml of Vitoxyl (2%), Nimbecidine (2%) and Achook (2%), and 85 g of fresh and dried leaves of *Vitex negundo* were evaluated for their efficacy against the grubs. Karanj oil cake, dry leaf powder of *V. negundo* and Achook (2%) were found to be effective (Padmanaban *et al.*, 1997). An integrated approach for the management of root grubs has been suggested (Veeresh *et al.*, 1985). This consists of application of insecticides during May-June, adult collection during emergence, intercropping with tapioca or sweet potato as trap crop to attract grubs and destruction of grubs by digging out trap crops in August- September.

In an attempt to identify an insecticide with enhanced bio action against *L. lepidophora* (II and III instars) four insecticides viz., carbosulfan, phorate, tefluthrin and chlorpyriphos were screened for their toxicity in the laboratory. On relative toxicity, carbosulfan was 4.2 times more toxic as compared to phorate followed by tefluthrin and chlorpyriphos in the case of second instar grubs. In the case of III instar grubs carbosulfan was 13 times more toxic than phorate. In field trials carbosulfan 6 G @ 10 grams / palm and phorate 10 G @ 10 grams/ palm caused a mean reduction of 66.76 per cent and 40 per cent respectively (Subaharan *et al.*, 2001). Though the efficacy of carbosulfan had been encouraging the data on pesticide residue of carbosulfan on crop matrix is essential.

The nematode cum bacterium culture DD-I36 *Neoaplectana carpocapsae* Weiser and *Achromobacter nematophilus* (Poinar and Thomas) was tested for the biological control of this pest. A suspension of 60- 100 nemas killed early instar grubs in five days. Soil treatment with 600-800 nemas killed grubs in 23 days (Anonymous, 1974).

Termites, *Odontotermes obesus* Ramb (Isoptera: Termittidae)

Termites infest seed nuts and seedlings in nursery during dry weather (Pillai and Kurian, 1959a; Rao *et al.*, 1961; Nair, 1975). Rarely they infest the bark of older palms. Normally termites infest seedlings through the collar region. The wilting of central shoot followed by the death of the seedling was the symptom of termite infestation.

STORAGE PESTS

The husked arecanut known as chali is generally stored in godowns for a period of one year in gunny bags prior to marketing. Improper processing and prevalence of moisture attracts the storage pests. The insects feed on the inner central core and these cause the appearance of holes on the surface of the nut. Ayyar (1940) was the first to report *Araecerus fasciculatus* infestation in stored arecanut. Later, Nair and Oommen (1969) published the results of a survey on storage pests of arecanut in Kerala. They listed 14 insects and mites and outlined the biology of the more important storage pests. Daniel and Kumar (1979) recorded 21 species of insects and mites infesting stored arecanuts in a survey of godowns in Mangalore (Table 2). Tender arecanut chips showed maximum resistance to infestation by insects (Nair and Oommen, 1969). Daniel and Kumar (1979) found that insect damage was maximum during rainy months when the atmospheric humidity was high and minimum during winter and summer months. The moisture content of the stored areca nuts varied from 8.0% to 28.3% on oven dry weight basis. Details on the life history and nature of damage of the important pests are given below.

Arecanut beetle, *Coccotrypes carpophagus* Horn (Coleoptera: Scolytidae)

Arecanut beetle is an important storage pest of arecanut. Beeson (1941) furnished the list of hosts of this insect. The damage was maximum during November. Nuts affected by

this beetle were not seen to develop secondary infestation by other insects. Damage even up to 100 per cent had been reported in a few cases (Daniel and Kumar, 1979). Life cycle was completed in 22-29 days (Oommen and Nair, 1968). Damage was caused mainly by adult beetles, which bore into the nuts and fed on the internal contents. The infested nuts showed holes of 0.6-1.0 mm in diameter.

Coffee bean weevil, *Araecerus fasciculatus* D. (Coleoptera: Anthribidae)

Both grubs and adults has been reported to damage stored arecanut (Ayyar, 1940). Infested nuts showed holes 1.5-2.5 mm in diameter. Unhusked nuts with intact perianth are not seen to have been infested by this insect even after one year of storage. Eggs are laid singly in small holes on the nut surface. The incubation period lasts for 5-6 days, larval period 2 I -23 days and the pupal period 7 days (Nair and Oommen, 1969). A parasite, *Anisopteromalus calandrae* (Howard) (Hymenoptera: Pteromalidae) was collected from this beetle (Daniel and Kumar, 1979).

Cigarette beetle, *Lasioderma serricorne* F. (Coleoptera: Anobiidae)

Cigarette beetle is a widely distributed storage pest infesting stored arecanuts in Kerala and Karnataka. The adult beetle is reddish brown with shining hairs. This beetle is found to infest stored arecanut almost throughout the year. The adults and grubs damage the nuts by making tunnels within the nuts and reduce them to powder (Nair and Oommen, 1969). It was observed that the life cycle of this insect is completed in 39-69 days. A predatory bug was collected feeding on the grubs of this beetle. The parasite, *A. calandrae* also is found on arecanuts infested by this pest.

Rice moth, *Corcyra cephalonica* (Stainton) (Lepidoptera: Galleriidae)

The caterpillars of this moth construct galleries of silk and frass over stored nuts, remain within and feed on them (Nair and Oommen, 1969; Daniel and Kumar, 1979). Nair and Oommen (1969) recommended the use of jute bags soaked in 1 per cent suspension of DDT or 0.1 per cent lindane for storing arecanuts and found that they remained free from insect infestation for six months. Phostoxin tablets used at the rate of 800 g per 1000 cm^3 are also effective in controlling stored arecanut pests.

VERTEBRATE PESTS

Squirrels

Squirrels feed on 3-5 months old tender nuts. The damage is more on arecanut in the Maidan tracts of Karnataka causing sometimes as much as 10-15 per cent loss. (Naidu, 1962). Nambiar (1949) reported nearly 20% crop loss in Assam during certain years. The control measures adopted by the farmers include shooting and setting up bait traps. Spraying of bunches with 5% solution of zinc phosphide for the control of squirrels had also been recommended (Naidu, 1962).

Rats

Rats usually feed on the tender nuts and rarely half mature nuts below perianth region. Baiting with zinc phosphide and fumigation burrows is commonly practiced for the control of rats. According to Pillai and Kurian (I959a) rats can be successfully controlled by zinc phosphide and anticoagulant rodenticides. The poison is mixed with cereal powder and kept in shallow containers in the crown or base of palm. Trapping, erection of physical barriers and application of chemical repellents etc. are other remedial measures. Avoiding shelter places in the gardens by clearing will be advantageous in reducing the incidence.

Table 2. Pests of stored arecanut

Name of the pest	Family	Reference
Araecerus fasciculatus DeG.	Anthribidae	Ayyar, 1940
Coccotrypes carpophagus H.	Scolytidae	Oommen and Nair, 1968
Lasioderma serricorne F.	Anobiidae	Nair and Oommen, 1969
Corcyra cephalonica (Stainton)	Galleriidae	-do-
Setomorpha rutella Zell.	Tineidae	-do-
Ephestia cautella (Walk)	Phycitidae	-do-
Tribolium castaneum Hest.	Tenebrionidae	-do-
Alphtitobius piceus 01.	-do-	-do-
Microcrypticus scriptipennae F.	-do-	-do-
Cryptolestes *pusillus*	Cucujidae	-do-
Tyrophague putrescentiae Schrank	Acaridae	-do-
Carpophilus mutilatus Er	Nitidulidae	-do-
Ahasverus advena Waltl.	Cucujidae	-do-
Attagenus gloriosae F.	Dermestidae	-do-
Carpoophilus pilosellus Mots	Nitidulidae	Daniel and Kumar, 1979
Thaneroclerus buquet (Lefebvre)	Cleridae	-do-
Sitoophilus *oryzae* L.	Curculionidae	-do-
Proceus sp.(?)depresses Woll.	-do-	-do-
Psocid sp	Psocidae	-do-
Pseudoscorpion	Pseudoscorpionidae	-do-
A mite (undetermined)	Cheyletedae	-do-

Birds

Woodpecker is another commonly seen avian pest damaging the arecanut stem in Kerala and Dakshina Kannada (Nair and Menon, 1963). The bird usualy pecked the stem tissues weakened by sun scorching and this hasteneds the deterioration of the tissues.

OTHER MAMMALIAN PESTS

The frugivorous bats (fruit eating) or flying fox occasionally cause loss by removing ripe nuts (Pillai and Kurian, 1959a; Daniel and Kumar, 1976). It is rather difficult to control this pest. Breaking their roosts by burning of sulphur in braziers under the roosting trees provided a temporary relief (Pillai and Kurian, 1959a). Nambiar (1949) reported damage by monkeys in Malnad areas of Dakshina Kannada and Uttara Kannada districts of Karnataka and Midnapur district of West Bengal.

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8. ALTERNATIVE USES OF ARECANUT AND UTILISATION OF BY-PRODUCTS

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INTRODUCTION

Arecanut is widely used for ages throughout South and South East Asia and the Pacific Ocean Islands. While its primary use has been as a masticatory, it has also found use among the local population in native systems of human and veterinary medicine, in religious and social functions and in fabricating farm and household articles. With the advent of modern systems of medicine, the use of arecanut for medicinal purposes steadily began to wane (Nayar and Annamalai, 1982).

The use of arecanut as a masticatory is also on the decline in the last few decades, with the incursion of modern ways of living among the rural people, particularly in south-east Asia. It has been in this context that studies on developing alternate and better uses for arecanut were taken up by the erstwhile Indian Central Arecanut Committee in the 1950's and the Indian Council of Agricultural Research with the Central Plantation Crops Research Institute (CPCRI), Regional Station, Vittal in the 1970's through many ad-hoc research programmes in various organizations/ Research Institutions like the Central Leather Research Institute, Chennai; Indian Drugs Research Laboratory, Pune; Central Food Technological Research Institute (CFTRI), Mysore; Department of Chemical Technology, University of Bombay; Oil Technological Research Institute, Anantapur and Punalur Paper Mills Ltd., Kerala with the funds provided by Karnataka State Agricultural Marketing Board (Anonymous, !982; Bhat, 1990).

In this chapter a brief review of the varied uses for which betel nut has been put to, in south and south-east Asia is given along with summaries of the work carried out on alternative uses of arecanut and utilization of various by-products/ raw materials of areca palm under the various schemes.

USES OF VARIOUS CONSTITUENTS OF NUTS

Chemical composition of the nut

The major constituents of arecanut are polyphenols, fats, polysaccharides, fibre and protein (Shivashankar et al., 1976; Table.1). The mineral matter includes calcium (0.05%), phosphorus (0.13%) and iron (1.5 mg/100g) (Anonymous, 1948). It also contains Vitamin B6 (286.9 mg %) and Vitamin C (416.2 mg%). The polyphenols, mostly flavonols, include

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about 10 per cent of (+) catechin, 2.5 per cent epicatechin, 12 per cent of (+) leucocyanidin, the remaining portion being complex flavonoids in varying degrees of polymerization (Nagarajan and Seshadri, 1961; Banerjee et al., 1961; CFTRI, 1961; Govindarajan and Mathew, 1963 and Mathew *et al.*, 1969).

Table 1. Concentration of chemical constituents of green and ripe areca nuts

Constituents*	Green nut (Kalipak stage)	Ripe nut
Moisture	69.4-74.1	38.9-56.7
Total water extractives	32.9-56.5	23.3-29.9
Polyphenols	17.2-29.8	11.1-17.8
Arecoline	0.11-0.14	0.12-0.24
Fat	8.1-12.0	9.5-15.1
Crude fibre	8.2-8.8	11.4-15.4
Total polysaccharides	17.3-23.0	17.8-15.4
Crude protein	6.7-9.4	6.2-7.5
Ash	1.2-2.5	1.1-1.5

*Expressed as percentage values calculated on dry weight basis.

Among the alkaloids present in arecanut, arecoline ($C_7H_{13}O_2N$) is the main and physiologically the most active one, varying from 0.1 to 0.67 per cent (Anonymous, 1948; Raghavan and Baruah, 1958; Dutta and Ditta, 1959). Other alkaloids present in tracer amounts are arecaidine ($C_7H_{11}0_2N$), guvacoline ($C_6H_{11}O_2N$), and guvacine ($C_6H_9O_2N$).

Changes in chemical composition with fruit development

Changes in chemical constituents of arecanut at different stages of maturity were studied by Mathew et al. (1964; Table 2). Polyphenols decrease with maturity and their higher concentrations present in the tender stages may help against infection. With maturation, the polysaccharides, fat and fibre contents increase. The free fatty acid (FFA) content decreases with maturity, indicating its use for biosynthesis of fat. Other workers have reported similar results (Raghavan, 1957; Kartha et al., 1959). In a few cases, the fat content increases upto the mature green stage, followed by a decrease (Banerjee *et al.*, 1961; Mathew *et al.*, 1964).

Tannins

Long before the chemistry of tannins was determined, the tannins in arecanut were used for dyeing clothes, rope etc., and for tanning leather in South-East Asian and Pacific Ocean countries. (Watt, 1889; Burkill, 1935; Baens, 1941; Brown, 1952).

Tannins are obtained as a by-product during the process of preparing immature betel nuts for masticatory purposes. In this, the immature nuts are husked and boiled in water or

Table 2. Composition of arecanut (South Kanara type) at different maturity stages

Composition	Stages of maturity of nuts				
	Very tender	Tender	Mature green	Semi ripe	Ripe
Average wet weight of fruit (g)	4.71	11.97	26.40	35.16	35.05
Moisture content of husk (%)	91.68	70.78	79.77	75.46	74.70
Average dry weight of husk (g)	0.22	2.43	3.38	5.25	5.40
Average percentage of husk (of total dry weight)	75.86	80.72	54.25	43.08	39.40
Moisture content of nut (%)	88.34	84.00	70.60	49.52	39.40
Average dry weight of nut (g)	0.07	0.58	2.85	6.94	8.31
Average percentage of nut weight (of total dry weight)	24.14	19.28	45.75	56.92	60.60
Total water extractives (%)	65.60	73.72	56.49	34.80	27.89
Polyphenols (as % tannins)	43.85	47.94	29.44	26.40	17.81
Alkaloids (as % arecoline)	Nil	0.06	0.14	0.20	0.22
Fat (%)	1.22	5.02	8.08	13.74	14.29
FFA (as % oleic acid)	1.40	2.13	0.88	0.65	0.45
Crude fibre (%)	1.97	6.32	8.23	10.75	13.42
Total polysaccharides (hydrolysable,%)	4.68	13.50	17.58	21.26	23.57
Nitrogen (%)	2.67	1.60	1.51	1.36	1.20
Ash (%)	3.77	3.31	2.52	1.71	1.50
Water soluble ash (%)	1.98	1.72	1.46	1.02	0.91
Water insoluble ash (%)	1.79	1.59	1.16	0.69	0.59
Alkalinity of soluble ash (ml of 1N HCl/100g)	4.00	3.50	2.52	2.75	2.50
Acid insoluble ash (%)	0.15	0.08	0.05	Nil	Nil

in the mother liquor left over from the earlier boiling, This liquor containing considerable quantities of tannins is known as chogaru or kali. The sediments found in the liquor when dried is called arecanut dust. The dust and chogaru are traditionally used as a masticatory or for tanning leather.

Raghavan (1957) found that tannic acid or gallic acid from immature nuts, when mixed with warm aqueous ferrous sulfate gave black writing ink of acceptable quality. Banerjee *et al.* (1963) have studied the physico-chemical characteristics of areca tannins as compared to wattle tannins. They compared the water extractives of tender arecanut, concentrated chogaru liquor, arecanut dust available as a by-product of arecanut processing and commercial Mimosa extract (Tables 3 and 4).

Table 3. Analytical data of different tanning materials

Analytic data	Tanning materials				
	Tender arecanut (air cooled)	Arecanut dust	Chogaru liquor	Mimosa extract	Aqueous extract of arecanut
Moisture (%)	15.2	13.47	48.28	10.35	11.71
Total soluble (%)	16.49	23.77	27.22	87.25	81.38
Tannin (%)	9.86	13.94	15.55	66.73	43.16
Non-Tannin (%)	6.64	9.83	11.67	20.52	38.22
Tannin/non-tannin ratio (%)	1.48	1.42	1.34	3.25	1.13
Insolubles (%)	68.31	62.76	24.50	2.40	6.90

Table 4. Acid and salt constituents of different tanning materials

Tanning material	pH of the liquor of 20° Bk strength	Weak acids mg. Eq l^{-1} of 100° Bk	Salts of weak acids mg. Eq l^{-1} of 100° Bk	Ratio of weak acids to their salts	Buffer index
Arecanut	4.6	55.0	285.0	0.19	2.22
Chogaru liquor	5.0	50.0	300.0	0.17	2.33
Arecanut dust	4.8	53.0	295.0	0.18	2.32
Mimosa extract	4.7	25.0	95.0	0.26	0.80

The areca tannins have a lower acid/salt ratio. As a result, they produce a mellower shade in leather. Being richly endowed with non-tannins (salt), they show a quicker rate of diffusion through leather. The hydrothermal stability of leather tanned by areca tannins is good. Chogaru liquor is not sufficiently good for tanning leather as the whole nut tannins, but it can still be utilized successfully for a wide range of leathers (Selvarangan, 1955; Govindarajan, 1968).

The above studies have shown that the condensed tannins of arecanut, could tan leather satisfactorily except for the colour (Anonymous, 1978a). Pilot plant studies (Anonymous, 1978b) showed that areca tannin extracted by steeping in water for four days (1 part nut: 4 parts water) had a pH of about 5.3 and that the total solubles accounted to 7.5 per cent, containing tannins and non-tannins in almost equal proportions. This material can be used as such or blended with myrob (1:1 or 1:2 ratio) for retaining chrome leather. Tannins extracted from defatted arecanut were of better quality. The percentage recovery of total solubles was also higher in this case (Table 5.)

Other uses for which areca tannins have been tested have been as an adhesive in plyboard manufacture (Narayanamurthi and Gupta, 1963; Rao, 1977) and as a textile dye (Anonymous, 1961, 1962, 1963, 1964).

Table 5. Constituents of water extracts of arecanut

Constituents	Tannin from whole nut	Tannin from defatted nut
Total solubles	75.0	88.0
Tannins	42.0	46.0
Non-tannins (Salts)	33.0	41.0

Studies carried out in the Department of Chemistry in Delhi University, showed that chogaru gave a satisfactory brown shade to cotton, which was fast to acid, alkali and washing tests. Chogaru was also found to be a good dye for wool and paper. It could produce a variety of shades with metallic salts as moderants (Anonymous, 1964). During the processing of raw nuts, the leuco anthocyanidins are polymerized to leucocyanidin, which is found in chogaru. These polymerised components are good inhibitors to the oxidation of sodium sulphate. However, the chogaru liquor was not an effective corrosion inhibitor. The Delhi University work has indicated the possibility of using leucocyanidin in the purification of sugar juice because of its action as an antioxidant.

Narayanamurthi and Gupta (1963) and Rao (1977) used chogaru for preparing tannin-formaldehyde adhesives for preparing polyboards. They tested a number of formulations on several species of timber for their glue-adhesion properties and found that chogaru possessed glue-adhesion strength in the dry and wet conditions according to IS: 303-1975 Specifications for plywoods meant for general purpose.

Another possible use of areca tannins has been as a natural food colour. They turn red at an alkaline pH, and with the increasing restriction in the use of synthetic food colorant, this possibility assumes greater importance. Two approaches are possible here (1) using natural pigments that are safe food colourants and (2) rendering the food color unabsorbable in the intestine by combining it with a macromolecular matrix. This line of study has been taken up by the Department of Chemical Technology, University of Bombay (Garde, 1982). According to this work, the areca polyphenolics can be fractionated into a single fraction of monomers and dimers and the polymers (highly polymerized substances - HPS) into another fraction. The HPS fraction is red in color. The results obtained were promising. Studies for optimizing the conditions to maximizing the yield of HPS, its purification for varying the extent of polymerization and to determine the effect of various environmental conditions on the yield and stability of the HPS fraction were pursued.

Studies by Raghavan (1957) revealed that maximum amount of tannin were obtained from arecanut during the first 24 hours of extraction at 28°C. Boiling only for a few minutes with sufficient solvent was necessary to extract maximum tannins.

Arecanut Fat

The nut contains 8-12 per cent fat. Solvents like hexane can extract fat from arecanut. Improper storage of raw nuts over prolonged periods lead to lipolysis. The diglyceride

distribution in the fat appears to be unusual and does not follow the predicted distribution pattern (Anonymous, 1978b; Shah, 1980).

Broadly, areca fat has characteristics comparable with hydrogenated coconut oil. It contains both saturated and unsaturated fatty acids. Areca fat can be made edible by refining it using an alkali (Anonymous, 1978a). The refined areca fat is harder than cocoa butter, and even better, due to its high myristic acid content. The fat can be softened by fractional crystallization using hexane and randomization using sodium methoxide, which gave products desirable for use as confectionery fat. Simple blending of areca fat with butter fat in 3:1 ratio followed by inter-esterfication of areca fat and cocoa fat at 1:1 ratio gave products acceptable in confectioneries. Limited studies showed that areca could be used as an extender of cocoa butter for various purposes. Further, sweets, savouries and biscuits prepared from refined areca fat were as good as those prepared from vanaspati fat (Reddy *et al.*, 1976). The analytical characteristics of areca fat are given in Table 6.

Table 6. Analytical characteristics of areca fat

Characteristics	Value (range)
Free fatty acids	Highly variable
Acid values (A.V)	Highly variable
Saponification values (S.V)	222 – 235
Iodine value (I.V)	17 – 26
Melting point (C)	38 – 42
Slip point (C)	38 – 39
Saturated fatty acids (%)	
Myristic acid	50
Lauric acid	18
Palmitic acid	14
Capric acid	1
Unsaturated fatty acid	
GS_3 (trisaturated)	60.2
GS_2 (monounsaturated disaturated)	22.0
GSU_2 (disaturated monounsaturated)	17.7
GU_3 (triunsaturated)	0.1

Defatted and detanned Supari

Scented supari has been prepared using both defatted and detanned arecanut. Normally for extracting tannins and fats, the nuts have to be crushed before extracting them with water or hexane, and the crushing and extraction make the arecanut somewhat softer, and this has sometimes been found to adversely affect the consumer acceptability of such scented supari. However this seemed to have become an adverse factor only in the case of detanned arecanut and not in defatted arecanut.

Alkaloids

As early as in 1886, it was discovered that the active principle of the arecanut was alkaloidal in nature and since then six alkaloids like arecoline, arecaidine (arecains) guvacine, guvacoline, isoguvacine and arecolidine (choline) have been identified which, probably contribute to the narcotic and antihelminthic properties of the nut. The total alkaloids of mature dry arecanut are about 0.35%. The stimulant action of arecanut has been attributed to the presence of the alkaloids, particularly arecoline. The well-known property of astringency, during mastication of the nut, may also be due to the presence of the tannin-alkaloid complex in the fruits.

Of these alkaloids, arecoline and arecaidine are present in the highest concentration, the remaining bases occur in very small amouts. Arecoline is the most important alkaloid of the group and occurs to the extent of 0.1-0.5%. Arecaidine is present to the extent of about 0.1% (Table 7).

Table 7. Arecanut alkaloids

Base	Formula	Melting points				
		Base	Chloro platinate	Chloro aurate	HBr	B.HCl
Arecoline	$C_8H_{12}O_2N$	B.p., 209	176	Oil	170-1	157-8
Arecaidine	$C_7H_{11}O_2N$	223-4	234-5	200	248-9	257-8
Guvacine	$C_6H_9O_2N$	271-2	233	197-9	280	316
Guvacoline	$C_7H_{11}O_2N$	27	211	-	144-5	121-2
Isoguvacin	$C_6H_9O_2N$	220	235	198-200	-	231
Arecolidine	$C_8H_{13}O_2N$	110	222-3	219-220	268-71	250

PROCESSING

Arecanut is consumed in raw as well as processed form. Different methods are practiced in States of India and the pattern of chewing product also vary. In different states it is used as fresh nut, chali or tender nut processed types (Jayalakshmi and Mathew, 1982; Shivashankar et al., 1976).

Fresh nuts are consumed in Assam and Kerala. The nuts in fresh, moist form is preferred by people of this area. They follow crude methods of preservation by steeping in water or in thick layers of mud. In Kerala such preserved nuts are called 'neetadaka' which has mild off-flavour. Chemical preservation with a mixture of metabisulphite and benzoate at acid pH has been developed, resulting in storage in good condition (Mathew *et al.*, 1963).

The most extensively used commercial type of arecanut is prepared by drying ripe nuts after dehusking (Fig. 1). This is called as 'chali' or 'kottapak' being most popular form in Karnataka and Kerala. Ripe nuts are generally dried for 35-40 days in the sun on flat

surfaces (Fig. 2). Depending on the size and quality grades are made and marketed. The well known grades are 'moti', 'srivardhan', 'jamnagar' and 'jini' (Fig. 3). Mecahanical through-flow driers are available for making chali. In such systems drying takes place for 60-70 hours (Nambudiri *et al.*, 1963). A dehusking devise has been developed to remove husk from dry arecanuts at CPCRI (Fig. 4; Bangali Baboo, 1980). Several such dehusking machines have also been developed by private enterpreuners. Another important form of arecanut is the tender nut processed red type called 'kempadike' or 'kalipak'. This is made from 6-7 months maturity fruits (Fig. 5). this is common in malnad areas of Karnataka. The green husk from harvested fruits are removed manually (Fig.6). After dehusking the nuts are cut into pieces and boiled in water (Fig.7) or dilute extract from a previous boiling for 2-3 hours and coated with 'kali' solution which predominantly contains polyphenols. The boiled nuts are then removed from boilers and sundried (Fig. 8). Oven drying is also practiced by some farmers. Depending on the size and quality the nuts are graded (Fig. 9). This type of arecanut is usually used for making scented supari.

PHARMACOLOGICAL USES

In several native systems of medicine, arecanut is assumed to provide several beneficial effects on digestion, strengthening of gums and stopping of bleeding etc. In Ayurveda, arecanut was long considered to have medicinal properties. Vagbhata's (4th Century AD) reference to arecanut is probably the earliest in any text. He describes its use in the treatment of leucoderma, leprosy, cough, fits, worms, anemia and obesity. It was also used as a purgative, appetiser, stimulant and as an antihelminthic. Work on pharmacological aspects of arecanut was carried out at the Indian Drugs Research Institute, Pune, and Central Drugs Research Institute, Lucknow. The pharmacological works carried out earlier were reviewed by Mujumdar *et al.* (1982). Some work was taken at Bombay University (Garde, 1982) for preparing chewing gum and toothpaste based on arecanut. Encouraging results have been obtained in preparing chewing gum and toothpaste using arecanut extract.

Carcinogenic activity

The incidence of laryngeal carcinoma is high in India and is the highest in Assam. Various etiologic factors like smoking, chewing of tobacco and betel nut have been cited as possible contributors. Betel nut chewing is least in Punjab, where incidence of laryngeal carcinoma is only 1%, but this increases towards the southern and eastern parts of India, and is very common in Assam where betel nut chewing is rampant. Consumption of pan masala, a widely prevalent habit even among those who refrain from smoking or tobacco use, was observed to increase the induction of benign and malignant tumors in different organs, whether used plain or laced with tobacco, indicative of its carcinogenic or co-carcinogenic influence in habitual users (Nigam *et al.*, 2001).

Fig.1. Dehusking of dry ripe nuts

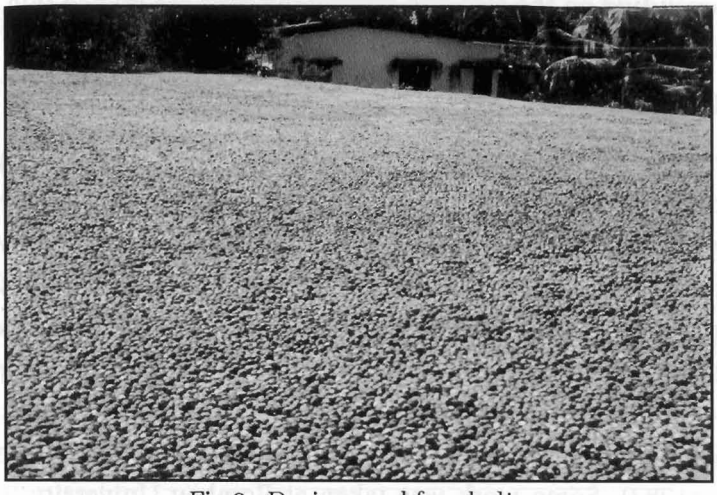

Fig.2. .Drving yard for chali

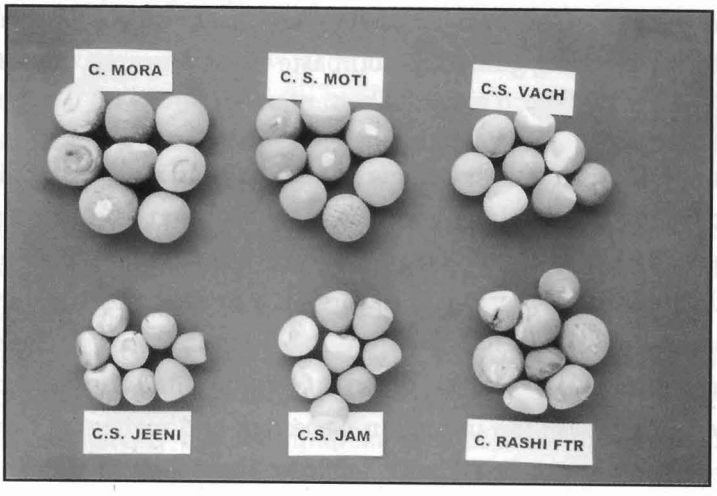

Fig.3. Grades of chali

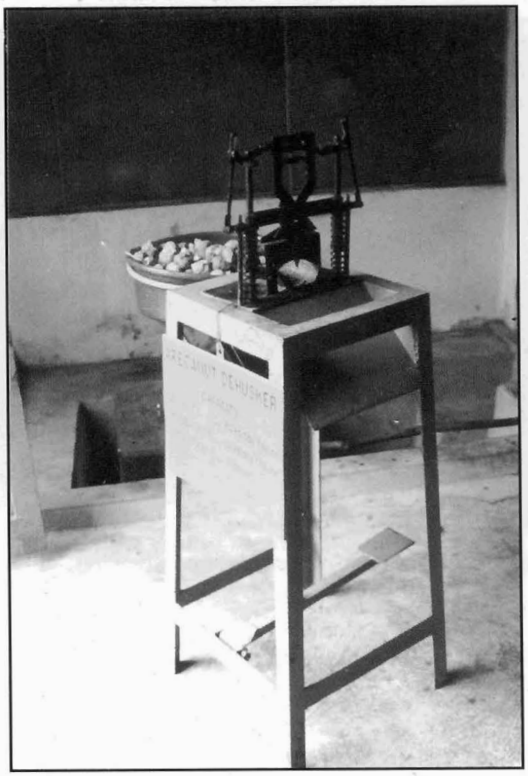

Fig.4 Dehusking machine

Fig.5. Harvested tender nut bunches

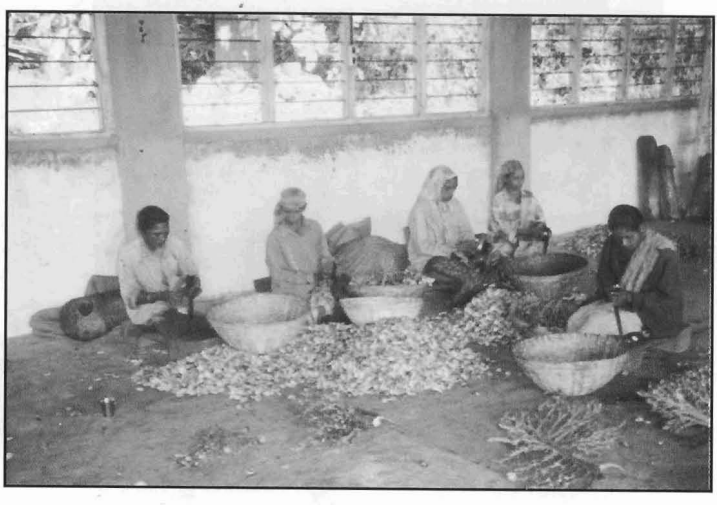

Fig.6. Dehusking of tender nuts

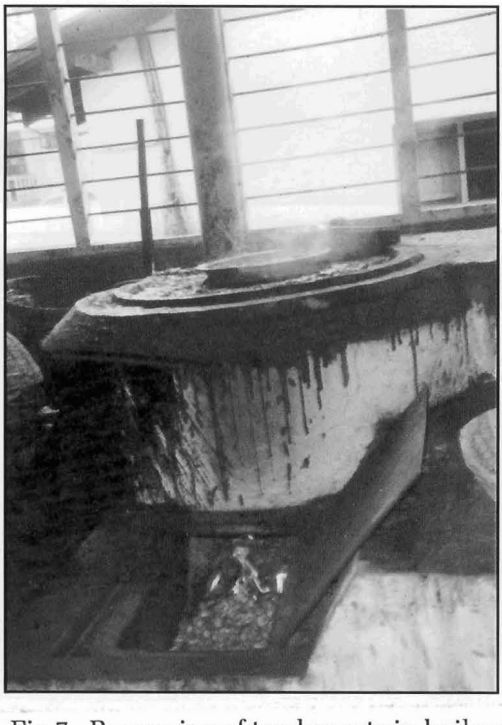

Fig.7. Processing of tender nuts in boilers

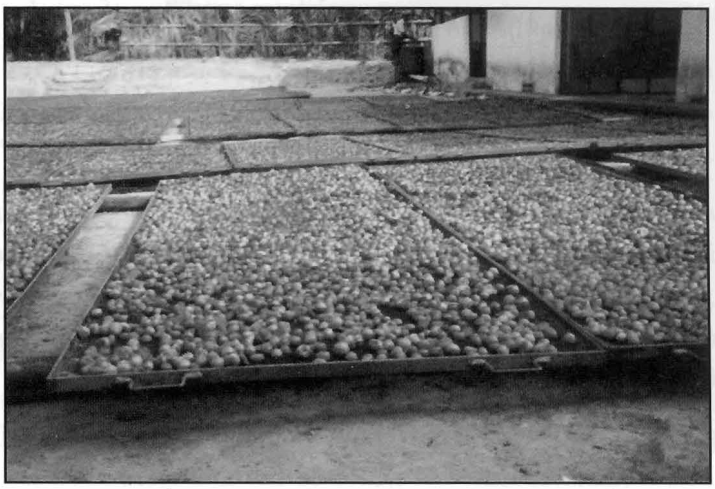

Fig.8. Drying of tender nuts after processing

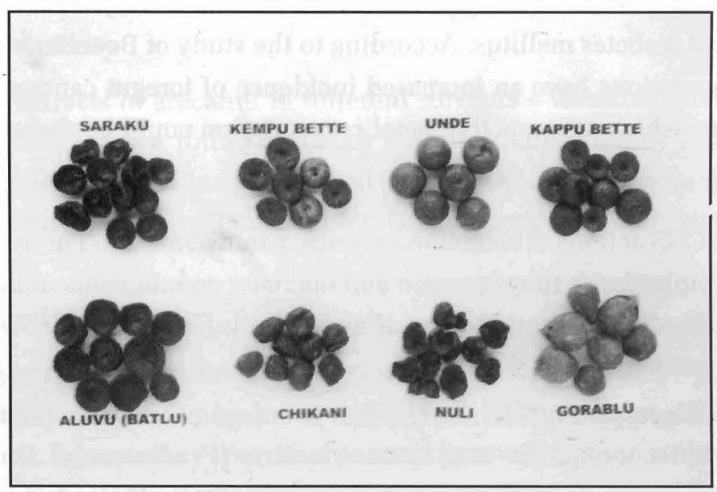

Fig.9. Grades of tender nut (Kalipak)

The mutagenicity of betel quid, arecoline (the main alkaloid in areca nut) (Jeng *et al.*, 1999; Dave *et al.*, 1992), arecaidine (a metabolite of arecoline) (Shirname *et al.*, 1984) and N-nitrosoguvacoline (the only N-nitrosamine product of arecoline) (Wang and Peng, 1996) has been reported. One of the nitrosamines of arecoline, 3- (methylnitrosamino) propionitrile (MNPN) is a powerful carcinogen in rats (Bagwe *et al.*, 1990).

Calcium hydroxide in the lime used by betel quid chewers, in the presence of areca nut forms reactive oxygen species, which might cause oxidative damage in the DNA of buccal mucosa cells of betel quid chewers (Nair et al., 1990) and cytogenetic damage (Nair *et al.*, 1992). Jeng *et al.* (1994) indicates that the cytotoxic effect of arecoline is due to glutathione depletion and not due to attack of oxygen free radicals.

Studies by Tsai *et al.* (1997) indicate that the cytotoxic and cytostatic effects of arecoline on oral mucosal fibroblasts could be modulated by changes in the cell density, serum concentrations and incubation time. Chang *et al.* (1998) concluded from their studies that arecoline is a cytotoxic agent and not genotoxic.

Hypoglycemic activity

Arecoline at 0.05 – 0.25 mg per kg body weight dose caused hypoglycemia (27 – 42%) and at 0.5 – 1.0 mg per kg dose produced hyperglycemia (23 – 29%) (Lang and Rigo, 1928). Arecoline hydrochloride at 0.5 mg dose decreased blood sugar level. Arecoline is known to cause hyperglycemia in normal rats and hypoglycemia in adrenalectomised rats (Gurin and Bagritsevich, 1972). Arecoline has hypoglycemic effect at low doses and hyperglycemic effect at high doses. However it has no significant effect on alloxan induced diabetes even though it reduces blood sugar levels (CPCRI, 1983). Mannan *et al.* (2000) found that betel nut usage was related to increased glycaemia in females and may contribute to the risk of developing type-2 diabetes mellitus. According to the study of Boucher *et al.* (1994), betel-nut chewing populations have an increased incidence of foregut cancers related to betel-nut nitrosamines, which suggests that betel consumption could be diabetogenic.

Central nervous system

(1) The CNS actions of arecoline are muscarinic in nature. The actions of arecoline are biphasic, as they increase and decrease spontaneous motor activity, water and food consumption as well as food reinforcement at low and high doses respectively.

(2) The depressant action of arecoline is antagonized by scopolamine but not by methylscopolamine and mecanylamine (Pradhan and Dutta, 1970). The depressant action of arecoline is of parasympathetic type (Neischulz and Schmersahl, 1968).

(3) Arecoline inhibits conditioned avoidance responses (CAR). Arecoline is a purely convulsant drug. The convulsions produced by arecoline are cholinergic (Herz, 1962; Herz and Yocoud, 1964; Nikiforov *et al.*, 1968; Stern, 1968; Peciffer and Jenny, 1957).

(4) Arecoline administered by intracerebroventricle route in unanaesthetized cat evoked emotional, behavioral and autonomic changes as well as motor phenomena with convulsions suggesting central muscarinic cholinoceptive site and action (Belesin *et al.*, 1974).

(5) Arecoline was shown to induce aggressive behavior in unanaesthetized cats (Belesin and Samardzic, 1979).

(6) The antinociceptive action of arecoline is reported (Herz, 1962).

(7) Arecoline penetrates the blood-brain barriers like other muscarinic drugs (Olds and Domino, 1969). Arecoline is known to prevent halothane induced shivering and delays the return to normothermia (Nikki, 1968;1969). Arecoline evokes muscarine like activating response on the electroencephalogram of enecephaleisole preparation of the cat. The activation response was not affected by addition of atropine methyl nitrate (Reiehl *et al.*, 1962).

Parasympathetic action

Arecoline produces both the muscarinic and nicotinic actions of acetylcholine. As a result, bradycardia, hypotension, increase in intestinal tone salivation and sweating are produced. These actions are antagonized by atropine (Leslie, 1965). Arecoline increases the tone and rhythm of the smooth muscles of alimentary canal. At presynaptic sites, arecoline appears to be useful for liberation and maintenance of neurotransmitter (Semenov and Krylov, 1979).

Cardiovascular Activity

All crude extracts of arecanut in different solvents – water, alcohol, acetic acid and calcium hydroxide – were found to cause capillary constriction (Sirsi et al., 1963). Cardiovascular effect of arecoline is mediated through the cholinergic system. It is effective by both subcutaneous and intravenous routes. Cardiac depression is brought about through vagal stimulation.

Urine and electrolyte secretion

Arecoline hydrochloride (1.25 –3.0 mg/kg subcutaneously) produced marked natriuresis and chlorouresis in hydrated dogs (Williams and Carter, 1965). This action is purely muscarinic. It has some direct effect on renal haemodynamics, as it affects the effective renal plasma flow. Arecoline increased Na, K and osmolity of urine without increasing the urine volume (Avrunin and Carter, 1967).

Ocular effects

Miotic effect of arecoline has been known for a long time (Fracassi, 1921). This effect is muscarinic in nature. Areca alkaloids accelerate the regeneration of visual purple. The alkaloids are supposed to promote the regeneration of rhodopsin in vivo but not in vitro. This action is probably due to acceleration of rhodopsin regeneration by activation of the functional components other than the outer segments of the rod cells (Kmilov, 1936; Kumori, 1961; Lee, 1957; Toida *et al.*, 1955; Young, 1933).

Antifertility activity

In male white rat, arecoline causes morphofunctional changes such as stimulation of hormogenesis and disruption of spermatogenesis (Rafaelskaya, 1980).

Other metabolic effects

Arecoline at lower doses depresses glycogen mobilization in toad liver. This action is reversed at higher doses (Kiyohara, 1931). Arecoline decreased lipase contents of arterial blood, with retention of lipase in the kidney (Sharilkova and Rapoport, 1939). It causes a prolonged decrease in creatine content in the pigeon muscle.

Arecoline did not affect either the Na^+-K^+ ATPase or $Mg2^+$-ATPase activity, while glutathione significantly inhibited striatal Na^+-K^+ATPase without affecting Mg2+- ATPase. This effect was partially reversed with arecoline. Thus arecoline may activate the pentose-shunt mechanism like ascetylcholine (Von Schwarzenfeld *et al.*, 1974).

Direct injection of arecoline into the adrenal gland resulted in increased secretion of adrenaline (Houssay and Molineli, 1926). Arecoline appreciably lowered the concentration of ascorbic acid in the adrenals of rats receiving reserpine (Gurin and Loginov, 1969). This action could be explained as the excitation of central m-cholino reactive structure, which activates the hypophysio-adreno cortical system. Arecoline increases excretion of CO_2 and H_2O and absorption of oxygen in rabbits (Preobrazhenskii, 1929).

It diminishes the rate and amplitude of phrenic nerve action potential. Application to medulla oblongata, through vertebral artery, results is expiratory aponea (Ger, 1967). Arecoline hydrobromide is used in an antisnoring composition, which was formulated into gargles and tablets (Khoe, 1975).

Structure- activity relationship

Of the six pyridine alkaloids present in arecanut, arecaidine and its methyl ester, arecoline have received the greatest attention as possible carcinogens. Each reacts with cysteine, both in vivo and in vitro, to produce a common cysteine â-alkylation adduct. The cysteine adduct of arecoline has lost its methyl-ester grouping, an observation that is reflected in the ready hydrolysis by lime of arecoline to arecaidine. This indicates that arecaidine is probably a more likely carcinogenic principle than arecoline (Ashby *et al.*, 1979).

Arecoline bears a structural resemblance to nicotine. Arecoline is pharmacologically active in its protonated form. Arecoline hydrobromide, arecoline methyliodide, arecoline hydrochloride are parasympathetic in nature. The $-COOCH_3$ group at C_3 position in the pyridine ring is responsible for the parasympathetic action. The arecoline hydrochloride was more potent parasympathetic agent than arecoline methyl iodide (Tsarev, 1952). Both synthethic as well as natural arecoline hydrobromide were equipotent for its antihelminthic activity (Tsarev, 1952;1953;1956; Fecoktistov, 1953).

Antihelminthic Activity

Arecanut decoction (1 in 10 dilution) as well as arecoline and its salts have been found to be effective in taenia infections. Arecoline is reported to be useful in infections like fasciolopsian cestode, ascariasis, heterales and Rallietina sp. Areca is used in veterinary practice as a vermifuge for tapeworm and roundworm in dogs (Goodman and Gilman, 1975; Mujumdar *et al.*, 1982).

ARECANUT HUSK

The husk is the outer cover of the areca fruit and constitutes 60-80 per cent of the total volume and weight of the fruits (fresh weight basis). About 1,00,000 tonnes of dry husk are estimated to be available annually in India alone. It is now largely being wasted in its use as an inferior fuel and mulch. It was used in Indo-China and the Philippines for toothbrushes (Brown, 1952; Anonymous, 1958).

The biochemical and physical properties of the husk have been studied by Baruah *et al.* (1957) and at the Jute Technology Research Laboratory (JTRL), Calcutta (Anonymous, 1973). The husk can be anatomically divided into three zones, viz., (1) the outer epidermal layer covered with the cuticle, (2) the middle layer that encloses the fibres; and (3) the hard and stony inner layer depressed to the nut.

Husk fibre

The husk fibres are predominantly composed of cellulose with varying proportions of hemicellulose, lignin, pectin and propectin. The fibres adjoining the inner layers are irregularly lignified groups of cells called 'hard fibres' and the middle layer below the outermost layer is soft fibre. The total hemicellulose content varies with development and maturity; the mature husk contains less hemicellulose than the immature ones. The lignin content increases proportionately with development till maturity is reached. The biochemical constituents of husk are given in Table 8 (Baruah et al., 1957; Govindarajan, 1968).

At the Jute Technological Research Laboratory, Calcutta, the physical properties of areca fibre were studied and compared with those of jute (Anonymous, 1973). The average filament length of areca husk fibre was very short (2.4 cm; C.V 30%) compared to the filament in jute yarn (68 cm; C.V 75%). Their tenacity, fineness and textural and torsional

Table 8. Biochemical constituents of husk

Constituents	Percentage (range)
Pectin	1.5-3.6
Protopectin	1.5-2.1
Hemicellulose	35.0-64.8
Lignin	13.0-26.0
Furfuraldehyde	18.8
Ash	4.4

rigidity were also studied. The areca husk fibre consists mostly of two types of filaments, one very coarse and the other very fine. The coarse ones are about 10 times as coarse as those of jute, and the fine ones are similar to jute fibre. Spinning trials with standard jute and coir machinery were not quite successful. However non-woven fabric, using synthetic rubber latex as bonding agent at 8 per cent concentration was prepared. Based on the various tests, JTRI proposed that areca husk fibre could be used for making items such as thick boards, fluffy cushions and non-woven fabrics (Ghosh *et al.*, 1975).

Retting trials for extracting the fibre have shown that perceptible softening could be obtained after three weeks of soaking. The fibres can be extracted later by beating with a mallet. Baruah *et al.* (1957) found that pectinolytic bacteria were more effective than hydrolytic agents for rapid softening of the husk and also that the quality and nature of the fibres depended mainly on cellulose content and non-cellulose encrustations.

Hardboards and plastics

Several studies have been carried out, particularly in the Forest Research Institute, Dehra Dun, to find out if arecanut husk could be utilized for preparing hard boards and plastics (Narayanamurthi, 1957; Narayanamurthi and Singh, 1964).

Narayanamurthi *et al.* (1947) studied the preparation of hard boards from areca husk by Asplund process. Insulation and hard boards of satisfactory quality were prepared by a process of defibration or hydrolysis with weak acid or alkali at the Forest Research Institute, Dehra Dun (Anonymous, 1952). The boards compared favourably with standard foreign boards like Masonite with respect to thermal conductivity, thickness, density and strength properties, but water absorption and swelling properties were not satisfactory.

Narayanamurthi and Singh (1961a, 1961b, 1964) developed several processes for preparing fibreboard and plastic boards from husk. Simple treatments of the husk followed by oil tempering with Cashew Nut Shell Liquid (CNSL) and adding furfural and aniline, to the mass, gave boards of increased strength and less water absorption. The preparation of plastics by thermal condensation with 20 per cent sodium thiosulphate and furfural was found to be the best method due to condensation of colloidal sulphur. The boards compared

favorably with oil tempered hard boards and filled phenolic plastics, though their modulus of elasticity was slightly lower than that of typical PF plastics. The boards had good microbial resistance and better properties than those made from bamboo. Chemical pulping of the husk and cold and hot setting adhesives could also make hard boards with satisfactory strength properties.

Plastics and hard boards of satisfactory strength and water repellant properties can be made from areca husk; but so far, these processes have not been commercially exploited. The insulation wool produced by beating air-dry husk with wooden mallet compares favorably with respect to thermal conductivity, moisture content, density of packing etc., with standard products like palcowool, defibrated teak bark and granulated cork (Anonymous, 1952; Raghavan and Baruah, 1957). Its usefulness in thermal insulations, acoustic correction, packing etc., appears to be promising.

Husk can be processed into insulation wool and felt in admixture with jute and caddles (Raghavan and Barauah, 1957). Industries Service Institute, Shillong (Megalaya), has developed some industrial uses for the arecanut husk. It was found that the fibre could be used as a cushioning material, a substitute to cotton wool and as a complimentary material to coir. It was used for making rubberised mattresses and fibreboards. Soft cushion pads made from spongy fibrous mass obtained by boiling the green husk with alkali and defibrated compared well with cushion pads made with imported material and that these could be used as packaging for books, for making cushioned envelopes, soft boards etc. (Anonymous, 1962; CFTRI, 1962).

Pulping and paper boards

The first work on preparing paper from arecanut husk was carried out during the early 1920's (Anonymous, 1922). During the 1950's and 1960's, more work was done on this aspect (Singh and Guha, 1960; Subramanian and Govindarajan, 1962; Guha *et al.*, 1963). Broadly, these have shown that brown wrapping papers in satisfactory yields and quality could be prepared from blends of arecanut pulp and bamboo or banana pseudostem pulp.

In subsequent studies carried out at the FRI, Dehra Dun, sulphate pulps prepared from digesting the husk, had fibre length of 0.96 mm, fibre diameter of 0.0196 mm, hot water solubility of 19.7 per cent, and lignin content of 30 per cent and pulp yield of 40.4-57.5 per cent (Anonymous, 1976a). The strength properties were not satisfactory for producing kraft wrapping, but brown wrapping paper with improved properties could be prepared when areca husk was mixed with jute or bamboo pulp (Table 9; Singh and Guha, 1960).

Studies carried out at CFTRI, Mysore (CFTRI, 1962; Subramanian and Govindarajan, 1962) in collaboration with Mandya National Paper Mills showed that areca husk when chemically pulped by soda cooking process with 17.5% NaOH in the edge runner, gave

Table 9. Properties of arecanut husk pulp sheets mixed with jute and bamboo pulps

Properties	Arecanut husk pulp sheets	
	Mixed with jute sticks and pulp (40-80 %)	Mixed with bamboo pulp (40-80 %)
Breaking length in m	6220-8448	4650-5000
Tear factor	92-103	124-143
Burst factor	32.3-43.1	27.5-32.1
Folding endurance	131-346	68-255

pulp material with properties of ordinary kraft paper. However, bleaching of pulp could not be done with sulphite process, but lighter and brighter pulp was achieved. Paper produced from mixing of beaten banana stem pulp (25%) to areca husk pulp, was found to provide strength equal to that of ordinary kraft paper (Table 10).

Table 10. Properties of paper produced from areca husk pulp mixed with banana stem pulp (25%)

Properties	Paper from areca husk pulp mixed with 25% banana stem pulp	Ordinary kraft paper
Breaking length in m	3133.0	3779.0
Tear factor	76.5	77.0
Burst factor	19.1	17.5
Folding endurance	73.0	70.0

In 1975, pilot plant level studies carried out at the Punalur Paper Mills Limited, Kerala (Anonymous, 1976b; CPCRI, 1974) confirmed the earlier finding that areca husk could be pulped chemically at 17°C for 4 hr giving 45-50 per cent yield. The pulp was short fibred and could produce paper of only low bursting strength and break factor. When the areca pulp was blended with bamboo pulp (3:1 ratio), the kraft paper made with it possessed physical properties comparable to paper made with pure bamboo pulp. A pilot plant for producing low-grade wrapping paper using an admixture of areca pulp (60%) and bamboo pulp (40%) have been developed (Anonymous, 1977; Guha *et al.*, 1963). All the studies have shown that it is difficult to bleach the paper made from areca husk pulp.

The data would indicate that while kraft paper of acceptable quality can be prepared from areca husk (Table 10), the high cost of transporting husk to the factory and the high amount of chemicals required for digesting the husk are factors to be reckoned with in exploiting it commercially.

Other possible uses

Areca husk can be a good source of furfural. When distilled with acid at high pressure and temperature, the husk yielded 5.5 per cent furfural (Anonymous, 1952; Singh, 1956). The husk contains about 18 per cent furfuraldehyde (Raghavan and Barah, 1957).

Preliminary investigations carried out at the Indian Drugs Research Laboratory, Pune, (Anonymous, 1981) revealed that the husk upon acid hydrolysis followed by neutralization and precipitation in ethanol, could yield 2-3 per cent xylose. Xylose is a monosaccharide and xyletol derived from xylose by hydrogenation is sweet.

Possibilities of producing activitated carbon from arecanut husk have been investigated by Latif and Khundkar (1952) and Chowdhury *et al.* (1971). The residue of areca husk after extracting xylose can be used for producing activated carbon of good quality, with yield of about 25-28 per cent.

Possibilities also exist for using areca husk as manure. It contains 1.0-1.1 percent N_2, 0.4-0.5 percent P_2O_5 and 1.0–1.5 per cent K_2O_5. Hence, it can form good organic manure if properly composted. The total quantity of 1,00,000 tonnes of dry husk would give, if collected and composted, about 1,000 tonnes N_2, 500 tonnes P_2O_5 and 1000 tonnes K_2O (Biddappa, 1960). However, the husk is very resistant to microbial degradation because of the presence of ligno-cellulose.

LEAF SHEATH

Leaf sheath is yet another raw material obtained from arecanut palm. In a year, a palm sheds 5-6 leaves. About 1,000 million-leaf sheaths weighing about 2,33,000 tonnes are available annually in India alone (Bavappa and Murthy, 1960; Menon *et al.*, 1982).

The sheaths measure 75-85 cm long and 35-40 cm wide at the centre and 15-20 cm wide at the stalk end. Freshly fallen sheaths contain 55-60 per cent moisture. This sheath of an adult palm shows a concavity in the centre. The leaf sheath is heterogeneous in structure, composition and appearance and these pose challenges for product development. The outer surface of the sheath is greenish or brown, waxy and tough, while the inner surface is creamy in color and has a natural glossy finish. The constituents of the leaf sheath are cellulose - 43 per cent; crude fibre - 33 per cent and ash -5 per cent. Its manure contains N_2 - 0.7 per cent; P_2O_5 - 0.3 per cent and K_2O - 0.1 per cent (Biddappa, 1960). In certain regions of Kerala, leaf sheath is also used as cattle feed.

Packaging paperboards

Trials had shown that pulp of quality suitable for making packing paper boards could also be obtained from areca leaf sheath. Laboratory level testing on pulping of areca sheath by digestion by sulphide process at 162°C for 3 ½ h gave a pulp yield of 36-40 per cent with

burst factor of 50 and tear factor of 113 and breaking strength of 6200 m. The pulp in admixture with other pulp could be used for making packing paperboards (Narayanamurthi, 1957; Subramanian and Govindarajan, 1962).

A study was carried out on utilizing arecanut leaf sheath for making paperboards at Tamil Nadu Agricultural University, Coimbatore (Raghupathy *et al.*, 2001). Paperboards were made with various combinations of arecanut leaf sheath with waste paper. 1:1, 1:2, 1:3, 3:1, 2:1 and compared with 100% areca leaf sheath and the quantities of these paper boards were tested as per the Bureau of Indian Standards (IS: 1060 (part-I)-1966). The paperboards made with greater amounts of arecanut sheath materials had more resistance to water absorption. The addition of paper increased the substance weight of the paperboards. The 2:1 and 3:1 combinations of arecanut leaf sheath and waste paper had best tear strength, tensile strength, bursting strength and water resistance with minimum substance weight.

Oyster mushroom production

Bioconversion of organic residues of arecanut plantation through mushroom cultivation offers the potential for efficient recycling of organic wastes, especially in a country like India, where the problem of protein deficiency exists. About 0.1317 million tones of dried areca leaf 0.0832 million tones of dried arecanut bunch waste and 0.2224 million tones of dry husk are estimated to be available annually in India (Chandramohanan, 1997). It is estimated that about 3800 kg of leaf sheath per ha per year are available. Areca leaf sheath is a promising substrate for the cultivation of oyster mushroom on commercial scale (Moorthy, 1993). Based on the studies conducted at CPCRI, Regional Station, Vittal, the scope and procedure for utilization of arecanut wastes for production of oyster mushroom are described.

Mushroom cultivation involves four important steps such as preparation of spawn, preparation of substrate, spawning of substrate and crop management. A low cost mushroom shed using pleated areca/coconut dried leaves and areca stem reapers has been developed which can be an important component of arecanut based farming system (Moorthy and Chandramohanan, 1991). The average yield of mushroom per bag containing 4 kg each of arecanut leaf sheath, bunch waste and arecanut husk were 641g, 988g, 684g, respectively (Chandramohanan, 1997; Fig. 10). The total cultivation period (number of days of spawning to third harvest) is 47 to 62 days. On an average 643 kg and 258.9 kg fresh mushroom yield can be produced annually by using arecanut leaf sheath and bunches available from 1 ha of arecanut plantation. By using theses two waste materials, gross returns to the extent of Rs.45,092 (@Rs.50 per kg of mushroom) can be obtained per year. The present cost of production is Rs.28,033/-. An additional net income of Rs.17, 059 yr^{-1} ha^{-1} can be realized.

Production of oyster mushroom, *Pleurotus sajor-caju* on substrates composed of arecanut leaf wastes (alone or in combination with paddy straw) was investigated. Good yields were obtained from whole leaf or leaf sheath, and comparable to paddy straw alone

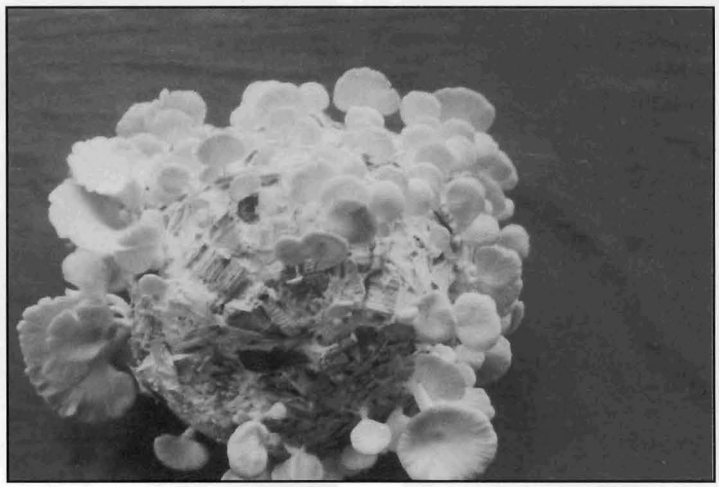

Fig.10. Oyster mushroom production

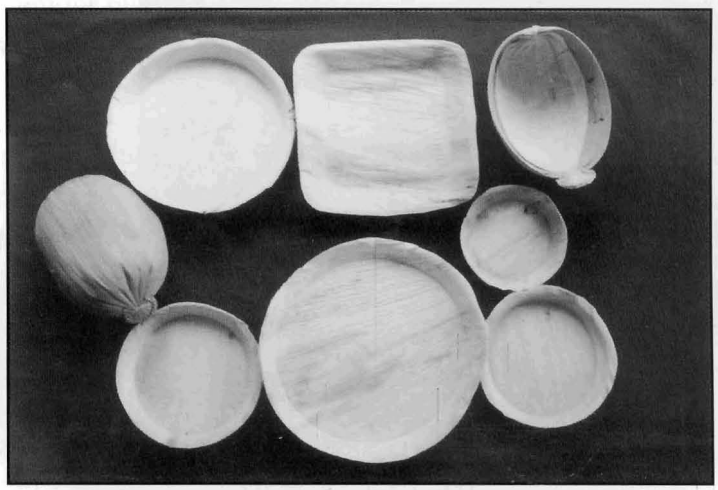

Fig.11. Caps, throwaway plates and cups

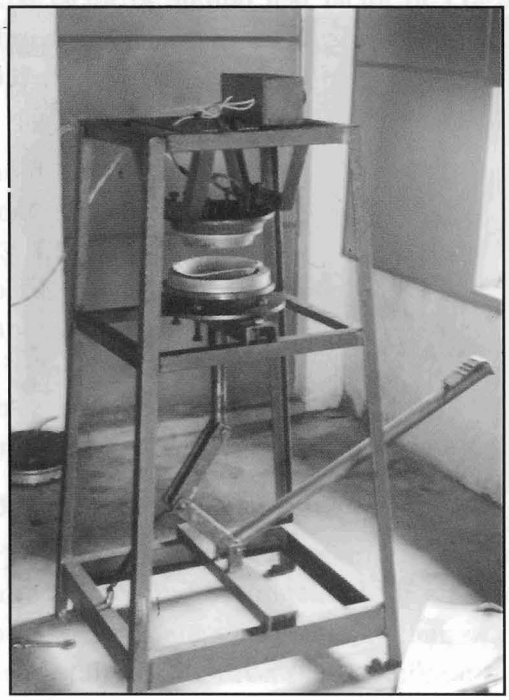

Fig.12. Leaf sheath plate making machine

Fig.13. Picture mounts

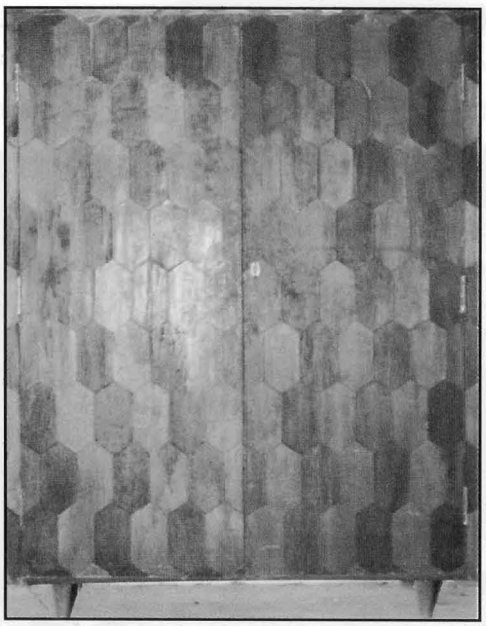

Fig.14. Wooden almirah

as substrates. Regarding arecanut leaf wastes, the sheath portion was a better substrate for P. sajor-caju cultivation (Pani and Das, 1999). The pasteurization methods and seasonal variations in mushroom production have been standardized using areca leaf sheaths. The yield obtained on arecanut husk was very poor in all the pasteurization treatments tried (Madhusdhanan and Chandramohanan, 1997).

Economic products

Taking cue from the numerous traditional uses to which areca leaf sheath have been and are being used (eg. caps and hats for farm workers; Fig. 11), containers and packing cases for collecting and transporting materials at home like toddy, fish etc. and scoop for watering garden in south and south east Asia, and based on its mechanical properties, a series of studies were initiated and sponsored by the CPCRI Regional Station, Vittal to develop active economic uses for the material. The process consists essentially of flattening the sheath under heat and pressure and then utilizing it for making various products (Menon *et al.*, 1982).

Throw-away cups and plates

The flexibility and pliability of the sheath when wet makes it a good material for heat moulding. The CFTRI, Mysore has developed a machine for making cups and throw - away plates that can substitute the paper plates now being used (Fig. 11; CFTRI, 1977, 1978, 1980). The machine is manually operated by leg and is capable of producing 100 cups per hour with one skilled operator and one helper. For this, the leaf sheath is subjected to 158°C temperature for 10 seconds in the moulding machine. Such cups and plates (Fig. 12) are already being produced in cottage level small- scale units in Karnataka and Tamil Nadu. The leaf sheath cups and plates have found market in the urban areas in functions and parties as replacement for plastic cups and plates. Several cottage industries have come up for these products in the 1990's.

Ply boards

The tensile strength though moderate, the flat surface of the processed sheath makes it a suitable material for preparing ply boards (Annamalai and Nayar, 1982). As the sheath is weak across the grain direction, they are glued together to make three ply boards.

Studies on glue adhesive properties of the boards (Annamalai *et al.*, 1982) have yielded satisfactory results. Ply boards were prepared using cold or hot setting urea formaldehyde (UF) resin as glue, extended with tamarind seed powder (TSP) or deoiled sal meal upto 15 per cent. Any ordinary 1.5 mm thick wood veneer was used as core ply and pressed at 4 kg cm^{-2} pressure for 16 h for cold setting glue and 14 kg cm^{-2} pressure at 95-100°C temperature for 7-10 min for hot setting glue. The glue shear strength of the boards (4.2 mm thick) was 45-55 kg in dry state and 12-16 kg in wet state (after 24 h soaking in water at 28°C) and the

boards could withstand delamination upto 6 days when soaked in water. These ply boards do not fully meet the ISI requirements of tea chest plywood, but they are superior in wet glue shear strength than most non-ISI grade ply boards available in the market.

Hence, tea chest and packing cases made of areca leaf sheath ply boards can be put to most of the uses for which ply boards are presently used. These boards also possess better impact strength and double the flexibility of the three ply wood boards. These are properties that are most desired for use in preparing suitcases.

A few trials carried out with the courtesy of a leading tea agent in Cochin, Kerala with the chests made from areca leaf sheath ply boards for transporting tea after storing for three months from Kerala to North India and to London were successful. Such tea chests not only withstood the rigours of long distance transport, but the quality of tea also remained unaffected. More than three-fourths of the tea chests made in India are produced from non-ISI grade ply boards produced by cottage and small-scale industries. Even if areca sheath ply boards are used to meet half the requirements, the saving on soft wood timber will be a significant gain in view of the increasing scarcity of timber in India.

Decorative veneer panels and picture mounts

Aesthetically attractive and imaginative novelties can be made from areca leaf sheaths taking advantage of the natural color and grain variations on the surface. The sheath surface is given a finish in varnish or French polish. They make beautiful picture mounts (Fig. 13) or decorative panels of wooden almirahs (Fig. 14) and teapoys (Menon *et al.*, 1982).

House sandals

The firmness of the sheath combined with its easy yielding nature and its ability to absorb moisture suggests its usefulness as a cheap substitute for leather or cardboard sole tops in home foot-wear and cheap summer wear sandals in dry regions like India.

Gin washers

The trials carried out at the Ahmedabad Textile Industries Research Association, Ahmedabad and Cotton Technological Research Laboratory, Bombay (CPCRI, 1978; Menon *et al.*, 1982) with cotton ginning rolls made of areca leaf sheath gin washers showed that their performance was not satisfactory. They generated heat faster, produced higher trash in lints and reduced the strength and output of yarn moderately as compared to the chrome leather gin washers that are used normally.

Other possible applications

Brief cases, bags, spectacle cases, tea and coffee trays, file boards and many other fancy and utility products have been prepared from areca leaf sheaths. Possibilities for using the sheaths in the manufacture of match boxes; matchsticks and paperboards for packing also

appear to be promising. The corky feel and lightness of the sheath make it possible to convert the sheaths into packing wool for making lining materials in place of cork sheets. Tests conducted for thermal and electrical conductivity of sheath have shown that it could enter manufacturing fields where thermal and electrical insulations are needed.

ARECANUT STEM AND LEAF

Arecanut stem forms an useful building material in the villages and it is widely used throughout south and south-east Asia for a variety of construction purposes. Because of its hardness and its golden-yellow color, the timber can be used for making a variety of elegant utility articles (Bavappa and Murthy, 1960). Stationery articles like rulers, shelves, waste paper baskets, etc. made of the stem are both durable and attractive. In south Asia, the stem after sharpening is used for dehusking coconuts. Nails made of areca stem are widely used in furniture industry. Hollow stems lend themselves to use as drainage and irrigation pipes in the villages. The leaves are a good source of organic manure.

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9. ECONOMICS, MARKETING AND DEVELOPMENT

M. Tamil Selvan, K. Sivaraman and K. Manojkumar

INTRODUCTION

Arecanut is a commodity having commercial, economic, religious, cultural and medicinal importance and is grown principally in the hot and humid regions of the world. Its economic importance is derived from the fact that it contributes substantially to the Gross National Product. Arecanut is cultivated in India over an area of 3,13,300 ha producing 3,79,200 tonnes during 2000-2001. More than 85% of the total area is held by small and marginal farmers. There is an urgent need to increase not only the productivity of arecanut but also the profitability per unit area of land on a sustainable basis. This chapter deals with the economics, marketing and developmental activities of the crop.

PRODUCTION SCENARIO

World Production

According to Food and Agriculture Organization, Rome, the current production of arecanut in the world is about 0.593 million tonnes from an area of 0.468 million hectares. India ranks first in both area (57%) and production (53%) of arecanut. Other countries, which produce arecanut in the World, are Indonesia (16% in area and 5% in production), China (10% in area and 29% in production), Bangladesh (8% in area and 5% in production), Thailand (2% in area and 2% in production), Malaysia (1% in area and 1% in production) (Figs. 1 and 2). Arecanut is also cultivated in Sri Lanka on a smaller scale.

The world production of arecanut showed a substantial increase during the last decade along with the area under cultivation (Fig. 3). The current world productivity of arecanut is 1.267 tonnes/ha. China ranks first in the productivity of arecanut with 3.752 tonnes/ha. India ranks fourth in terms of productivity (1.189 tonnes/ha) (Fig. 4).

Indian production

The crop is cultivated in India mostly in small and homestead holdings very often as a mixed crop along with coconut, jack, mango, banana, cocoa and spices. The main pockets of production of arecanut in India are distributed in the states of Karnataka (34% of area and 39% of production), Kerala (29% of area and 28% of production), Assam (27% of area and 17% of production), Meghalaya (3 % of area and 4% of production), West Bengal (3% of area and 4% of production), Andaman & Nicobar Islands (1% of area and 2% of production) (Figs. 5, 6). Arecanut is also grown in others states namely, Andhra Pradesh, Goa, Maharashtra, Mizoram, Tamil Nadu, Tripura and Pondicherry.

In the case of productivity Maharashtra ranks first with 3.947 tonnes/ha followed by Tamil Nadu (2.036 tonnes/ha). Though Assam contributes significantly to the arecanut

Arecanut (Balasimha, D. and Rajagopal, V. Eds), CPCRI, Kasaragod - 671 124

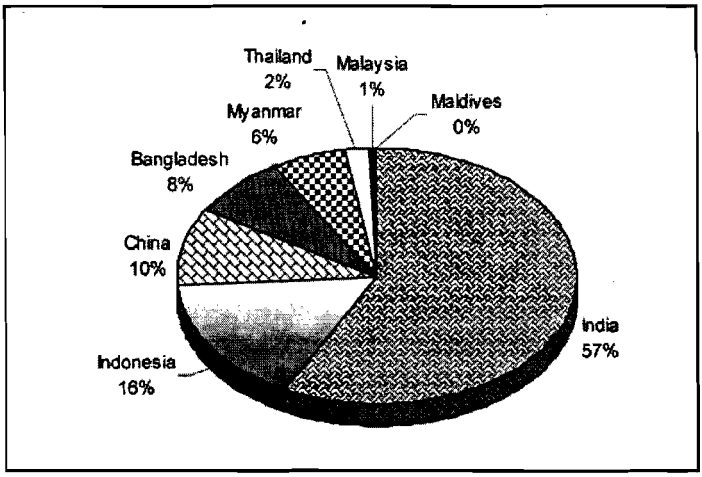

Fig. 1. Share of different countries in area under arecanut during 1999

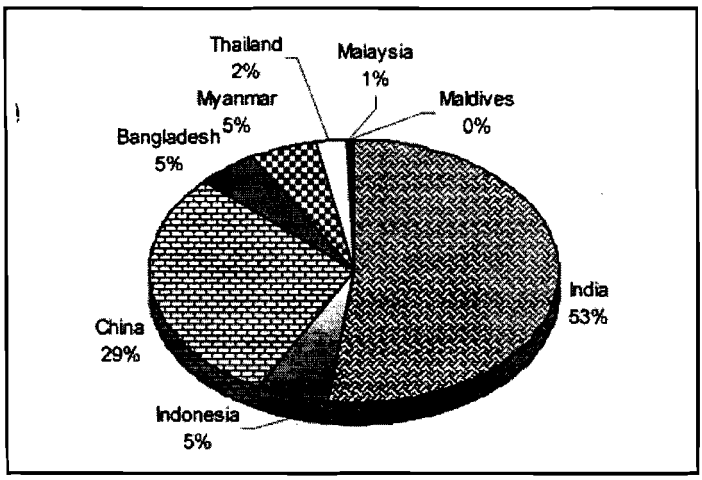

Fig. 2. Share of different countries in arecanut production – 1999

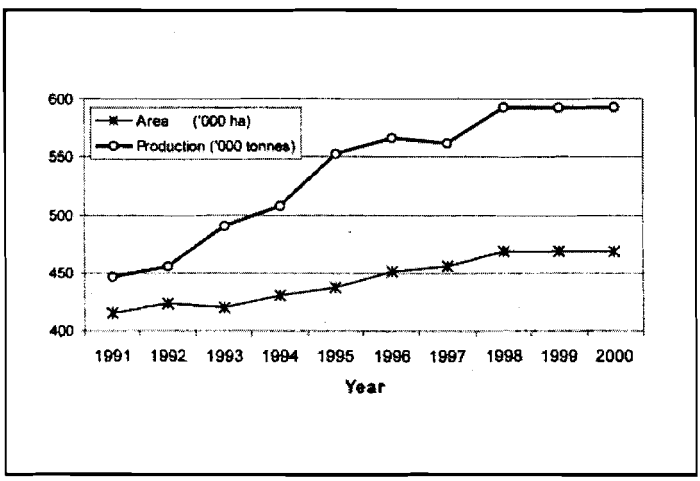

Fig. 3. World area and production of arecanut from 1991 to 2000

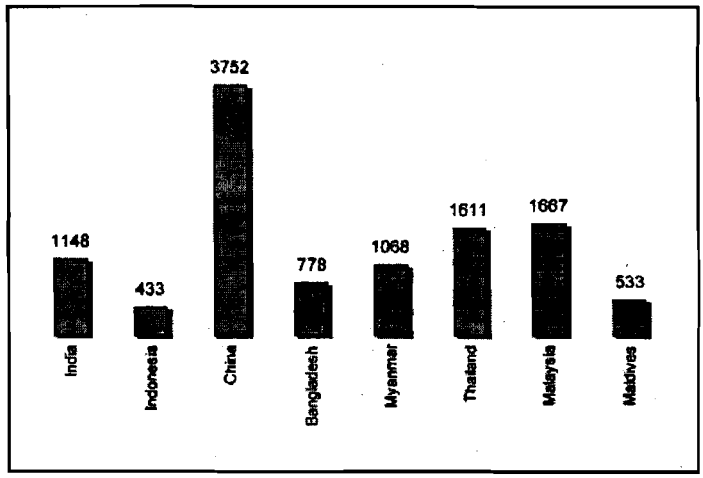

Fig. 4. Productivity (kg/ha) of arecanut in different countries

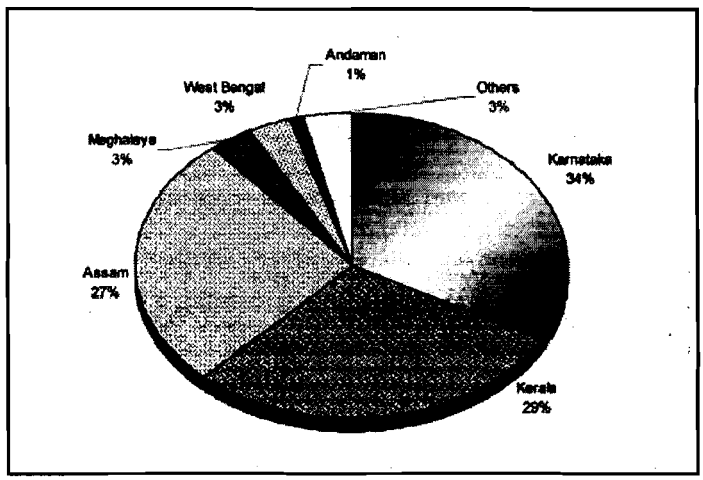

Fig. 5. Share of different states in area under arecanut

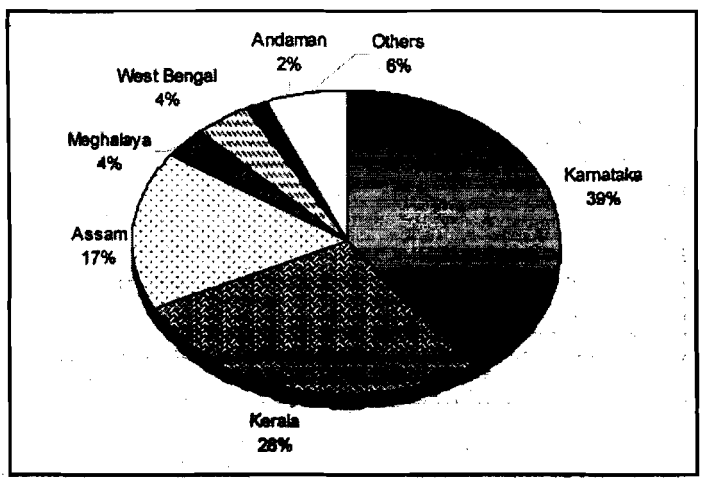

Fig. 6. Share of different states in arecanut production

Table 1. Statewise area ('000 ha) of arecanut in the country

Year	Karnataka	Kerala	Assam	Other States	India
1957-58	30.9	49.7	10.4	5.8	96.7
1960-61	30.5	54.3	22.0	6.2	113.0
1964-65	34.2	59.5	25.4	6.9	125.9
1969-70	38.6	83.7	21.8	16.6	160.7
1974-75	48.2	93.0	31.2	16.8	189.2
1979-80	53.1	60.9	50.8	18.5	183.3
1984-85	57.5	56.8	51.2	20.0	185.5
1989-90	62.9	63.2	63.1	20.3	209.5
1994-95	72.4	71.7	72.0	27.8	243.9
1995-96	78.3	76.5	72.3	27.9	255.0
1996-97	84.6	72.8	74.1	29.7	261.2
1997-98	93.1	76.1	73.8	30.7	273.7
1998-99	91.5	80.6	74.5	31.1	277.7
1999-2000	107.4	76.1	73.5	32.0	289.0
2000-2001	119.1	85.4	73.2	35.4	313.1

Source: Directorate of Economics and Statistics, New Delhi

Table 2. Production ('000 tonnes) of arecanut in the country

Year	Karnataka	Kerala	Assam	Other States	India
1957-58	26.8	38.6	9.9	5.3	80.6
1960-61	27.0	44.2	17.5	6.7	95.5
1964-65	38.5	37.2	24.1	7.8	107.5
1969-70	50.7	51.9	23.3	11.8	137.7
1974-75	65.6	57.2	32.0	9.9	164.7
1979-80	77.2	53.2	49.8	9.3	189.5
1984-85	84.4	46.3	64.3	23.7	218.7
1989-90	91.9	66.0	70.4	23.0	251.3
1994-95	105.8	90.5	57.1	36.3	289.7
1995-96	114.2	91.2	52.4	37.7	295.5
1996-97	121.0	80.1	64.0	42.6	307.7
1997-98	133.3	94.0	56.7	49.5	333.5
1998-99	131.5	92.5	55.4	50.7	330.1
1999-2000	147.1	80.1	52.9	54.3	334.4
2000-2001	162.5	84.5	68.3	63.6	379.2

Source: Directorate of Economics and Statistics, New Delhi

sector its productivity is very low (0.744 tonnes/ha). The productivity of arecanut in Karnataka is 1.437 tonnes/ha, which is above the national average (1.189 tonnes/ha). Kerala has the productivity 1.148 tonnes/ha that is below the national average (Fig. 7).

Area

The area under arecanut in the country, which stood at 96,700 hectares during 1957-58 evidently showed an increasing trend and reached 277,700 hectares during 1998-99. This means after four decades the area has increased by 187%. The estimated area under arecanut is considered to be sufficient to get the production required for the country. The major contributors of arecanut in the country are Karnataka, Kerala and Assam. Contribution of these states to the total area was about 94% during 1957-58, which has declined to 88.8% during 1998-99 due to the emergence of other states into arecanut cultivation.

During the year 1957-58 the leader in arecanut cultivation was Kerala with 49,700 ha, which was 51% of the total area followed by Karnataka with 30,900 ha and Assam with 10,400 ha. During that period other states having considerable area under arecanut were West Bengal, Tamil Nadu and Andhra Pradesh that accounted only 6% of the total area. Later, states like Meghalaya, Goa, Mizoram, Tripura, Pondichery and Andaman and Nicobar Islands entered into arecanut cultivation.

It is observed that the trend in area of arecanut exhibited an increasing trend up to the year 1974-75. But in the year 1975-76 a decline of 6.2% in area could be observed compared to the previous year. The interesting fact about this decline was, the reduction in the area, which was wholly contributed from the Kerala State. In Kerala the area declined to 76,600 ha in the year 1975-76 from its previous year's figure of 93,000 ha. i.e., a reduction of 17.63%. So much of reduction has never been recorded in any other states or at any period during the last four decades. From 1975-76 onwards the area of arecanut in Kerala State started falling and reached 56,800 ha during 1985-86, which was 39% of the area in 1974-75. This declining trend remained for a period of ten years. The main reason behind this can be the yellow leaf disease, which has partially wiped out the arecanut gardens in the southern districts of Kerala and also affected the central and some regions of the northern part of the state. Apart from taking heavy toll of palms every year, the disease rendered arecanut cultivation uneconomical to the farmers due to reduced yield. The pressure on land in the state and the attraction to grow remunerative cash crops in the place of arecanut are the other reasons for decreasing the area under the crop. Though the area exhibited an upward trend since 1986-87, the state couldn't reach its royal status of 1974-75 and also lost its leadership in the case of arecanut cultivation. During 1998-99, Kerala's share in the country's arecanut area was only 29% (80,600 ha). The increase in area is only 62% of 1957-58 that is very low compared to Karnataka and Assam (Table 1).

But in the case of Karnataka State a clear linear trend could be observed in the area under cultivation. The area deviated from its trend line only in two occasions. First deviation was during 1965-66 that registered a decline of 8.42% compared to the previous year. The state regained the upward trend within five years. But this decline was not reflected in the National figure due to the increased area in other states. Second deviation was from 1981-82 to 1987-88 a low growth rate had prevailed in the arecanut area. But during 1998-99, the area of arecanut cultivation in Karnataka State was 91,500 ha which was 32.9% of the country's area and thus the state became the leader in the India's arecanut cultivation. The percentage increase in area over four decades was 196%. Arecanut cultivation in Karnataka is looked upon as a profitable venture. Availability of suitable land for extending cultivation and other infrastructure facilities encouraged the farmers to take up arecanut cultivation. Adoption of scientific cultivation practices and well-organized marketing systems through the Agricultural Produce Market Committees in the state seems to have contributed to the steady increase in area of arecanut cultivation.

In the case of Assam, a linear trend with seasonal variations could be observed during the last forty years. The area which stood at 10,400 ha (10.7% of the total area) during 1957-58 reached 74,500 ha (26.8%) during 1998-99 and this figure is very near to the Kerala's figure. The percentage rise in area over 1957-58 was nearly 613%. Availability of land and the steady demand for the produce in Northeastern region encouraged the farmers to take up arecanut cultivation.

Among other arecanut growing states, remarkable area contributed to country's arecanut cultivation are Meghalaya and West Bengal with the contribution of 9,600 ha and 8,200 ha respectively during 1997-98. In Maharashtra, there was no increase in arecanut cultivation over last forty years.

Production

The arecanut production in the country showed a substantial increase during the last four decades. The country's arecanut production, which stood at 80,600 tonnes in 1957-58, showed an increasing trend and reached 3,33,100 tonnes during 1998-99, which was considered to be sufficient to meet the internal demand of the country. Unlike area, the production exhibited quite an increasing trend. Moreover during the last decade the growth rate in production was very high. During 1987-88, the production in the country was 2,26,700 tonnes. After ten years i.e. during 1998-99 the estimated production of arecanut in the country was 3,33,100 tonnes, which marked an increase of 47% within ten years.

Like in area, Kerala was also the leader in arecanut production during 1957-58 with 38,600 tonnes, which was almost 48% of the national production. During that period Karnataka and Assam contributed 33.27% (26,800 tonnes) and 12.27% (9,900 tonnes) respectively. Rate of growth over production for the Kerala State was very low compared to

Karnataka and Assam. During 1963-64 the production decreased by 14.13% of the previous year in Kerala. During 1975-76, the production declined by 16.61%. The state again witnessed a reduction of 21.25% during 1983-84. Main reason behind the reduction of arecanut production in the state was the spread of yellow leaf disease. In Kerala, the extent of reduction in the production is less when compared to the decline in area, which might be due to the increase in productivity of the crop. In Kerala, the production estimate for 1998-99 was 92,500 tonnes, which was 28% of the total production in the country.

The production in Karnataka, which stood at 26,800 tonnes in 1957-58 showed an increasing linear trend and reached 1,31,500 tonnes (39.8% of total production) during 1998-99 and became the highest arecanut producing state in the country. Karnataka exhibited quite a positive linear trend through out the last forty years and achieved an increase of 491% within the last four decade. Adoption of scientific cultivation practices and well-organised marketing systems through the Agricultural Produce Market Committees in the state seems to have contributed to the steady increase in the production of arecanut in the state.

Assam also took a predominant position in the production with 55,400 tonnes during 1998-99, which was only 9,900 tonnes during 1957-58. Though the production in Assam was also on increasing trend till 1988-89 with the production of 78,200 tonnes, the production decreased to 55,400 tonnes in 1998-99, with a decline of 29% in a decade.

In other arecanut growing states like West Bengal, Meghalaya and Maharashtra a remarkable increase in production of arecanut within the last four decade was achieved (Table 2).

Productivity

Productivity of arecanut in the country during 1957-58 was 833 kg/ha. At that time the same was 869 kg/ha and 956 kg/ha respectively in Karnataka and Assam and was greater than the National average. During 1998-99 the yield of arecanut in the country reached 1189 kg/ha. Now the yield of arecanut in Assam is very low compared to Karnataka and Kerala. Karnataka has the highest yield, 1437 kg/ha and having the high productivity since 1964-65. From 1974-75 onwards the productivity of arecanut in Karnataka State is almost steady. The productivity of arecanut in Kerala was 776 kg/ha during 1957-58 and was less compared to Karnataka and Assam. From 1977-78 onwards, Kerala's productivity showed an increasing trend and now has reached 1148kg/ha (Fig. 7). It was due to the cultivation of high yielding varieties.

Consumption

Although the production of arecanut is location specific, the consumption is wide spread throughout the country. The conventional acceptance of the commodity as masticatory

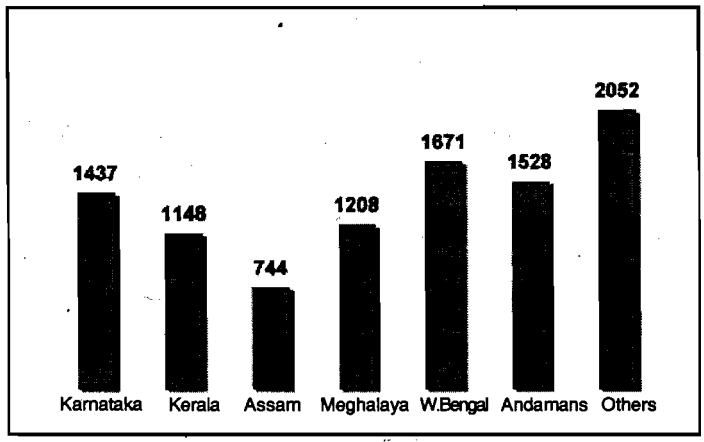

Fig. 7. Productivity (kg/ha) of arecanut in different states during 1998-99

is itself the source of principal demand. Major portion of arecanut produced in the country is being consumed in the domestic market. Arecanut has been widely used in the manufacturing of 'Pan Masala' and 'Gutka'.

Arecanut is used mainly as masticatory with betel leaves and lime by the people mainly in the age group 15 to 49 years. The people in this age group are considered as eligible population for consumption of arecanut. The per capita consumption in the hinterland is estimated at 2.01 grams per eligible adult while in the consumption base it is 1.58 grams per eligible adult (Viswanath and Narappanavar, 1994). Consumption of arecanut in the country steadily increased from 0.114 million tonnes during 1956-57 to 0.336 million tonnes during 1998-99. Similarly domestic production increased from 0.07475 million tonnes to 0.330 million tonnes for the same period. The gap between production and consumption was very wide during late fifties and early sixties and thereafter production was sufficient enough to meet the consumption upto 1993-94 and thereafter consumption requirement was satisfied through import in moderate quantities varying from 545 tonnes during 1994-95 to 10,823 tonnes during 1997-98.

Projection of National Commission on Agriculture

National Commission on Agriculture (NCA, 1976 Part VI page 380) taking a practical view at that time, assumed a yield target of 1.5 tonnes per hectare for Kerala and 2.0 tonnes per hectare for Karnataka and North Eastern states. This meant a production of about 2,70,000 tonnes from the existing area of arecanut in these parts, giving an overall yield of 1.6 tonnes/ha. Calculating the demand for the adult equivalent of the population in 2000 AD at the rate of 250 grams per head per year, the requirement of arecanut worked out to be about 1,90,000 tonnes leaving a surplus of about 80,000 tonnes for utilization in medicinal and other kinds of industrial needs and for export. Considering the extent of area under this crop at that time the Commission was of the opinion that the existing research or developmental setup in the States

and at the centre should be sufficient. What is needed was to develop high yielding varieties as well as the accompanying package of practices. Considering the present area and production of arecanut (2000-01), the projection made by the Commission has been on the lower side since the latest production is about 3,79,200 tonnes from an area of 3,13,300 hectares. The increase in production and very high prices prevailed up to 1999-2000 showed that our internal capacity to utilize the increased production was much higher than the projection made by the National Commission on Agriculture. However, indiscriminate area expansion in non-traditional areas and a possible glut in the market as well alleged market manipulation by the traders could have slumped the price of arecanut at present.

ECONOMICS OF CULTIVATION

Arecanut being a cash crop warrants high initial investment. Unlike crops like paddy, jowar and ragi the arecanut plantation takes a long time to give the yield. In such a situation, computation of the cost becomes more complicated. However, few estimates have been made by different agencies regarding the cost and returns from pure arecanut crop.

Cost of Cultivation

Cost of cultivation refers to the total expenses incurred in cultivating one hectare of arecanut. The life span of arecanut palm is expected to be 30-35 years. Generally the palm starts yielding from the sixth year and yield get stabilized by the 11th year of planting. From 11th year onwards items of cost remain the same while yield continued to get upto 30 years and thereafter declines. Beyond thirty-five years the returns over cost would be small and the present worth of this income would be negligible at the current interest rate. The cost of production of arecanut is the cost involved in producing one quintal of arecanut ('supari'). Cost of production consists of two major components, i.e., establishment costs and maintenance costs.

Dineshkumar and Mukundan (1996) reported that expenditure was the highest during the first year of planting due to preparatory cultivation, cost of seedling and planting. They also reported that the largest share of the total cost was human labour accounting for about 45 percent. Expenditure on manures and fertilizers accounted for 26 per cent while plant protection costs accounted for nine percent (Table 3). The estimated costs and returns from pure arecanut crop from the first year to the eight year are presented in Table 4.

The cost specified in the Table include the value of all inputs including family labour, depreciation, land revenue, water cess and interest at the current bank rate. Considering the stabilized yield of arecanut per hectare and the average price per quintal, the estimated figures reveal that by the end of twelfth year of planting, the initial investment along with the recurring expenditure will be recovered. From the 13th year onwards net profit at least Rs. 16,000 can be obtained annually from one hectare of arecanut garden taking into

Table 3. Inputwise share of cost of cultivation (11 years)

Item	Percentage to total
Human labour	44.75
Materials for shading	4.79
Seedlings	6.17
Manures and fertilizers	25.92
Plant protection chemicals	9.24
Depreciation charge	4.13
Land tax	0.26
Miscellaneous	4.74
Total	100.00

Source: Dineshkumar and Mukundan, 1996.

Table 4. Estimated costs and returns from pure arecanut crop (in Rs)

Year	Cost	Returns
1st year	39370	
2nd year	18330	
3rd year	18570	
4th year	19220	
5th year	21410	10330
6th year	22860	28330
7th year	24140	41200
8th year onwards	24140	41200

Source: Anitha, 2000

consideration the yield and price fluctuation. The argument advanced here is based on the promise that the intermediaries do not eat into the returns of the cultivators. But in reality, the situation is different. Though the market forces peg up the prices, the benefit does not percolate to the cultivator. Like in any other agricultural commodity, in case of arecanut also, the intermediaries are the ultimate beneficiaries. This calls for the attention of the authorities to evolve such a system, wherein the cultivator gets the benefit. Anitha (2000) in her study classified the cost into two categories, namely, pre-harvest costs and post harvest costs. The preharvest costs include items like cost and preparation of land, land revenue, cost incurred to fence the land, digging of well and installing pumpsets, cost of irrigation, digging pits, seedlings and planting, manure and manuring, plant protection, watch and ward, etc. The post harvest expenditure includes costs like dehusking, boiling and drying, pandal materials, fuel and electricity, grading, storage and other costs (Table 5).

Benefit Cost Ratio

Benefit cost ratio indicates the return on a rupee of investment. It is defined as the ratio between the present worth of benefits and that of costs. A project with benefit cost

Table 5. Cost of Cultivation and Processing of arecanut (Rs. per ha)

Year	1	2	3	4	5	6	7	8	Total
Pre harvest expenditure	35000								35000
1. Cost and preparation of land	500	500	500	600	600	600	600	600	4500
2. Land revenue	800	900	900	1000	1000	1000	1100	1100	7800
3. Fencing	3500								3500
4. Well and pumpset	3000	600	600	600	600	600	600	600	7200
5. Farming and irrigation channels	1550								1550
6. Digging and pits	2750								2750
7. Seed and planting (including transportation)	2200	2200	2200	2500	2500	2500	2500	2500	19100
8. Manure and manuring	200	200	250	250	250	250	250	250	1900
9. Plant protection	500	500	500	500	500	500	500	500	4000
10. Watch and ward									87300
Post harvest expenditure									
11. Dehusking									500
12. Boiling and drying									1300
13. Pandal materials									1200
14. Fuel and electricity									300
15. Grading									200
16. Storage and other costs									250
Total									91050

Source: Anitha, 2000

ratio greater than unity is considered viable. Dineshkumar and Mukundan (1996) estimated the benefit cost ratio of arecanut as 2.29. Since this ratio is greater than unity, the investment is economically viable and indicates the high profitability of arecanut cultivation.

Net Present Worth

The most straightforward discounted cash flow measure of a project is the net present worth. This is simply the present worth of the cash flow stream. It tries to project the feasibility of cultivation and is the difference between the present worth of benefits and present worth of costs. The formal selection criterion for the net present worth measure of project worth is to accept all projects with a positive net present worth when discounted at the opportunity cost of capital. Dineshkumar and Mukundan (1996) have estimated net present worth of a hectare of arecanut plantation was Rs. 95,506.

Internal Rate of Return

Internal rate of return is that discount rate which just makes the net present worth of the cash flow equal zero. It represents the average earning power of the money used in the project over the project life. The formal selection criterion for the internal rate of return measure of project worth is to accept all projects having an internal rate of return above the opportunity cost of capital. According to Dineshkumar and Mukundan (1996), the internal rate of return for arecanut plantation is 27.64%.

MARKETING

The success of any agricultural activity depends much on the availability of an efficient market mechanism. Better marketing is essential in commodities like arecanut where production is concentrated in a few states and consumption spread all over the country and this can be achieved by proper regulatory measures as well as the adoption of scientific methods of marketing.

Preparation of Arecanut for Marketing

Harvesting

Unlike other agricultural crops, harvesting of arecanut is a hazardous job. It requires competent labourers who are specialists in tree climbing. On an average the height of a fruit bearing arecanut palm is about 30 feet in height. The labourers climb the trees and they pull down the ripened arecanut fruits in bunch and pass them to a person on the ground with the help of ropes. The professional climbers during the course of plucking, do not climb each and every tree, instead they climb up to the top of one tree and from there they move to other trees by swinging from top to top. After the fruits are plucked, the bunches are moved to the processing yard.

Processing

Arecanut fruit bunches are processed further before being taken to the market. The cultivators themselves generally under take this activity. The following processes are involved and are undertaken by the farmers: separation of nuts from the stalk, husking, slicing, boiling and drying. Separation of nuts from the stalk involves removing the nuts from the bunches. The next stage is husking. The layer covering the nuts is removed with the help of specially devised knife for the purpose. After removing the husk, the nut is cut into two or three parts and then sent to the boiling process. During the boiling process, some colours, which are prepared from the husk of some trees, are added. The boiled piece nuts are then dried for nearly 10 to 15 days. The nuts are graded into different varieties according to the quality and size. They are ultimately packed in gunny bags before being sent to the market.

Assembling and distribution

Arecanut is marketed in various forms as unhusked whole fruit, dehusked and dried nut, boiled and dried whole kernel or their cuts. Lakshmanachar and George (1982) reported that nearly one third of the total arecanut production in India reaches the consumers as ripe fruit and the remaining in the processed form.

The processed arecanuts are brought into the market by several agencies. Sometimes, the agents assemble this produce at different centres before bringing them to the main market. In the sample district, the important agencies that assemble the arecanut are: growers (who bring their produce to the market), itinerant dealers and village merchants, village co-operative societies, marketing co-operative societies and traders ('mandi' owners).

Small-scale cultivators sell their produce to itinerant dealers and village merchants. Most of the large cultivators carry their produce to the main market. It was also observed that the small cultivators would have committed to village merchants to sell their produce as they have availed of loans from these agencies. The nuts are sold in unhusked whole nuts or in processed form.

i) Unhusked whole arecanut: Marketing of semi-ripe, fully ripe or fermented arecanut is of commercial importance only in Kerala, Assam and West Bengal. In Kerala, where areca growers generally do not undertake processing, about 30 percent of the produce is marketed after harvest, either as semi-ripe of fully ripe whole arecanut in the nearest markets. This is mainly used for local consumption. A small part of the produce is stored in the form of fermented arecanut ('neetadakka') for sale in the off-season. The growers, nearly 50 percent by the itinerant merchants and the remaining by a few processors and co-operatives assemble about 35-40 per cent of the produce in the primary market. Both growers and itinerant merchants sell the produce to the processors in the assembling markets for conversion into whole dry arecanut ('kottadakka') or split ('parcha') (Lakshmanachar and George, 1982).

In Assam, about 90 per cent of the crop is consumed locally in the form of semi-ripe, fully ripe or fermented arecanut. The assembling and distribution take place mainly through hundreds of primary markets or hats located all over the state. In these markets the growers themselves assemble nearly 60 per cent of the produce, while village merchants, itinerant merchants and processors assemble the remaining 40 per cent. In the primary markets the growers sell arecanut to the local buyers on retail basis or to their agents who purchase and sell it to shop keepers for retail distribution. Processors purchase ripe arecanut for conversion into whole ('gota supari') or split ('kata supari') dry arecanut. There are also wholesale markets like Guwahati, Nowgong etc., which function mainly through the commission agents or wholesale merchants (Anonymous, 1961; Shamanna, 1958).

Bulk of production in Maharashtra is in the form of ripe nut. The general practice followed in the state is to remove the outer skin of the fruit from three sides and dry partially.

Afterwards the produce is sold to the middlemen and commission agents who take up dehusking, drying and sorting.

Arecanut crop in Goa is harvested only in ripe stage. About 92 per cent of the production is converted into 'chali' and the remaining consumed as fresh nut or preserved in water for use in the off-season. Most of the small growers invariably take loan from commission agents and village merchants on the understanding that the produce after harvest will be sold to them at the prevailing market price. Commission agents and village merchants get the necessary advance for this purpose from the wholesale merchants.

ii) Processed arecanut: In Karnataka, 95 percent of the harvested crop is converted into different types of processed (boiled or unboiled) arecanut (Lakshmanachar and George, 1982). The growers in Malnad tract do the processing and in Maidan region the agents who take the garden on lease do it. Mangalore, Shimoga, Sirsi, Sagar, Siddapur and Kumta are the important assembling markets in Karnataka. The share of the growers in the assembling of the produce has been estimated at 60 per cent. The itinerant merchants account for about 10 to 15 percent of the total quantity assembled and the remaining quantity by the co-operative societies. Commission agents, and wholesale merchants attend much of the wholesale distribution. Retail distribution is done by the agencies like growers, village merchants, commission agents, wholesale merchants and shopkeepers or retailers. In Kerala, about 70 per cent of the production is converted into processed arecanut. It consists of both unboiled and boiled types. It is estimated that 70-75 per cent of the processed arecanut is produced by professional processors and assembled by them. The growers and itinerant merchants assemble the remaining portion. In Kerala, role of co-operatives in the assembling and distribution of processed arecanut is insignificant. Pala, Ponkunnam, Alappuzha, Kochi, Thrissur, Kasaragod etc. are the important assembling and distributing markets in Kerala for processed arecanut.

In Assam, only about 70 percent of the production is converted into processed arecanut. The main assembling markets are at Guwahati and Dhurbi and to some extent Shillong. The processors assemble about 90 per cent of the produce. The share of the wholesale merchants and co-operative societies in assembling of arecanut is insignificant.

In Tamil Nadu about 40 per cent of the crop is marketed at mature stage for preparing special types of processed arecanut. In Mettupalayam area, sun dried nut is prepared. The processing methods followed to prepare 'kalipak' are similar to those in Kerala. Assembling is mostly done at Chennai and commission agents and brokers operate in this market. For local distribution, wholesale merchants contact commission agents through brokers and obtain their requirements on credit basis. Further distribution is carried out through retail shopkeepers and 'panwalas'.

Transportation

The cultivators who bring their produce to the main market have to make arrangements for transportation. At the village level, if the produce is sold, the purchasing agents take up this responsibility. A share of transportation expenditure is passed on to farmers who sell the produce to the purchasing agents. Arecanut produce is transported through trucks, tractors, own bullock carts and other suitable means. Till 1987-88, the farmers had to make their own transport arrangements to shift the produce from growing centres to marketing centres. Since 1993-94, the APMC has started extending transport facilities to the farmers to enable them to bring their produce to the market yard. A moderate service fee is charged. Private transport operators extended this facility to avoid exploitation of farmers. The movement of raw arecanut that is mostly confined to growing state is almost entirely by head loads, bullock carts and trucks. In the case of processed arecanut the outward movement is by lorries, trains and steamers.

Grading

The absence of standard grades in arecanut for the different varieties based on scientific analysis is a great handicap in the arecanut trade. Grading of arecanut is done by merchants based on the long-standing trade practices, which are not always quite precise and scientific. Grading involves grouping the nuts into different categories based upon their quality. Grading of arecanut produce is undertaken at two stages. One by the growers and the other by commission agents and processing societies.

The Agricultural Marketing Adviser to the Government of India fixed grade specifications for whole dried areca nut under 'Agmark' standards during 1952 based on the existing trade practices in the leading arecanut market at Mangalore. But grading did not take place under the Agmark standards in any of the states and no trader applied for certificate of authorisation for grading and packing. These specifications have been revised subsequently. Compulsory grading of arecanut under 'Agmark' for export has not yet been introduced although some quantities of arecanut are regularly exported from India. A very nominal quanity (78 tonnes) of arecanut was only graded under Agmark for internal trade on voluntary basis, during 1979-80. However, over 14,0481 tonnes were graded during 1979-80 at producers level mostly in Karnataka (at Mangalore, Shimoga and Sirsi) and to a certain extent in Goa and Assam (Lakshmanachar, 1973a).

Storing

The processed arecanut if scientifically stored will allow the nut to mature further and this improves the quality of the nut. The longer the storage, the higher the quality of the nut. Proper storing also helps the farmers to get better prices. For the purpose of temporary

storing of arecanut, the cultivators depend upon gunny bags to protect the produce from pests and moisture. The village merchants who collect the produce from the growers do not have storage facilities. The commission agents sometimes finance the village merchants to purchase arecanut in the district. However, storage of the produce for a minimum period is inevitable in the assembling and distributing markets. Further, scientific storage is necessary to prevent any spoilage by insects and moisture. The commission agents and marketing societies are also providing storage facilities in the market. In the sample district, the cultivators do not store the produce in their houses. They store their produce in the 'mandies' (markets) of commission agents and the warehouses of marketing co-operative societies till the marketing trends become favourable to them. Nearly 70 percent of the storage facilities are provided by the commission agents and the rest by the marketing co-operative societies. Details of the storage facilities available in the districts of Karnataka are given in Table 6. It is apparent from the table that the private commission agents both in Shimoga and Sagar markets provide maximum storage facilities to the farmers.

It has been estimated that about 8-10 percent of the harvested ripe arecanut is stored in pits or steeped in water for consumption during off-season in Kerala, Assam and West Bengal. Due to improper methods of preservation, the stored ripe nuts emit foul smell. However, the kernel inside is in good condition except for the putrifying smell of the husk infiltrated into it. In Assam, ripe nuts are preserved in pits covered with mud or in running water in streams. Husk of nuts stored in pits gets fungal infection and the white coloured core and the portion between the brown veins of the kernel damaged to some extent. To overcome the deterioration of ripe nuts in storage, a method of preserving them in a solution of mixed preservatives has been developed (Govindarajan, 1968).

Table 6. Availability of warehousing facilities

Agencies	Godowns	Capacity in metric tonnes
Commission agents in Shimoga	50	12,750
Commission agents in Sagar	25	10,800
MAMCOS Ltd	08	4,250
APSCOS	05	3,600

Source: Anitha, 2000

As regards processed arecanut, storage for a minimum period is inevitable in the assembling and distributing markets. Chali nuts are generally stored in single or double gunny bags and kept in fairly well constructed dry rooms. The nuts in storage are protected from infection by sulphur fumigation that also helps for bleaching the colour of the nut.

Generally the co-operative marketing societies and regulated marketing committees provide place to local commission agents. They also normally provide storage space free of charge and assure the quality and condition of the goods stored in their godowns.

Though warehouse facilities for arecanut are available in all the arecanut growing states, quantities stored in the warehouses in Kerala, Karnataka and Tamil Nadu are relatively small (around 1000 tonnes). From the small quantity handled by the Warehousing Corporations it is evident that they are yet to make an impact in the storage of arecanut for sale in the off-season.

Packing

No special packing is used when the crop is sold in the form of raw arecanut in the primary market. It is packed loosely in small lots in bamboo baskets or very often, it is taken in bunches as such without separating nuts. In the case of processed arecanut, not much elaborate packing is resorted to, either in villages or in the assembling and distributing markets. It is packed in single or double gunny bags. High grades of thinly sliced processed arecanut in Kerala are mostly packed first in mats made out of palmyrah leaves and then packed in single gunny bags or wooden boxes before they are despatched (Anonymous, 1961).

Types of Markets

There are primary, secondary and terminal markets dealing in agricultural commodities including arecanut. The primary markets are at the village level and generally held once in week on a fixed day. They are usually located in the interior parts and serve the needs of villagers. The secondary markets are regular wholesale markets held daily at fixed places and are usually situated in the district or taluk headquarters, and important trade centres. Both assembling and distribution take place in these markets (Lakshmanachar and George, 1982).

Marketing Channels

In the present marketing system of arecanut, the intermediaries play a predominant role. The marketing channels for arecanut in the sample district of Karnataka are given below (Anitha, 2000).

(i) Channel 1 - Grower–Commission Agents-Wholesalers Retailers.
(ii) Channel 2 - Growers-Village Traders – Commission Agents – Wholesalers – Retailers.
(iii) Channel 3 - Growers – Itinerant Dealers – Commission Agents – Wholesalers – Retailers.
(iv) Channel 4 - Growers – Service Co-operatives – Wholesalers – Retailers.

Marketing Practices

In Kerala, the crop is sold mainly as tender arecanut for the preparation of 'kaliadakka' (boiled and coloured types). The common practice is to remove the husk and sell the produce as raw arecanut. Since the nuts are perishable in this form, the producers and itinerant merchants are often compelled to sell them to the processors or to their agencies immediately.

Sales are affected by open negotiations between the seller and the buyer either in the nearby market or in the processors' premises based on weight. After settling the price, the goods are delivered on the spot and payment is received in cash. In the case of ripe arecanut the same method of sale is followed but the price is settled based on the number of nuts.

In Assam, the ripe nuts are assembled in heaps on the scheduled market days by the various marketing agencies and individual lots are sold by open bargaining between the buyers and the sellers after inspection of the samples. Payment is immediately made in cash, based on the number of arecanuts. When sales are effected in the premises of the gardens, growers need not pay any expense but when disposed off in nearby villages, a market toll which varies from place to place has to be paid. Although major portion is locally consumed, small quantities are sold for use in neighbouring states of Manipur, Tripura etc.

In the important arecanut markets like Mangalore and Sirsi in Karnataka, the commission agents conduct auction and arrange for the sale of the produce received from the growers. The agents store the produce in their godown without any charge and also advance loans to the customers on the security of the produce, pending disposal. The buyers are mostly local merchants who after taking delivery of the produce despatch it to different consuming centres. The local market committees regulate the marketing practices and auctions are conducted in the presence of officials.

The chief agencies engaged in the retail distribution of processed arecanut are the provisional merchants and shopkeepers operating in various cities, towns and village markets. To a small extent 'pan' shopkeepers are also involved in retail distribution. These retail agencies purchase their requirements from wholesale merchants in the nearest market. Retail distributors incur expenditure on transportation of processed arecanut from wholesale markets and also for sorting out and cutting nuts into pieces. Different trade types and varieties of arecanut and centres of production as well as grade specifications are specified (Tables 7, 8, 9).

Marketing Costs and Margins

It is estimated by the market studies that the producers' share in the consumer's price is about 70 per cent in the case of unhusked whole arecanut. But in the case of varieties such as 'chali', 'parcha' etc. the growers, share is 71 per cent while it is 76 per cent in the case of boiled varieties such as 'api', 'batlu', 'choor erazel' etc. The higher share in the case of boiled varieties is attributed to distribution in the consuming areas nearer to the producing states (Lakshmanachar and George, 1982). In Karnataka, the grower's share in the consumer's price is comparatively higher, since the growers invariably process their produce and market it after preliminary grading. Rates of sales tax on arecanut vary from state to state (Table 10). Besides sales tax there is central sales tax for inter-state transactions. As some of the

Table 7. Trade types and varieties of arecanut and centres of production and consumption

Trade names	Method of preparation	Important grades arranged in order of quality (in trade)	Main centres of production	Main centres of consumption
RIPE ARECANUT				
Adakka Pukka Tamul Kacha Tamul Neetadakka Bura Tamul	Fresh ripe areca fruit Fresh semi-ripe areca fruit Ripe areca fruit stored in water Ripe areca fruit stored in pits		Kerala, Karantaka Assam, West Bengal Kerala Assam	Kerala Assam and some areas of Karnataka Kerala (in off season) Assam (in off season)
RIPE DRIED ARECANUT				
Chali Supari Kottadakka Kottapakku Assam kata	Ripe areca fruit dried and husked Ripe areca fruit cut lengthwise into two, dried and husked.	Moti, Srivardhan, Jamnanagar, Jini, Chali, Malabar, Koka(the variery choll is the dried areca fruit stored in husk for an year and then sold in husk).	Dakshin Kannada, Uttara kannada and Shimoga (Karantaka), Kannur, Kozhikode, Kottaym, Alappuzha, Kollam and Thiruvananthapuram (Kerala), Mettuppalayam (T. Nadu), Ratnagiri, Colaba (Maharashtra), Assam and West Bengal.	Gujarat, Hyderabad, Madhya Pradesh, Uttar Pradesh, Rajasthan, Delhi, Assam and West Bengal
PROCESSED GREEN NUTS				
Nayampak	Green nuts cut breadthwise into two equal bits and dried	Sithanam, Uduthuram, Vettai	Thrissur, Thiruvananthapuram and Kottayam (Kerala)	Southern districts of Tamil Nadu
Iylon	Green nuts cut breadthwise into 1-2 mm. Thick sections and dried.	Iylan, Sithanam, Iylon alagu, Iylon vettai.	Kerala state	Southern districts of Tamil Nadu
Unde	Green nuts, husked, boiled whole and dried.	Api, Chikkni, Barda, Gotu	Uttara Kannada dist., Sagar and Sorab taluks (Karantaka)	North Karnataka, Satara, Sholapur, Kolharpur and Hyderabad

Deshawaram, Ottavettu	Green nuts cut breadthwise into two equal bits, boiled and dried.	Nuli, Pheeton, Rajalu, Vantibette, Gorabalu	Shimoga, Chickmagalore dist.	Karnataka, Tamil Nadu and Andhra Pradesh
Naluvettu	Green nuts cut breadthwise into four equal slices, boiled and dried.		Thrissur and Plakkad districts of Kerala (produced in small quantities)	Few markets of the southern districts of Tamil Nadu
Churu	Green nuts cut lengthwise boiled and dried.	Kalichur, Payachur, Vellavi chur	Kerala state, Hassan, Tumkur and Chitaldurg dist. of Karnataka state	Tamil Nadu, Andhra Pradesh and Karnataka
Mukkalchur	One longitudinal cut and tow or three longitudinal cuts perpendicular to the first direction.			
Edachur	Two or three longitudinal cuts and another two or longitudinal cuts perpendicular to the first direction.	Kalichur, Payachur, Vellavi chur	Kerala state, Hassan, Tumkur and Chitaldurg districts of Karnataka state	Tamil Nadu, Andhra and Karnataka states
Pettchur or Lavangachur	Number of longitudinal cuts in one direction and again in direction perpendicular to the first.			
Podi (big small)	Green nuts cut both lengthwise and breadthwise to give bits, boiled and dried.	Kalipodi, Vellavipodi	Thrissur and Palakkad districts of Kerala state. Tumkur and Hassan districts of Karnataka state.	Karnataka and Tamil Nadu and Andhra Pradesh
Erazel	Green nuts very thinly sliced breadthwise, boiled, coated with kali and dried.		Thrissur and Palakkad districts.	Tamil Nadu
Kettumpadi and Chalakudi	Green nuts thinly sliced lengthwise, boiled, coated with kali and dried		Thrissur and Palakkad districts.	Tamil Nadu
Nirolu	Tender nuts, boiled, sliced breadthwise into slices and dried in sun		Hengal taluk and Dharwar district.	North Karnataka districts

Scented supari	1. Green processed arecanuts cut into small bits, mixed with powdered spices, and flavoured. Copra ans sugar crystals also added in few cases.		Tamil Nadu and Maharashtra	Throughout India
	2. Ripe arecanut, softened by steping in dilute sugar syrup, strongly scented.		Lucknow and Banaras	Throughout North India

Source: Lakshmanachar and George, 1982.

states do not buy their requirements directly from the producing states, sales tax on this commodity is levied at two or three points resulting in upto 25 per cent sales tax of the value of the original consignments when it reaches the ultimate consumer.

Regulated Markets

Karnataka, Kerala, Tamil Nadu and Goa have established regulated markets for arecanut. After regulation, market charges levied have been minimised since in the regulated markets there are no brokerage, charity and other charges (Nambiar, 1979). In Karnataka, there are 23 regulated markets situated in the important arecanut growing regions *viz.*, Chitradurg, Challakere, Hiriyur. Shimoga, Sagar, Tumkur, Gubbi, Muliyar. Kunigal. Madhugiri, Pavagada. Sira, Turuvekare, Tarikere, Kadur, Holenarasipur, Chamarajnagar, K.R.Nagar. Kumta, Mangalore, Siddapur, Yellapur and Sirsi. These regulated markets together handle more than 80 per cent of the marketable surpluses of arecanut in the state (Lakshmanachar and Joseph, 1973). In Kerala although five regulated markets were established in the erstwhile Malabar area during 1956-1968, at present there are only four at Kanhangad. Perambra, Changaramkulam and Vattamkulam. Altogether only less than 16 per cent of the marketable surplus is transacted in these markets (Lakshmanachar and George, 1982).

Co-operative Marketing

Co-operative marketing societies play an important role in the marketing of arecanut, especially in the state of Karnataka. It is reported that more than 400 marketing co-operative societies are functioning in India and of this nearly 120 societies are operating in Karnataka. The societies deal with market arrivals in bulk and assist their members in selling their produce whenever they wish. The societies provide other services like provision of credit facilities, storage facilities and supply of fertilizers and chemicals (Anitha, 2000). The co-operative societies are fairly successful in their functioning and they are handling more than 30 per cent of the marketable surplus in the state. Some of the marketing societies have transporting facilities and collection depots in the important areas of production, which are

Table 8. Grade specifications for whole dried arecanut (kottapak)

Grade designation	Diameter* in inches	Special characteristics	Colour of pith			
		Minimum percentage if *topiwalla* nuts**	Copra white minimum (%)	Yellowish brown maximum (%)	Damaged nuts minimum (%)***	General characteristics
Moti special	1" and over but not exceeding 1.2"	75	90	Nil	½	The nuts shall be whole, fully husked of light colour and reasonably mature and dry. The nuts shall not be worm eaten or otherwise damaged from outside or inside.
A I	-do-	40	60	10	1	
AII	-do-	10	10	60	2	
Srivardhan special	0.9" and over but less than 1"	75	90	Nil	½	
AI	-do-	40	60	10	½	
AII	-do-	10	10	60	½	
Jamnagar special	0.8" and over but less than 0.9"	75	90	Nil	½	
AI	-do-	40	60	10	½	
AII	-do-	10	10	60	½	
Jeeni special	Under 0.8"	75	90	Nil	½	
AI		40	60	10	½	
AII		10	10	60	½	

*To allow for accidental errors in grading 5% of nuts of the next lower or higher grade shall be permitted.

**A nut having a portion of its endocarp adhering to it.

***Damaged nuts including cracked and broken nuts (*bomda*) pieces, nuts fully husked and those the pith (*bhong*) of which is black or otherwise damaged by moulds, insects etc.

easily accessible to the growers (Lakshmanachar, 1973b). All the important marketing societies in the state except the Honnavar Agricultural Produce Co-operative Society Ltd. are now functioning as the agencies of the Central Arecanut Marketing and Processing Co-operative Ltd., Mangalore.

Table 9. Grade designation and definition of quality cut-boiled and dried arecanut.

Grade designation	Size (Diameter in mm)	Broken nuts (Maximum percentage by weight)	General characteristics
			ALL THE NUTS SHALL BE
Pheeton big Pheeton medium Pheeton small 18 and above	Below 18 but not less than 16 Below 16 but not less than 15	0.5 0.5 0.5	a) Prepared from tender nuts b) Of uniform colour i.e., bright shining to dull red colour c) Free from insect infestation and visible mould and d) Reasonably dry and be the tapering end (posterior) of the cut-nut.
Rajalu big *Rajalu* medium *Rajalu* small	18 and above Below 18 but not less than 16 Below 16 but not less than 15	0.5 0.5 0.5	a) Prepared from tender nuts b) Of uniform colour i.e., bright shining to dull red colour c) Free from insect infestation and visible mould and d) Reasonably dry and be the stalk-end (anterior) of the cutnut with a depression at the top.
(+) *Kadihasa* composite	Below 15	0.5	a) Prepared from tender nuts b) Of uniform colour i.e., bright shining to dull red colour c) Free from insect infestation and visible mould and d) Reasonably dry and shall include both anterior and posterior portions of the cut-nut.
* *Bette* big *Bette* medium *Bette* small	18 and above Below 18 but not less than 16 Below 16 but not less than 15	0.5 0.5 0.5	a) Prepared from mature nuts b) Of uniform colour i.e., bright shining to dull red colour c) Free from insect infestation and visible mould and d) Reasonably dry and shall include both anterior and posterior portions of cut-nut.
Nuli	This variety has irregular shape and size		a) of no uniform shape or size, shrunken in appearance b) of light to dark red in colour, c) thin in structure, brittle and lightest of all other nuts, d) reasonably dry and e) free from insect infestation

Note : To allow for accidental errors in grading, 5 percent of the next lower or higher grade shall be permitted.

+ *Kadihasa* include pieces of *pheeton* and *Rajalu* which are below 15 mm in size.

* Upto 1 percent of the *Minikai* and upto 5 percent of *Gorabalu* shall be permitted.

Table 10. Sales tax in various states as on March 2001

State	Percentage
1. Karnataka	4.0
2. Kerala	4.0
3. Tamil Nadu	8.0
4. Andhra Pradesh	7.0
5. Orissa	8.0
6. West Bengal	12.0
7. Delhi	4.0
8. Maharashtra	3.2
9. Rajasthan	10.0
10. Goa	3.0
11. Gujarat	6.6
12. Madhya Pradesh	4.0
13. Bihar	12.0
14. Uttar Pradesh	4.0
15. Assam	8.8

In Kerala, the arecanut marketing co-operative societies, on the whole, have not made much progress. Most of the terminal markets for arecanut produced in Kerala are located outside the state. The first co-operative marketing society for arecanut in the state was set up in 1943 at Kumaranellur (Lakshmanachar & George, 1982). Subsequently a few more marketing societies were set up and fifteen of them received financial assistance from the erstwhile Indian Central Arecanut Committee, Calicut. Most of the societies are now working as the agents of the Central Arecanut Marketing and Processing Co-operative Ltd., Mangalore.

The Kerala State Co-operative Marketing Federation was established in 1960 with a view to co-coordinating the activities of all the primary marketing co-operative societies functioning in the state dealing in arecanut and other agricultural commodities (Lakshmanachar, 1971). The Federation had been given financial assistance from the National Co-operative Development Corporation at the instance of the erstwhile Indian Central Arecanut Committee. Besides arecanut, the Federation is now concentrating its activities on other commodities like cashew, cocoa etc.

The Central Arecanut Marketing and Processing Co-operative Limited (CAMPCO)

Research and developmental measures adopted in arecanut led to substantial increase in the production of arecanut in the country and towards the end of 1971 there were indications of an imminent price fall. By the end of 1972 the prices fell by almost half of the 1969-'70 prices. This created panic among the growers of Kerala and Karnataka in particular and the two state governments constituted a committee each to look into the problem. The committee constituted by the Government of Karnataka examined the situation in detail

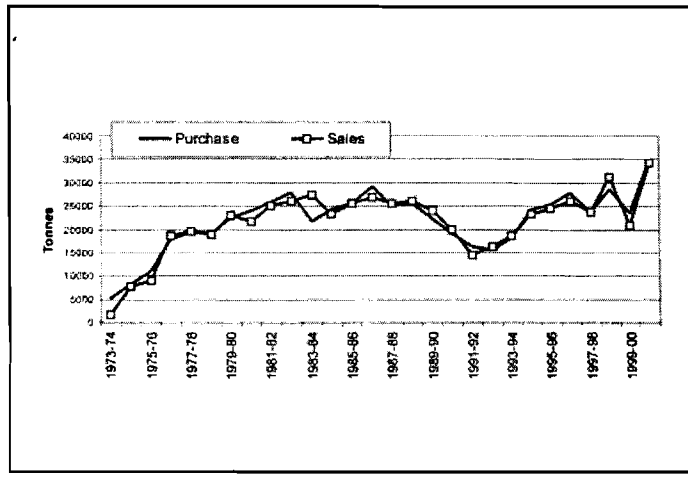

Fig. 8. Procurement and sales of arecanut by CAMPCO Ltd., Mangalore

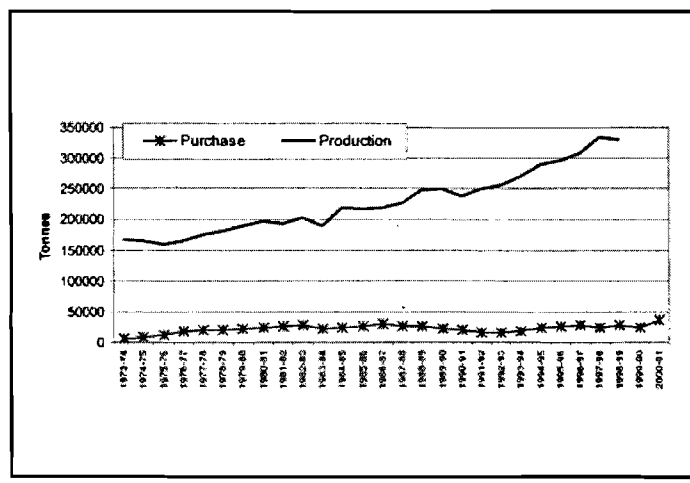

Fig. 9. Production of arecanut in India and procurement by CAMPCO Ltd.

and attributed the reasons for the fall in price to increased production, bleak export potential, lack of alternate uses, market speculation, manipulation by intermediaries, poor holding capacity by the growers and inadequate marketing arrangements. The committee therefore recommended setting up an apex institution to purchase, stock and sell arecanut and also to take up processing, wherever possible.

The Central Arecanut Marketing, Processing and Cooperative Limited "The CAMPCO" was born on 11th July, 1973 under Section 7 of the Karnataka Cooperative Societies Act, 1959, read with Section 4(2) of the Multi Unit Cooperative Societies Act 1942. The institution is presently functioning under the Multi State Cooperative Societies Act 1984. The following are its main objectives:

i. To procure arecanut and cocoa of the members and if necessary, from other growers on agency basis or on outright purchase basis.

ii. To arrange for sale of arecanut and cocoa and their products to the best advantage of the members and also to advance loans to members on the pledge of goods and to do all other things necessary to carry out the objectives.

iii. To promote and develop areca and cocoa production, marketing and processing. (Cocoa Procurement and processing objective has been included during 1979).

The area of operation of this Cooperative extends to the States of Karnataka and Kerala. However, for the marketing of arecanut, cocoa and their products, the whole country has been covered. Arecanut purchase operations have been extended to Assam, Andaman and Goa but at Assam it had to be closed due to disturbance.CAMPCO entered the arecanut market in November 1973 and within a short period of its entry into the market; the Cooperative was able to bring the market to the pre-fall level and by its judicious and effective procurement and sales policy, and efficient business administration. CAMPCO has been able to assure the growers of an economical price for their produce. Thus, by the operations of CAMPCO, the growers are now getting a very remunerative price for their produce, and CAMPCO has been able to stabilize and maintain the arecanut market at a very economical level, thus improving the economic conditions of areca growers. CAMPCO started procurement initially in 5 centres only and today, it operates through 96 Procuring Centres throughout the States of Karnataka and Kerala. During the year 2000-2001, CAMPCO's procurement and sales of arecanut was 35,049 tonnes and 34,451 tonnes valued at Rs 323.97 crores and Rs. 335.92 crores respectively. Procurement and sales of arecanut by CAMPCO Ltd, Mangalore is given in Fig.8.

There is a very wide gap between quantity of arecanut procured by the CAMPCO and the total produce available in the country (Fig. 9). Hence there is need to encourage CAMPCO to procure at least 60 % of the produce available in the country to safeguard the interests of the small and traditional arecanut farmers.

Though the CAMPCO was not a dominant buyer, its purchase could induce a degree of competitiveness in the market. Its presence may have collusive action on the part of market intermediaries. The large number of buyers (nearly 15 percent of the total registered traders in Mangalore market) operating at SKACMS ruled out the possibility of any such collusive action. Similarly, large number of small and medium purchasers in the market (who purchase less than 20 bags per day and from nearly 42 percent of the total buyers) reflects the condition of easy and free entry into the market. Thus the co-operative arecanut marketing system has fulfilled another vital feature of a competitive market. In addition, it emerged as a leader in the market and in turn could exercise a significant and positive impact on the market prices.

The CAMPCO's performance in the market had a positive impact even in real terms on the prices of arecanut. This has resulted in higher incomes to the arecanut growers of

Karnataka. In addition, the CAMPCO could induce a structural change with acceleration in the monthly prices of arecanut. The CAMPCO's price influencing mechanism was effective in this regard compared to its intervention through procurement quantity. In this respect the CAMPCO has to execute its procurement policy very carefully; it is like using a double-edged knife. As an enterprise it has to make sufficient transactions so as to run the business effectively. While doing so, it is supposed to give remunerative price and a fair deal to the grower members. On the other hand, as an integral part of the entire marketing system, it has the responsibility to ensure the stability of the arecanut economy. For this purpose, it has to intervene and influence the market through its procurement programmes so as to assure high and stable prices of arecanut in the market. Again, here, it has to make purchases in such a way that it should not have an unfavourable impact on the market prices of arecanut.

The CAMPCO's procurement and market intervention, however, did not achieve significant long-term stability in the economy. Arecanut prices witnessed high year-to-year fluctuations during the post –CAMPCO period and compared to the pre-CAMPCO period in the Mangalore market. This highlights that growth and instability are not mutually exclusive in the arecanut economy of Karnataka. The CAMPCO's procurement programmes, in this respect, should be aimed at moderating the annual fluctuations in the prices of arecanut and provide the inter-seasonal stability in the market. Stabilising the production of arecanut helps to achieve this objective to some extent. In addition, provision of market intelligence services, long-term prices trends and future projection of the prices, supply and demand for arecanut on a regular basis will assist the growers to take appropriate decisions regarding the stock, disposal of arecanut, new planting, expansion of area under arecanut and so on. The CAMPCO can establish a separate market information cell, and bring out periodicals to disseminate production as well as marketing information to the arecanut growers (Prakash *et al.*, 1998).

Market Intelligence and Price Fluctuation

Dissemination of market price

In the case of arecanut, arrangements for market intelligence in the past were not at all satisfactory. Non-availability of market intelligence to the growers and most of the merchants is one of the main reasons responsible for high fluctuations in the price of this commodity in different markets. At present the local authorities in the main producing states have made arrangements through the press and radio for disseminating information on daily and weekly prices, arrivals etc. The Directorate collects and maintains information on on market information both domestic and foreign (Nambiar, 1974). The Directorate of Arecanut and Spices Development, Calicut is also disseminating market information through its Journal, 'Indian Journal of Arecanut, Spices and Medicinal Plants'.

Price behaviour of arecanut

Price of an agricultural commodity plays a vital role in the marketing economy of the Country. The price of arecanut depends on variety, grade, colour, maturity, moisture content etc. Price fluctuations are mainly due to variation in supply position of the commodity, transport facilities from one region to the other, efficiency of the market intelligence service, availability of credit and storage facilities and above all the system of marketing free from exploitation. The price fluctuations generally do not affect consumption and demand (Lakshmanachar and Shenoy, 1964).

The Arecanut price during 1971-72 was Rs.664 / q which fell down to Rs. 414 / q during 1972-73, which was the lowest ever. At this point of time the farmers of then Mysore state (now Karnataka) requested for intervention and the government constituted a Committee under the Chairmanship of T.T. Paulose. The Committee had given many valid recommendations. One is establishment of CAMPCO Ltd, which was initiated and came into existence. Since than the price went up to Rs. 692 during 74-75 and steadily increased to 2539 during 1985-86 and subsequently it started falling to Rs.2092 during 1986-87 and Rs.1604 during 1987-88 and regained only during 1989-90 and this set-back made the farmers to think of diversification, however, a spurt in the increase in the price had come during 1990-91, which was a jump from Rs. 2564 to Rs. 4024. At this point of time the 'Panparag', 'Panmasala', 'Gutka', etc. came into the market, which has boosted the price of arecanut. The price during 1997-98 was Rs.7005 and again a quantum jump to Rs. 9052 during 1998-99 and Rs.13181 during 1999-2000, which was really a very strong spurt in the price (Table 11). This motivated many of the farmers to take up arecanut cultivation. After such spurt, the price which had fallen down to Rs.8397/q in 2000-01, created panic among farmers. For the same period the price behaviour of Metro Market Bombay showed a high profit margin to the traders particularly during 1999-2000. At the same time on comparison with international price the export price from India was Rs. 8796 /q during 1998-99 while import price was Rs. 2796 and the domestic price was Rs. 9052 / q While analysing the reason for high price for arecanut the 'Gutka' making and selling is the most profitable item in the country, which is ruling the price. Considering the harmful effects of 'Gutka', 'Panmasala', 'Panparag', etc. which are only stimulant, if there is a total ban then there will be a drastic fall in price of arecanut in the country and the farmers has to face a very severe financial crisis. Hence there is a need to work out a strategy for fixing a support price in view of the cost of cultivation, market demand and others factors.

The price was maximum in during 1999-2000 and ranged from Rs. 11,626 to 13,181 / q The fall in price started from November 1999. If we compare the import data and the price it can be seen that the fall in price of arecanut is not due to the import. As per the official statistics the quantity of arecanut imported during 1999-00 was only 3022 tonnes.

Attractive price prevalent from 1994-95 encouraged farmers to go in for new planting of arecanut. This could be assessed from the increased sale of arecanut planting materials

Table 11. Annual price history of arecanut (Rs./quintal) in major markets

Year	Kerala					Karnataka			Assam
	Cochin (Dry)	Kozhikode (dry)	Thrissur (Iylan)	Thrissur (Choor)	Mangalore (Supari)	Shimoga (Saraku)	Sirsi (Chali)	Sagar (White areca)	Gauhati (Supari)
1991-92	5423	4592	7351	7873	5816	9653	5667	5546	5344
1992-93	5263	5271	9347	10555	5532	11110	5395	6106	5151
1993-94	5054	4585	9345	10547	4871	10438	4852	4091	NA
1994-95	5183	5397	8077	10555	5931	10718	5956	5748	5167
1995-96	5285	5745	7834	10383	6123	11442	6136	5872	4968
1996-97	5789	5947	10323	14412	6505	17050	6770	6316	6310
1997-98	6116	6387	11278	12826	7005	13929	6912	6611	5933
1998-99	8200	8116	11820	12106	9052	16224	8920	8851	7935
1999-00	7926	11625	14181	14559	13181	17147	13135	12328	12913
2000-01	6484	6378	12798	12687	8999	16697	7808	6768	7549

from the Research Institutions, State Government Farms and Central State Farms. These new plantings from 1994-95 would have reached yielding stage by this time and resulted in increased production. This excessive production also resulted in the fall in arecanut prices. Considering the recent price trend and the demand of arecanut farming community, the Government of India has already raised the import duty on arecanut to 100 per cent as against 35 per cent during June 2000. The price behaviour of arecanut in the selected markets is given in Table 11 and Figs. 10, 11.

A methodological attempt where non-parametric regression frame was used to analyze the time series data on arecanut (Jayasekhar *et al.*, 2003). The data have been classified into different periods based on sudden change/shift points. The differential growth rates and trends in various periods showed that three shift points corresponding to four periods were discernible. Although prices were stable after drastic fall in 1972-73, from mid-80s onwards frequent price fluctuations were observed. Commercialization of arecanut trade made marketing system highly complicated and conducive for trade manipulations. The price instability revealed in the irregular time series component proved the poor market intelligence in arecanut trade.

Keeping in view of the prevailing prices in the country it may be difficult to compete with the other arecanut growing countries where the price is very low compared to Indian price. So the possibility of competing with other countries and entering into the export market with the necessity of keeping the domestic price of arecanut high to safeguard the interests of arecanut farmers in the context of removal quantitative restrictions and WTO regime is extremely difficult.

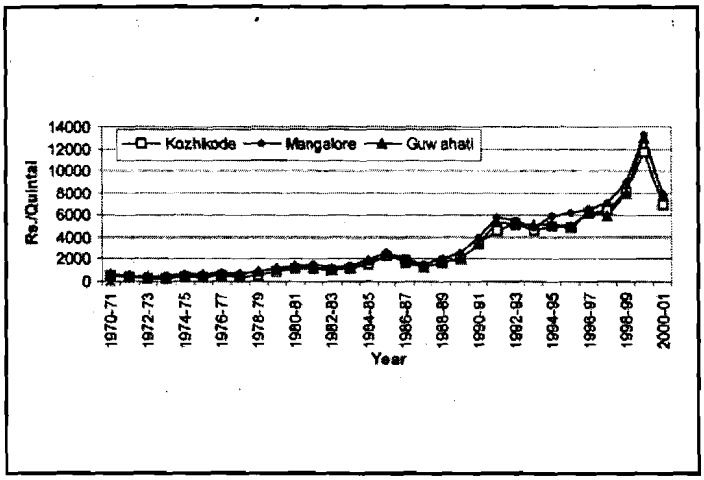

Fig. 10. Price trend of supari at selected markets in the major arecanut growing states of India

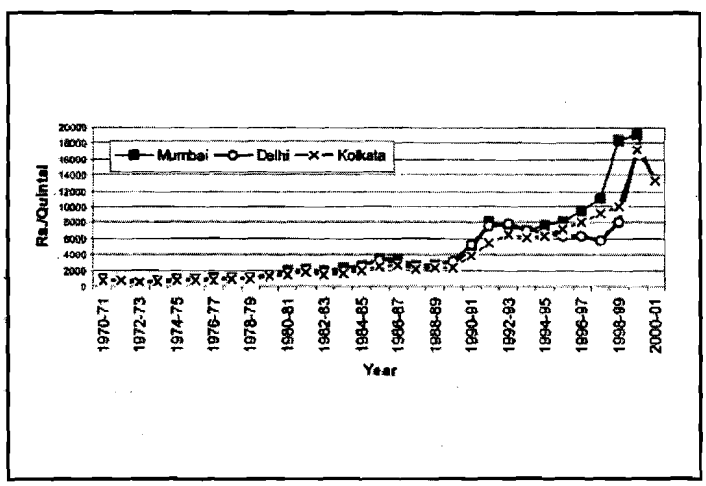

Fig. 11. Price trend of arecanut at metro markets in India

Foreign Trade

Imports

During fifties the arecanut production in the country was not sufficient to meet the internal requirement. This was reflected in the huge quantities that were imported during fifties. The quantity imported during that periods ranged from 18,364 tonnes to 50,600 tonnes. The imported arecanuts were in the form of betel nut whole, betel nut split etc. Thereafter the import gradually began to decline year after year due to the decision of the Government of India to restrict the import with a view to give incentive to the arecanut farmers. From 1974-75 to 1993-94 there was no import of arecanut. Since 1994-95 India started importing arecanut due to the increase in domestic consumption as seen in to fill the gap in demand. The quantity of import varied from 545 tonnes to 10823 tonnes during the years 1994-95 to 1999-2000. As per official estimate of the Directorate General of Commercial

Intelligence and Statistics, Kolkatta, 3022 tonnes of arecanut was imported during 1999-2000 from Sri Lanka, Indonesia, Bangladesh, Singapore, Hong Kong and Myanmar.

Export

Arecanut is a commodity, which has a very limited export potential. The bulk of production is consumed within the country. However a small quantity of arecanut is exported mainly meant for the Indian settlers abroad. The important countries to which arecanut is exported are Nepal, UK, Singapore, Maldives, Saudi Arabia, Russia, Thailand, Australia, USA etc. Quantity of export varied from 330 to 823 tonnes during the last ten years. Trend in import and export of arecanut in the country is given in Fig. 12 and Table 12. The trend

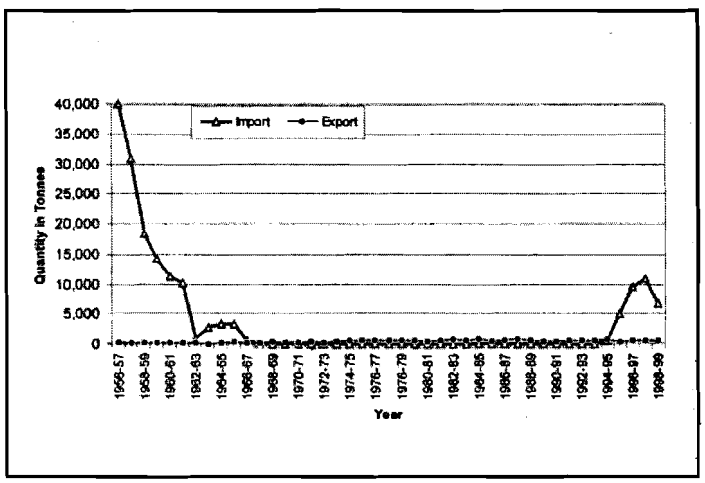

Fig. 12. Trend in import and export of arecanut in India

Table 12. Export and import of arecanut in India

Year	EXPORT		IMPORT	
	Quantity (Tonnes)	Value ('000 Rs.)	Quantity (Tonnes)	Value ('000 Rs.)
1994-95	823	60002.0	545	7024.9
1995-96	406	36076.0	5091	94674.6
1996-97	513	41908.0	9565	212232.3
1997-98	664	36550.0	10823	339647.8
1998-99	533	46891.8	6708	187557.4
1999-00	734	69178.3	3022	94356

Source: Directorate General of Commercial Intelligence & Statistics, Kolkata.

very clearly indicates that that there is a very limited scope for export of arecanut or its processed products.

DEVELOPMENT

Arecanut research and development programmes started simultaneously with the allotment of annual grants of few lakhs of rupees by the Indian Council of Agricultural Research in the mid 40s. To tackle the urgent problems facing arecanut industry and also to consider setting up of organizations to undertake systematic crop development and marketing of arecanut an ad-hoc committee was set up in 1947. The committee initiated an All India survey in 1948 to understand the agricultural practices adopted in different arecanut growing regions in the country. The recommendations made based on the survey were: (1) the need for intensive cultivation adopting effective cultural and manurial practices, (2) control of pests and diseases, (3) setting arecanut research station to initiate work on fundamental and applied research programmes, (4) establishing regional arecanut nurseries to supply quality planting materials, (5) to gather statistics on arecanut production and productivity, and (6) to initiate extension programmes to improve production (Velappan and George, 1982).

Indian Central Arecanut Committee

Government of India constituted the Indian Central Arecanut Committee (ICAC) in May 1948 to undertake programmes on crop improvement, development and marketing of arecanut. The functions assigned to the Committee were assisting the Government of India in the improvement and development of the production and marketing of arecanut and arecanut products and all matters incidental to it. The objectives were: (1) assisting or encouraging agricultural, industrial, technological and economical research, (2) undertaking production and distribution of seeds of improved varieties, (3) encouraging and assisting the production of improved cultivation and plant protection practices, (4) encouraging the purchase, curing, grading and marketing of arecanut and its products through co-operatives or other agencies, (5) giving financial and technical assistance for cultivation, curing, processing, grading and marketing of arecanut and its products, (6) establishing and maintaining research centers and farms, curing centres etc., (7) establishing market intelligence service, (8) carrying out propaganda and publicity in the interest of arecanut industry, (9) recommending the maximum and minimum prices to be fixed for arecanut and controlled purchase and distribution of imported nuts, (10) rendering advice on all matters relating to the development of the industry and (11) advising the Government of India on all matters within the functions of the Committee or performing many other duties assigned by the Government.

The developmental activities undertaken by the Indian Central Arecanut Committee were; (1) Survey of wastelands suited for arecanut cultivation in India, (2) Establishment of arecanut nurseries, (3) Establishment of arecanut research stations, (4) Disease investigation

scheme, (5) Simple manurial trails on arecanut in ryots' gardens, (6) Technological research on arecanut, (7) Pilot scheme for the study on cost of cultivation of arecanut, (8) Samples surveys for correct estimation of area and production of arecanut, (9) Propaganda and publicity

The Central Arecanut Research Station was established at Vittal in 1956 by the ICAC, which subsequently merged with the Central Plantation Crops Research Institute in 1970 under the aegis of ICAR. This institute was having arecanut research activities in its regional station, Vittal (Karnataka), and research centres at Hirehalli (Karnataka), Kannara (Kerala), Kahikuchi (Assam), Mohitnagar (West Bengal) (Velappan and George, 1982).

Directorate of Arecanut and Spices Development

The Directorate of Arecanut and Spices Development was created as a subordinate office of Department of Agriculture and Co-operation for continuing the development work of the crop after the dissolution of the Indian Central Arecanut Committee established in 1949. The research work done by Arecanut Committee was handed over to the ICAR and the development activities entrusted with the Directorate of Arecanut and Spices Development. The ICAC could not do much for the development of the crop during the I Five Year Plan Period. Establishment of arecanut nursery for distribution of quality seedlings in the potential region of Assam, West Bengal and Kerala was the only activity carried over by the Directorate then.

During the Second Five Year Plan period arecanut development was initiated by allocating Rs. 14.11 lakhs. The actual measures contemplated for achieving the increase in target of area and production were: (1) Establishment of new nursery, (2) Demonstration plots, (3) Pump set etc. for irrigation, (4) Supply of fertilizer and measures and credit, (5) Subsidy and plant protection measures, (6) Publicity propaganda.

During this period, though the area actually exceeded the target, the production fell short of the target mainly due to delay in implementing the schemes. During the Third Five Year Plan the total provision made for the developmental schemes was Rs. 5.424 million. The principal development measures adapted to the different states were production and distribution of seedlings, organization of demonstration plots, agricultural practices, manuring, plant protection etc. In view of the development measures adopted during the third plan period the production of arecanut increased by two and half times the target of increase in production. The total production of arecanut at the end of the III Five Year Plan reached at 1,21,864 tonnes as against the production of 96,000 tonnes at the end of II Five Year Plan. During the periods 1966-67, 1967-68 only annual programmes were initiated. During the IV Plan Period no extension of area under arecanut was contemplated. The scheme-wise outlay of development work on arecanut during the IV Plan was about Rs. 10.87 lakhs.

During the V, VI and VII Five Year Plan Periods only limited developmental measures had been implemented. As the production of arecanut has reached the level of self-sufficiency there was no scheme during the VII Plan. However during 1991-92 and 1993-94 an amount of Rs. 111 lakhs were released for the development of arecanut in the states of Kerala, Karnataka and Assam.

In order to overcome the constraints like wide gap in yield due to non-adoption of recommended package of practices, incidence of diseases, lack of irrigation etc. Central Sector Schemes with an outlay of Rs. 5 crores was implemented during the VIII Five Year Plan period. The following measures were taken up under the scheme: (1) Control of foot rot disease, (2) Distribution of sprayers, (3) Control of *Ganoderma* disease in Assam through rejuvenation and pre-planting demonstration, (4) Eradication of yellow leaf disease, (5) Installation of irrigation unit under arecanut garden, (6) Production and distribution of arecanut seedlings for replanting and gap filling.

Considering the trend in demand for arecanut and the sophisticated ways in which it is used for chewing, an annual growth rate of 4% was envisaged during the VIII Plan period. Accordingly the production target of 3.4 lakh tonnes has been made for 2000 AD. The additional production is to be achieved mainly through productivity increase in the existing gardens.

Impact of Development Programmes

The Second Five Year Plan (1956-61) registered maximum annual growth rate in both area and production of arecanut. This was due to the various development activities undertaken during First & Second Five Year Plan Periods by Indian Central Arecanut Committee under the Ministry of Agriculture and research activities done by Central Arecanut Research Station, Vittal and Regional Arecanut Research Stations in the country. The second Five-Year plans also registered significant increase in both area and production. During Fifties the arecanut production in the country was not sufficient to meet the internal requirement.

Implementation of various development and research programmes undertaken during the first three plan periods was almost remedied the above problem. Remarkable achievement made in that period was the substantial reduction in the import of arecanut. Fifth Five Year Plan registered low annual growth rate in production and the growth rate in area were negative. The reason for this reduction in area was the yellow leaf disease prevailed during that periods. By the end of sixth plan itself the production of arecanut has reached a level of self-sufficiency. Annual growth rate in productivity was maximum during VI Five-Year Plan (Fig. 13).

Constraints

Till recently, arecanut was the most profitable plantation crop in the country. Because of the higher prices, people started expanding area indiscriminately irrespective of the

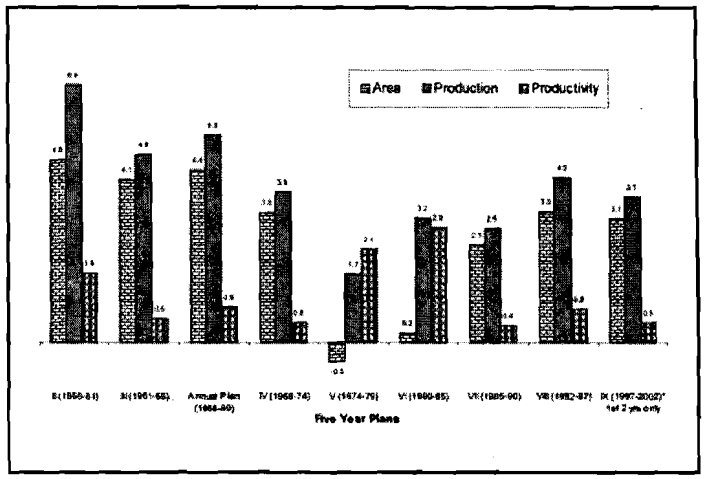

Fig. 13. Average annual growth rate(%) in area, production and productivity of arecanut in India during Five Year Plan Periods.

suitability of the crop to a particular region both in non-traditional and traditional areas converting the paddy fields into areca gardens. This has led to increased problems in arecanut cultivation leading to possible excess production resulting in the steep price fall. This led to the traditional arecanut farmers in Karnataka to approach State and Central Governments for taking appropriate action so that the farmers could be saved from penury.

There is an urgent need to increase not only the productivity of arecanut but also the profitability for unit area of land on a sustainable basis. This necessitates diversification based on the concept of cropping / farming systems. In the present context of removal of quantitative restrictions and the WTO regime, unless we are competitive in terms of price and quality, it is going to be very difficult to sustain arecanut cultivation over a period of time. As far as the productivity is concerned, the Indian productivity is 1189 kg / ha of dry arecanut whereas the yield in China is 3752 kg / ha. If arecanut farmers have to be competitive there is an urgent need to improve the productivity of the crop, which is possible since the farmer in Maharashtra is getting 3942 kg / ha. This also needs motivation of the farmers and educating them on the need for improving productivity and providing them appropriate technical support in terms of viable technologies and education to achieve the target.

Location specific technologies including cropping/farming system recommendations are available for increasing not only the productivity of unit land area but also profitability. Government of India through its schemes implemented through state department of agriculture/ horticulture may spread the message through mass media about need for being competitive in terms of price and quality to withstand the competition from the neighbouring countries.

Committees Setup to Study the Farming Crisis in Arecanut

Paulose Committee

During 1973, the State Government of Mysore had decided to appoint a committee under the chairmanship of Shri. T. T. Paulose, Director, Directorate of Arecanut and Spices Development, Government of India to undertake a study of the entire situation of arecanut and make recommendations based on the study for the consideration of the Government. The Committee submitted its report on 31st March 1973.

The following were the recommendations of the Paulose Committee:

1. Imports of arecanut, even of smaller quantities or on barter basis, should be stopped. In view of the present position regarding production within the country, there is absolutely no justification for any import. Strict vigilance should also be exercised to prevent any unauthorised entry of arecanut into India from outside.
2. All further expansion of area under arecanut should be discouraged. Even in existing gardens, whenever the need for under planting arises, the possibility of planting other more remunerative crops should be considered. In the light of this suggestion, distribution of arecanut seedlings from all Government nurseries and farms should be discontinued. Institutional financing agencies should be requested not to afford any financial assistance for extensive cultivation of arecanut.
3. Since the income from arecanut has fallen below economic levels, the cultivators should be encouraged to take up cultivation of various intercrops like, cocoa, pepper, cardamom, tuber crops, fruit plants etc., in their gardens to supplement their income. Financial and technical assistance for the cultivation of inter-crops should be granted liberally. Although certain cultivators now practice inter-cropping these intercrops are not receiving the desired attention. Moreover the practice is to be adopted by other cultivators also, for which suitable propaganda should be conducted.
4. Deterioration in quality has been partly responsible for obtaining lower prices in arecanut. Generally the cultivators do not grade their produce, but leave this work to the merchants with the result that the benefits of grading go to the latter. This has been partly responsible for the great difference in the retail price and the price obtained by the producer. Further, harvesting of immature or over mature nuts, improper processing, drying etc., also leads to deterioration in the quality of produce. If sufficient care is taken by the growers in the matter of time of harvesting, proper processing etc, and if the produce is properly graded and marketed, it will be possible to secure better prices even under present conditions. Although certain schemes for popularising grading were in operation in the State in the past, the growers do not seem to have taken advantage of it. It is necessary to undertake suitable propaganda work amongst the growers to make proper processing and grading more popular.

5. Loan facilities for intensive cultivation should be liberalized. While in the past many of the cultivators did not need any financial assistance in view of the attractive prices for arecanut, under present conditions unless the cultivator is helped adequately and in time, he will not be able to adopt proper cultivation methods which may lead to fall in unit production and consequent further reduction in his income. The rules for repayment of such loans also need scrutiny to avoid the difficulties now experienced by the growers. Besides production loans, produce loans should also be granted in adequate measure to strengthen the bargaining power of the growers.

6. Unsatisfactory marketing arrangements has been the base of the problem. The large number of intermediaries functioning in the field of marketing has brought down the producers' share in the consumers' price. The irony of the position is that even at present in most of the consuming centres, the price paid by the consumer is almost as high as what it was in 1970-71, whereas the producers' price has come down to less than half. This exploitation of the producer could be stopped only by reducing the number of intermediaries and creating a situation whereby the producer will also have a say in the matter of regulating prices. Although a number of Cooperative Marketing Societies are functioning in the State and it must be admitted that when compared to other arecanut producing States, the Cooperative Areca Marketing Societies in Karnataka are functioning more efficiently - since they do not have sufficient arrangements to directly approach the consumers' markets, Cooperative marketing has not made the desired impact despite the large volume of their transactions. Moreover, these Societies do not have sufficient storage facilities and arrangements for control of storage pests and diseases, which ultimately lowers the quality of the product. It is therefore necessary to have a Central Organisation for purchase of the bulk of the produce, for its proper storage and timely release for sale as and when there is demand. The existing buyers' market in arecanut can then be converted into a seller's market to the advantage of the growers.

7. At present only a small quantity of arecanut is exported mainly to Nepal and also to meet the needs of Indian settlers abroad. The scope for expanding the export trade is also limited. The short fall in production in Bangladesh is only a temporary phase. In a few years, production in that country is bound to increase and will become self-sufficient in arecanut. Pakistan needs larger quantities of arecanut. In Sri Lanka, there is no possibility of their buying arecanuts from India. When the habit of chewing is declining even in India, it would be difficult to popularise this habit in foreign countries among people who are not accustomed to it in the present form. The only possibility is expansion of the export trade is scented supari, which now earns about three to four lakhs of rupees in foreign exchange. There are at present a very large number of scented Supari manufacturers in India, each adopting his own formula for the

manufacture without any control over the quality of the produce and the ingredients used. If export trade in this item is to be expanded, it is necessary to improve and maintain the quality of the product and to make available to the manufacturer some of the other ingredients required, namely Clove, Cardamom etc. at reasonable prices. Recently there has been a report about the use of saccharine that is an additive in scented supari owing to certain legal restriction on its use. If the use of saccharine is not permitted for reasons of health, it will be necessary to find an alternative additive for manufacturing scented supari so that such restrictions may not lead to withdrawal of the commodity from foreign markets at a time when we can ill-afford to loose the opportunity for expansion of any arecanut based industry (Anonymous, 1973).

Rethinam Committee

In the light of various representations received from arecanut growers including the CAMPCO (The Central Arecanut and Cocoa Marketing and processing co-operative Limited) regarding fall in arecanut prices and other issues related to arecanut, Government of India constituted an expert committee under the Chairmanship of Dr. P. Rethinam, Chairman, Coconut Development Board with the members drawn from representatives of the growers, the CAMPCO, officials of Department of Horticulture, Government of Karnataka, Ministry of Commerce, Government of India, Director of CPCRI and the Director, Directorate of Arecanut and Spices Development as the member Secretary.

The following were the terms of reference of the committee:

1. To examine the various issues related to production and utilization of arecanut and suggest measures for increasing returns per unit area.
2. To examine uses of arecanut and suggest alternate use for better utilization
3. To examine the marketing and import duty etc. and suggest measures for improving marketing and profitability to farmers

The Committee has examined all issues related to arecanut and has submitted a detailed report with its recommendations in May, 2001 to the Ministry of Agriculture, Government of India. Based on the recommendations, Government of India has developed action plans for the future. One of the action plans is to discourage further area expansion in arecanut. Considering that there is no alternative use for arecanut other than the masticatory purpose. Though alternative uses of arecanut have been reported, viable technologies are yet to be developed for exploiting it economically. Further arecanut crop doesn't contribute to food or nutritional security of people and doesn't have considerable export potential for future. Under this circumstances the expert committee recommended initiatives to increase the productivity of arecanut, so as to increase the income from unit area of land through crop

diversification in the existing arecanut plantation adopting inter and mixed cropping with location specific crops. The committee has made the following recommendations.

1. Arecanut as a crop neither contributes to food and nutrition security of people nor has any significant foreign exchange earning potential. However, the reported medicinal values of arecanut and other alternative uses need to be explored profitably for the sustenance of the arecanut farmers in future.

2. Appropriate action may be initiated to discourage the conversion of command areas into arecanut plantation in Karnataka and the new areas coming up in the coastal Andhra Pradesh as mixed crop in coconut and other states by curbing the financial assistance given either by centre or state governments.

3. Seednuts and seedlings are to be distributed from Govt. nurseries / ICAR institutes / Central State Farm Nurseries only for replanting of old plantations with high yielding varieties and not for any new area planting.

4. Adequate steps to be taken by the State Govts. to create awareness among the farming community about possible impact of the indiscriminate expansion of area over a period of time and the need to have sustainable income.

5. For productivity increase of existing plantations, which are young or old, assistance to drip irrigation may be extended.

6. To discourage the new area expansion of arecanut the financial institutions like NABARD, Cooperatives, Nationalised Banks, etc. may phase out the financing of area expansion.

7. The research efforts made so far had resulted in releasing of five high yielding varieties suitable for different regions. Production technologies like nutrient and water management are also available. Cropping system showed the profitability of arecanut +cocoa mix, areca + pepper on areca + banana as well as areca + pepper + clove + nutmeg which needs to be popularised to get sustainable income from various crops instead of mono cropping. Viable plant protection technologies are also available. A few farmers who are adopting such cropping systems are getting higher income and also additional employment potential. This needs popularization through demonstration, which can be included in the Tenth Five Year Plan.

8. The data on arecanut area and production provided by the Directorate of Economics and Statistics and the data available on trade do not match. Resultantly lots of difficulties were felt in planning process. This issue is to be examined.

9. The research and development organisations like CPCRI (ICAR) and SAUs in South India may design suitable harvesting devices and appropriate small dryers and grading

machines, which can go a long way for reducing the drudgery of harvest, cost of harvest and this will also help to go for on-farm processing.

10. Technical and financial assistance for the entrepreneurs to encourage / promote alternate uses of arecanut by-products such as arecanut stem, leaf sheath etc. for making disposable plates and cups, caps, umbrellas, curios and other products derived from arecanut. National Horticulture Board (NHB) may consider funding for such project similar to that of horticultural crops.

11. Since the price fluctuations in arecanut are violent, there is a need to workout a strategy for providing price support in order to safeguard the traditional arecanut growers to get sustainable income. For example, a sudden rise in price from Rs.9052 / q to Rs. 13,187 during 1999 – 2000 and again the price plummeting to Rs. 7886 in the Mangalore market during 2000 – 2001 shows the vulnerability of the marketing system to the extraneous factors. Arecanut marketing seems to be complicated system. Large number of intermediaries are involved besides a few cooperative organisations like CAMPCO and other cooperative societies in Goa and in other states. While the cooperative society at Goa could procure 60% of the produce, CAMPCO with its network could only procure 10% of production.

12. One of the factors associated with high risk of farmers is lack of storage facilities either with CAMPCO or with farmers. Therefore the committee supported that a capital subsidy of Rs.5 crore may be given for constructing airated humidity controlled godowns at different places. This may be a back-ended 30% subsidy scheme. The pattern of assistance available with NHB may be extended to the cooperative societies like CAMPCO and other cooperative societies in corporate sector and farmers in different areca growing States.

13. CAMPCO is a well-organized society in the marketing of arecanut and has vast experience in marketing arecanut. They should extend their activities in other States also.

14. The Committee observed that the tax structure varies in different States. Since it is a primary product, it should not attract any tax. Appropriate steps need to be taken by the Govt. on this aspect.

15. The CAMPCO being the apex body may have to take up marketing of arecanut; it is necessary that CAMPCO may take up a detailed survey on industrial uses, etc.

16. The import duty on arecanut was increased from 35% to 100% to safeguard the interest of farmers by the Govt. of India. However, instances are reported that arecanut is brought as dry fruit. Arecanut should not be covered under dry fruits. Appropriate action may be initiated so that the unscrupulous import should not take place (Anonymous, 2001).

Strategies for the Future

There is a good scope in increasing the productivity of arecanut per unit area. Adopting efficient water management, (drip / micro irrigation and integrated nutrient management, Integrated Pests and Disease Management (IPDM) for which the technologies are already available through the research conducted mainly by CPCRI and SAUs. Replacing the old plantations with high yielding varieties currently available to the farming community. Instead of depending upon the mono-crop in order to utilize the horizontal and vertical place, the available plantations can be utilized for growing inter and mixed crop like arecanut, pepper banana, arecanut pepper clove/ nutmeg, etc. These technologies are already available and the few farmers, who have adopted the technology, have obtained higher production per unit area. Besides the opportunities for generating additional employment will also be available. In the present context of WTO the productivity increase, production cost reduction only can make farmers competitive for which farmers should be educated through appropriate media / methods.

Though, the uses of arecanut in the pharmaceutical, cosmetic and industrial purposes have been identified, commercially viable technologies are yet to be developed. Till such time those technologies are developed, there seems to be no escape from the possible violent market fluctuations created by the manipulative traders. There are also evidences to show that chewing arecanut is carcinogenic and therefore there is always a risk of discontinuation of such intoxicants due to awareness of health consciousness among the consumers.

Many alternative uses of arecanut have been reported. In ayurvedic science its use is recommended due to its qualities of stimulation to the sex glands and its aphrodisiac qualities. It also possesses the quality of removing bad odour from the mouth. It has also been reported to be effective as digestant, carminative, anti-diabetic properties, curing skin diseases, improving eyesight, relieving asthma, low blood pressure etc. Use of arecanut is also reported in the manufacture of toothpaste, toiletries etc. Hence, alternative uses of arecanut in pharmaceutical, cosmetic and toiletry products need to be exploited. However, viable technologies are to be developed to exploit these alternative uses properly. It is suggested that research organizations like Indian Council of Agricultural Research (ICAR) and its research institutes, State Agricultural Universities, or collaborative research with CSIR organizations like Regional Research Laboratories, Central Food Technological Research Institute (CFTRI), Mysore, Defence Food Research Laboratory, Central Drug Research Institute, Lucknow, Indian Institute of Chemical Technology, Hyderabad, Cancer Research Institute, Bombay, Tata Memorial Centre, Bombay and Leading Ayurvedic Medicine Manufacturing units to take up research on a priority basis. It is also suggested that ICAR to fund these research organizations through ad-hoc research schemes from AP cess funds.

As on today arecanut is mainly used for masticatory purposes. It is used as an intoxicant. It is commonly used with lime and betel leaf for chewing. It is also consumed as processed arecanut in the form of 'gutka', 'panmasala' and 'panparag' etc., which are hazardous to health. It is also essential to develop technologies for value added products through products development in terms of pharmaceutical, industrial and cosmetic values.

Marketing in arecanut is a complex process involving mostly private traders and Cooperatives like CAMPCO and other state cooperative organizations in Goa, Karnataka and Kerala. CAMPCO established in 1973 is able to procure only 10 % of the produce available in the country and the private traders handle the rest. Due to manipulative practices of traders the CAMPCO is not able to compete with private traders in the procurement of arecanut at a reasonable price to the farmers. However, the Goa Bagayaddar Society in Goa was able to procure 60 per cent of the produce available in Goa. Hence there is a need to assist CAMPCO in such a way that at least 60 – 70 per cent of the produce is procured by the CAMPCO.

Examination of available data indicates that the annual growth rate of consumption of arecanut is around 3%. At this rate, the requirement of arecanut by 2020 is around 6,17,000 tonnes. By doubling the productivity to the level of 2360 kg/ha it is possible to reach the demand without additional area expansion. Now is the time to decide whether we should continue to increase the quantity of a produce which cannot be utilized other than masticatory purpose or to divert this valuable land for production of crops which can contribute to the food and nutrition security of people or export earnings. Since the arecanut is reported to be carcinogenic, may be in future with growing awareness of health hazards, its usage may be restricted. The Committee discourages the new area expansion under arecanut and emphasis that over a period of time two third of arecanut land will have to be released for cultivation of remunerative crops. The Committee stresses that the productivity of arecanut will have to be increased to at least 3000 kg/ha in the remaining one third of arecanut to meet the demand of arecanut by the habitual chewers and for religious functions.

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