7 *Plantation crops in the economy of the tropics*

K.V.A. BAVAPPA and M.K. NAIR

Tea, coffee, rubber, coconut, arecanut, cashew, cardamom and pepper, which are categorized as plantation crops, are restricted in geographical distribution to the tropics, mostly between 20° North and 20° South of the equator. Although these plantation crops have been successfully exploited to boost the economy of several countries in the tropical belt, they hold a special place in the Indian economy. Coconut, arecanut, pepper and cashew were cultivated by individual land owners, who were not organized to the same extent as plantation owners of tea, coffee and rubber. Large-scale plantations of tea, coffee and rubber were started only after the arrival of Europeans. However, cultivation of spices such as pepper and cardamom was in vogue from very early days in India. This is true to some extent of coconut as well. These crops have certain similarities in that they are all perennial in nature, give sustained income over a long period of time, have a fairly long juvenile phase and are crops of international trade. Among the plantation crops, spices were the earliest to be cultivated and to attract international trade.

Plantation crops in India

About 3 million hectares are under plantation crops in India, representing only about 1.65 per cent of the total area cropped. The total export earnings from plantation crops during 1983–84 was about Rs 10 000 million, which represents about 15 per cent of the total export earnings from all commodities. India is the world's leading producer of cashew, tea, arecanut and cardamom, and is third in coconut and fourth in pepper production. Therefore in the volume of their

international trade and their importance in the national economy, plantation crops compare well with all other crops put together. In addition to the primary products from these crops which are largely exported, the by-products from many of them also have considerable commercial and industrial importance. Coir, wood and shell products from coconut (Thampan, 1981), leaf sheath in arecanut (Nayar and Annamalai, 1982) and cashew nut shell liquid (CNSL) and *fenni* (an alcoholic beverage) from cashew apple are some of the by-products which have already made an impact in the industrial field.

Other than pepper, cardamom and probably arecanut, most plantation crops were introduced into India and have received little attention with respect to scientific culture. In crops such as coconut, cashew, cardamom and pepper, systematic replanting programmes have never been undertaken, resulting in stagnation of yield, if not a decline in production. However, crop based research and developmental efforts, and relatively large sized holdings in tea, coffee and rubber, have helped to obtain a steady increase in production and productivity in these crops. The situation is slowly changing in other crops as well, due to the increased awareness of the importance these crops have in international trade. In many cases suitable attention is being paid, both at central as well as at regional levels, to the improvement and scientific culture of these crops.

Coconut, *Cocos nucifera*

Origin and antiquity. Coconut palms are indispensable to the millions of inhabitants of more than 90 countries in the tropics. The palm is a primary source of food, drink and shelter to a large proportion of the population in these countries. About 70 per cent of the crop is grown in Asian and Southeast Asian countries, 10 per cent each in the Pacific Islands and the Caribbean Islands and over 5 per cent in Africa (Maramorosch and Hunt, 1982).

References to coconut are available in the Indian Classics, such as *Mahabharata*, *Ramayana*, *Markhandeya Purana* and *Brahmanda Purana* (Mayuranathan, 1938). Cosmas Indicopleustes, an Egyptian monk who visited Western India and Sri Lanka, mentioned coconut in 545 AD and in his book *Topographia Christiana* he described coconut as the 'great nut of India' (Rosengarten, 1984). The planting of coconut in Sri Lanka in 589 AD is recorded in *Mahavamsa* – an ancient chronological history. A description of the preparation of coconut wine in Java is given in an early Chinese report of the T'ang Dynasty (618–907 AD). Marco Polo in 1218 AD called it *nux indica* or the 'Indian nut', and he described coconut growing in Sumatra, Madras and Malabar (Rosengarten, 1984).

It is presumed that the generic name, *Cocos*, as well as the popular name coconut are derived from the spanish word 'coco' meaning 'monkey face', probably a reference to the three scars on the base of the shell

resembling a monkey's face. However, subsequently some confusion seems to have been created between the words 'coco', 'cocoa' and 'cacao', which has persisted even to the present day. Rosengarten (1984) traces this confusion to Samuel Johnson's Dictionary of 1755.

Martius (1850) placed the origin of coconut on the West Coast of Central America, near the Isthmus of Panama. However, this has been contested, on the basis of evidence for the cultivation of coconuts in Sri Lanka by about BC 300, as well as the discovery of a fossil (Pliocine) *Cocos* in New Zealand (Hill, 1929) and others in the deposits in the deserts of Rajasthan (Kaul, 1951). Evidence is also available for the cultivation of coconut on the Pacific Coast of Panama in pre-Columbian times where coconuts were discovered by early Spanish explorers. Coconut appears to have reached western Mexico by about 1540 AD and from there it spread to Mexico in the last years of the 16th century (Bruman, 1945). Purseglove (1972) believes that if coconut had reached the Pacific Coast of Panama before the discovery of the New World, it might have been carried there by ocean currents from Polynesia. According to Purseglove, the available evidence points to the domestication of coconut in the Indo-Pacific area, a view held by many other earlier scholars (de Candolle, 1886; Beccari, 1917; Vavilov, 1951; Corner, 1966; Child, 1974). According to the most widely accepted theory, the origin of coconut is in the Old World, somewhere in Southeast Asia or the Pacific Islands from where it might have been transported to other regions either by early explorers or by sea currents. Edmondson (1941) found that coconut is capable of germinating even after floating in the sea for a period of 110 days, and within this period it is capable of travelling up to 4900 kilometers. If this is accepted, it indicates the possibility of natural dissemination over short distances between the islands in the Pacific and Indian Oceans (Harries, 1978).

Production and productivity. India, with 1.113 million ha of coconut plantations, produces an estimated 5664 million nuts and ranks third in the world in area cultivated as well as in total production. Kerala has the maximum area within the country, with 666000 ha of coconut palms, producing 3036.4 million nuts. Tamil Nadu, with an annual production of 1132.4 million nuts, ranks second, followed by Karnataka with 883.8 million nuts, though in total area Karnataka is second only to Kerala. Tamil Nadu, with only 11 per cent of the total area contributes 20 per cent of the production and has very high productivity. The highest productivity of 9787 nuts/ha is in West Bengal, which produces 32.3 million nuts annually. An analysis of the area, production and productivity in coconut in the country during the last two decades shows that although there has been a marginal increase in the total area under the crop, the production and productivity have been showing a steady decline. The average national productivity per palm is only about 30 nuts, which is one of the lowest in the world. Overcrowding of the existing gardens due to indiscriminate planting, extension

of coconut cultivation to marginal and poor soils, non-adoption of improved management technology and nonavailability of high yielding hybrids and cultivars for planting purposes, are some of the reasons for the low productivity. The devastating root 'wilt' disease in the eight southern districts of Kerala, the Thanjavoor wilt in Tamil Nadu and Thatipaka disease in Andhra Pradesh have also contributed to the decline in productivity.

Climate and soil. Coconut grows in tropical climates, from sea level up to an altitude of 900 metres. A decline in productivity at higher altitudes has been noticed. It is essentially a tropical plant, growing mostly between 20° North and 20° South of the equator. A well distributed rainfall of about 2000 mm per year is optimal for growth and high yields in coconut. However, the palm can tolerate a wide range in the amount of rainfall, between 1300 mm and over 3000 mm. The crop grows well in areas where the mean annual temperature is around 27°C with a diurnal variation of 5–7°C. Higher temperatures may induce barren nuts, while lower temperatures (< 25°C) can cause abnormalities in the fruit (Child, 1974). Coconut is grown on a wide range of soils in India (Pandalai *et al.*, 1953). In Kerala, wherever the annual rainfall is over 3000 mm per year, the palms grow well in laterite soils. Though sandy soils lacking water holding capacity are unsuitable for coconut cultivation, when supplemented with organic manures this type of soil can also support a good crop.

Genetic variability and varieties. Tall and dwarf are the two distinct varieties of coconut. The tall palms, sometimes referred as var. *typica* Nar., are the most commonly cultivated in all the coconut growing areas of the world. Tall palms generally grow to a height of 25–30 m. They have a comparatively long pre-bearing age of 6–10 years. They are normally cross-pollinated as there is usually no overlapping of male and female phases. Fruit is generally medium to large in size and the nuts mature within a period of 12 months. West Coast Tall, Lakshadweep Ordinary, East Coast Tall and Andaman Ordinary are some of the distinct Tall types present in India. Among the introduced types, Philippines, Fiji, Strait Settlement, and San Ramon are promising when compared with the local West Coast Tall, yielding over 50 per cent more nuts and 62–77 per cent more copra.

Dwarf palms, sometimes referred to as var. *nana* (Griff.) Nar., are characterized by their short stature. They are quicker to come into bearing (3–4 years), are easier to harvest and are short-lived. They have thin trunks without a swollen base or 'bole' and the fully developed fronds rarely exceed 4 m. Though the dwarf palms yield heavily, they have a tendency to irregular bearing. Dwarfs are identified mainly by the colour of their nuts. They are presumed to have originated from tall palms either through mutation (Menon and Pandalai, 1960) or by inbreeding in talls (Swaminathan and Nambiar, 1961). In India two important dwarf types found are Chowghat Dwarf Green and

Chowghat Dwarf Orange, mainly described by the colour of their nuts and petiole. In the case of talls, the copra content is usually over 150 g/nut, while in dwarfs it ranges from 90 g to 120 g/nut. Among the recent introductions, the Philippine variety 'San Ramon' was found to produce large sized nuts yielding on an average 380 g copra per nut (the maximum recorded being 586 g). The oil percentage varies from 66–70 in talls and is about 65 in dwarfs.

In India, in addition to these two groups, there are a few other distinct types, such as Lakshadweep Micro, Kappadam, Andaman Giant, Calangute, Nadora and Benaulim, which are talls, and Gangabondam, a semi-tall. Ramachandran *et al.* (1977) reported Ayiramkachi, an intermediate type between tall and dwarf in Tamil Nadu. Different tall and dwarf cultivars have also been identified from Orissa (Panda, 1982).

The first coconut hybrid between tall and dwarf was reported from India in 1937 (Patel, 1937). Even in the nursery, the hybrids, involving tall as the female parent and dwarf as the male parent, exhibited hybrid vigour for vegetative characters, such as height, girth and number of leaves.

Subsequent studies (Satyabalan, Rathnam and Kunjan, 1970) using three different dwarfs as male parents (Dwarf Green, Dwarf Orange and Gangabondam) have indicated the influence of the male parent in the hybrids, and have shown CDO to be the better male parent among the dwarfs. Rao and Koyamu (1952) reported the practice of selection of vigorous seedlings in open pollinated Chowghat Dwarf Orange nurseries and subsequently Satyabalan (1956) observed that such vigorous seedlings are a natural cross between Dwarf Orange types and are superior to both tall and TxD hybrids in spathe production, yield of nuts and total production of copra. The heterotic effect for yield characteristics was higher in the reciprocal combination, dwarf × tall (Figure 7.1).

To overcome 'Lethal Yellowing' disease in Jamaica crosses have been made between the local tall palms and all the three resistant colour forms (yellow, green and red) of the 'Malayan Dwarfs'. Resistance appears to be transmitted to the F_1 generation. To save the time that is normally needed to establish an introduced (male) variety, the Research Department of the Coconut Industry Board of Jamaica have devised methods of freeze drying coconut pollen and have exchanged pollen with all the major coconut producing nations.

Early results from Malaysia indicate that the Malayan Dwarf and West African Tall hybrids yield earlier and are more productive than the Malayan Tall coconut. This hybrid has the best frond production rate, thus ensuring a higher bunch number, more female flowers and better nuts, as well as copra, per palm. Likewise, hybrids with the Rennel Tall variety (a large-fruited coconut) give the highest copra per nut yield.

Figure 7.1 A profusely bearing T × D hybrid coconut.

Problems encountered in tall × dwarf production programmes are associated with the technical difficulties involved in the mass production of hybrids. The method requires trained climbers for the purpose of emasculation and hand pollination of tall mother palms. In the dwarf × tall hybrid production programme, this disadvantage can be overcome since hybrids can be produced on a large scale by regularly emasculating dwarf mother palms planted exclusively for this purpose and pollinating the female flowers with pollen from the selected tall parents.

Of the two dwarf coconut palms, Dwarf Orange is preferred as the female parent in India rather than Dwarf Green, since it carries a genetic marker, so that any dwarfs arising among the hybrids can be easily located in the nursery. Dwarf × tall hybrids are more vigorous than either of the parents and are prolific yielders. They come into bearing 4–5 years after planting and out-yield ordinary tall palms and tall × dwarf hybrids.

Current seed production programmes are geared towards the production of these hybrids on a commercial scale through the establishment of seed gardens. Tammes (1955) was probably the first to introduce the concept of seed gardens for the production of coconut hybrids on a mass scale by planting alternate rows of tall and dwarf, and allowing natural pollination to take place by emasculating female parents. However, the recent trend in all countries has been to establish pure blocks of dwarf palms for the production of hybrid seeds. All the dwarf palms in a block are emasculated and assisted pollination is carried out using selected pollen.

Cultural practices. Selection of seed nuts and seedlings is of utmost importance as the performance of the new plantation will only be apparent several years after planting. The mother palms should be selected from a seed garden with a record of consistently high yields and free from the incidence of diseases. The mother palms selected should be regular bearers with yields of not less than 80 nuts/palm/year and should have been giving regular and high yields for at least the previous 5 years. February to May is considered to be the optimum season for the collection of seed nuts on the West Coast of India. The seed nuts should be fully mature, with a dried husk and free movement of water within the nut. As far as possible the harvested bunches should be brought down by means of ropes.

Well-drained, coarse textured soil is preferred for raising seedlings in a nursery. A nursery should be created in the open with adequate shade provided in summer. May–June is the most appropriate time for planting seed nuts in the nursery. Any seed nuts in which the water has dried up or the kernel has become rotten during storage should be discarded. A necessary precaution is to dip the nuts in a suspension of HCH (BHC), 400 g of 50 per cent wettable powder in 100 litres of water, at the time of sowing. Seed nuts may be sown in trenches (20–25 cm deep and 40 cm apart), either vertically or horizontally with a spacing of 30 cm between the nuts. The depth of planting may be adjusted so that the husk is just visible at the surface. Watering may be required every few days in the summer months. Mulching and shading are essential immediately after the monsoon, particularly when the nursery is located in the open in sandy soils.

In favourable environmental conditions West Coast Tall seed nuts will commence germination within 8–10 weeks after planting and up to 95 per cent of the seed nuts should germinate within 5 months. Only vigorous seedlings are selected for planting on the basis of characters such as early germination, number of leaves, girth at collar and splitting of leaflets. The seedling should be removed from the nursery only when they are required for planting in the field. At the time of pulling out, the roots can be neatly cut and seedlings removed gently along with the nuts.

The area proposed for the plantation should have an assured supply of moisture either through well-distributed rainfall or adequate irrigation facilities. Shallow soils with underlying hard rock, low lying areas subjected to water stagnation and heavy clay soils should be avoided. A spacing of 7.5 m to 9.0 m is recommended for coconut plantations, depending on the variety and the crown size. This will accommodate 124–177 palms/ha in the square system of planting. In the triangular system of planting an additional 25 palms can be accommodated. The single hedge as well as the double hedge system of planting can also be adopted. In well-drained soils, planting in the main field is done with the beginning of the southwest monsoon. In low lying areas prone to

waterlogging seedlings are transplanted at the end of the monsoon. Transplanted seedlings should be shaded and irrigated during the summer months.

The recommended fertilizer rates for adult coconut palms in India are 500 g N, 320 g P_2O_5 and 1200 g K_2O/year for an adult palm. Fertilizers are generally applied in 2 split doses, one third of the recommended dose may be applied following the summer showers and the remaining during the first week of September. The fertilizer is spread around the palm in circular basins of a radius of 1.8 m and 25 cm deep. The first application of fertilizer for young palms is recommended 3 months after planting at the rate of 50 g N, 40 g P_2O_5 and 135 g K_2O. During the second year, one third of the dosage recommended for an adult palm is to be applied in 2 split doses in May and September–October. The dosage is doubled in the third year and the full fertilizer dosage is applied from the fourth year onwards. In addition, 1 kg of dolomite or 0.5 kg magnesium sulphate/palm/year may be given in acidic soils. It is advantageous to apply large quantities of green leaf or farmyard manure or compost, especially if the soil is low in organic matter.

Coconut palms respond to summer irrigation. Under west coast conditions 6 cm of irrigation water once in 2 weeks during summer months has been found to be beneficial, increasing yields in sandy loam soils. Regular intercultivation and adequate manuring are essential to maintain the production level in coconut. However, the method of intercultivation depends upon the local conditions, soil type, and distribution of the rainfall. Cover cropping is recommended in order to add organic matter to the soil and prevent soil erosion in coconut gardens. *Mimosa invisa* Mart., *Stylosanthes guyanensis* Aubl. and *Calpogonium mucunoides* Desv. are the recommended popular cover crops.

Intercropping coconut with pineapple, banana, elephant foot yam, groundnut, or sweet potato, and mixed cropping with cocoa, pepper, cinnamon, clove or nutmeg are being increasingly recommended in order to augment the income per unit area. Certain combinations such as coconut with cocoa have been found to be well suited to west coast conditions, increasing the income from the unit area without adversely affecting the coconut yield.

Pests and diseases. The coconut palm is attacked by a number of pests and diseases. The important pests include the rhinoceros beetle (*Oryctes rhinoceros* L.), the red palm weevil (*Rhynchophorus ferrugineus* F.) and the black headed caterpillar (*Nephantis serinopa* Meyr.). The adult rhinoceros beetle bores into unopened fronds, spathes and leaf petioles and causes extensive damage. Control is achieved by extracting the beetles from the crown with a beetle hook, filling the innermost leaf axils with a mixture of 5 per cent HCH (BHC) dust and sand and treating the possible breeding sites with 0.01 per cent HCH (BHC) or

carbaryl. The red palm weevil mostly attacks young coconut palms. The major symptoms are the presence of holes, exudation of a viscous brown fluid, extrusion of chewed up fibres through the holes, longitudinal splitting of leaf bases and wilting of inner leaves. The infected palms can be saved by injecting a 1 per cent solution of carbaryl into the affected area. Black headed caterpillars live on the underside of leaflets, inside silken galleries, and feed voraciously on leaf tissues and the affected leaves dry up. Spraying the lower surface of leaves with 0.02 per cent dichlorvos of 0.2 per cent HCH (BHC) controls the pest. As this pest is subject to parasitization by a number of parasites, biological control is also possible.

The major diseases of coconut palm are root wilt disease and bud rot. The important symptoms of root wilt are flaccid or wilting leaves, chlorosis, and decay of the root system. The recent finding of mycoplasma-like organisms in the sieve tubes of affected palms is a major breakthrough in the etiology of this disease. The disease is now kept under control by the use of different management practices such as balanced manuring, removal of palms in advanced stages of the disease and the adoption of mixed cropping.

Bud rot is caused by the fungus *Phytophthora palmivora* (Butl.) Butl. The first symptom of a palm affected with bud rot is the yellowing of younger leaves. The spindle then withers and drops. The soft tissues in the crown rot and ultimately the palm dies. Control is achieved by cutting and removing all the affected tissues of the crown and applying Bordeaux paste and spraying 1 per cent Bordeaux mixture on the spindle leaves and crowns of diseased palms, as well as on neighbouring plants.

Future outlook. The national average yield of coconut at present is only 30 nuts/palm/year against the productivity potential of over 570 nuts/palm/year (Swaminathan, 1983). Individual palms consistently yielding over 400 nuts/palm/year have been identified in southern Kerala (Iyer, Rao and Govindankutty, 1979). The yield realized in the well-maintained plots in research stations at present is 174 nuts/palm/year in TxD hybrids under irrigation. The best yield realized in farmers' plot is 110 nuts/palm/year. Thus the existing gap between the national productivity of coconut and the potential yields is very wide and intensive research and developmental efforts are required to bridge this gap. Intensive cropping in the interspaces with annuals and perennials under the high density multicropping system has the potential to increase the overall productivity of coconut gardens. A beneficial crop combination of cocoa and coconut, which increases the yield of coconut palms, has been indicated by Nelliat *et al.* (1979).

Exploitation of the élite palms identified with high yield potential needs more concerted efforts immediately. As coconut is a highly cross-pollinated crop, it is difficult to realize seedling progenies with the same yield potential as the mother palm even in the case of élite

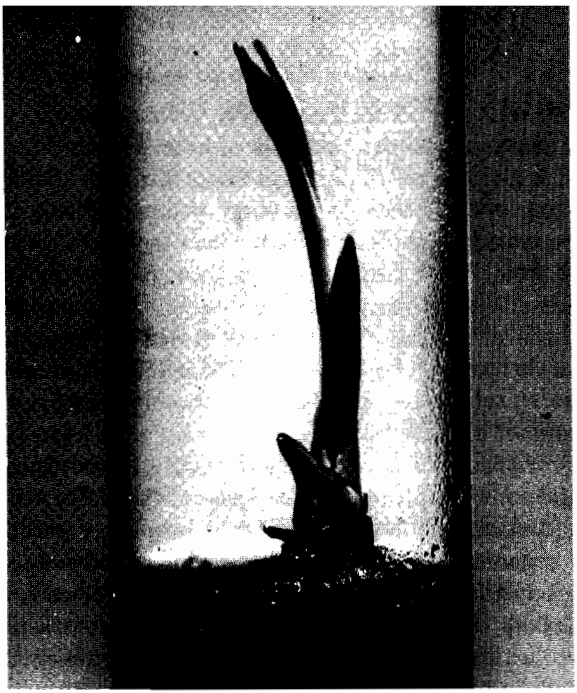

Figure 7.2 A coconut seedling growing in a test tube from tissue culture.

trees. The research results at CPCRI indicate that only about 4 per cent of the élite palms have given rise to seedlings with a comparable yield performance. The immediate alternative seems to be to multiply these élite palms vegetatively through tissue culture. Successful induction of somatic embryogenesis in coconut has already been reported by Raju *et al.* (1984), and the intensified efforts in this direction are expected to succeed in the near future and to thereby contribute to the increased productivity of coconut in India (Figure 7.2).

Arecanut, *Areca catechu*

Origin and antiquity. The arecanut palm, *Areca catechu* L. is the source of the common masticatory nut popularly known as arecanut or betelnut. It is extensively cultivated on the west coast of India in the states of Kerala and Karnataka and to some extent in Assam, Meghalaya, Tamil Nadu and West Bengal. It is used by all sections of the Indian population as a masticatory and is an essential part of several religious and social ceremonies.

The earliest reference in the ancient Sanskrit literature to the antiquity of the arecanut is in *Anjana Charitra* by Sisu Mayana (BC 1300), where reference is made to groups of arecanut palms full of inflorescences and branches presenting a nice appearance. Magha, the famous Sanskrit poet (probably BC 650), in his *Sisupala Vadha* mentioned an arecanut garden mixed with coconut. Kalidasa (4th century AD) in his

Raghuvamsa refers to the arecanut palms being used as a support for the betel vine. *Amara Kosha* by Amara Simha (6th century AD) contains a number of synonyms for the arecanut indicating the popularity of the nut during the period. Extremely artistic drawings of the arecanut palm are found even today in Ajanta Caves in Central India (Cave No. 17, late 5th century AD; Rao, 1982).

There has been some speculation regarding the origin of the generic name *Areca*. De Candolle's (1886) hypothesis with regard to the origin of the generic name from the 'Telenga name' has not received much support in the literature (Bavappa, 1964). The possibility of the generic name being coined by Linnaeus, based on a popular Malayan name *adaka*, or a Kannada name *adike*, was indicated by Bavappa (1964). According to McCurrach (1960) the name *Areca* was derived from a Malayan word meaning 'cluster of nuts'.

There is considerable speculation about the origin of the arecanut palm. According to Watt (1889), it is a native of Cochin China, the Malay peninsula and neighbouring islands. It is considered to be a native of the East Indies (presently Indonesia) and Cochin China by Thomas Green (Gode, 1961). Blume (1836) considered the natural habitat of the arecanut palm to be the Malay peninsula, Thailand and the neighbouring islands. Describing 4 cultivars of *A. catechu* and nine other species from the Philippines, Beccari (1919) considered that it was in the Philippines that *A. catechu* finally assumed specific characteristics. Blatter (1926) agreed with Martius (1850) and De Candolle (1886) that the exact place of origin of the betel palm is uncertain and that the tree has been extensively cultivated from time immemorial in all parts of the East Indies. The maximum diversity of *Areca* species has been reported from Malaya, Borneo and the Celebes and thus the Indonesian group of Islands may be taken as the centre of maximum variation (Bavappa, 1963).

Production and productivity. An analysis of the statistics of cultivated area, production and productivity of arecanut in India for the last 20 years reveals that the area under arecanut had increased from 116 830 ha in 1961–62 to 180 000 ha during 1982–83, showing an increase of about 54 per cent. The production also shows a steady rise from 95 170 tonnes to 185 000 tonnes during the period. The productivity increased from 815 kg/ha to 1024 kg/ha, an increase of about 26 per cent.

Kerala, Karnataka and Assam account for 90 per cent of the area under arecanut and 95 per cent of the production. Meghalaya, Tamil Nadu, West Bengal and Maharashtra together contribute 8.6 per cent of the cultivated area and 3.8 per cent of the production (Bavappa, 1977; Velappan and George, 1982).

Climate and soil. In the northeastern region of India where a sizeable area is under arecanut it is mostly grown on the plains since at higher elevations the winter temperatures would be too severe for the crop. The palm grows at altitudes up to 1000 m above sea level, as at higher

levels the quality of the fruit suffers (Nambiar, 1949; Bhat and Khader, 1982). Arecanut grows in a wide range of temperatures, from a minimum of 4°C (Mohitnagar, West Bengal) to a maximum of about 40°C on the west coast, though a temperature range of 14 to 36°C is considered optimal (Nambiar, 1949; Bhat and Khader, 1982). Low temperatures around 5°C with low humidity cause heavy damage to the foliage. Arecanut flourishes in areas of heavy rainfall, such as Malnad of Karnataka (4500 mm per year), as well as in low rainfall areas such as the Maidan parts of Karnataka or parts of Mettupalayam in Coimbatore district (750 mm).

The largest area under arecanut is found in the gravelly laterite soils of the red clay type, of southern Kerala and coastal Karnataka (Nambiar, 1949). In the Maidan parts of Karnataka, arecanut is planted in fertile clay loam soils (Naidu, 1962). Of all the soils, the deep black fertile clay loams in the tank irrigated areas support the most luxuriant tree growth. Sticky clay, sandy, alluvial, blackish and calcareous soils are not favourable for arecanut cultivation (Aiyer, 1966).

Genetic variability and varieties. The genus *Areca* began as a monospecific genus in Linnaeus's Species Plantarum (1753). The genus expanded rapidly from its monospecific status and is at present believed to contain about 76 species. Among these, *Areca catechu* is the only cultivated species, the nuts of which are chewed as a mild stimulant, though the nuts of a few other species such as *A. triandra* Roxb. are also occasionally used as a masticatory.

Crop improvement work in *Areca* has mainly been through the introduction of exotic and indigenous types and the refinement of selection procedures in mother palms, seed nuts and seedlings. Currently a world germplasm collection of *A. catechu* and related species maintained at the Regional Station of Central Plantation Crops Research Institute, Vittal, India, consists of 6 species of *Areca* and 34 cultivars of *A. catechu* introduced in various stages, starting from 1959. In addition, 24 indigenous accessions of *A. catechu* are also available in the germplasm collection. The variation between the cultivars of *A. catechu* in the size and shape of fruits and the colour of flowers was described from Assam by Raghavan and Baruah (1956). Murthy and Bavappa (1962) recognized 64 cultivars based on fruit size alone, from Kerala, Karnataka and Maharashtra.

A comparative yield evaluation of 16 exotic cultivars for a period of over 9 years indicated that 5 introductions, VTL-3, VTL-11, VTL-12, VTL-13 and VTL-17, have high yield potentials of 6 to 50 per cent more than the local cultivars. Among these accessions, VTL-3 obtained from Beijing (China) was found to have the most desirable characteristics, such as earliness in bearing, more female flowers per inflorescence, higher nut set, cumulative higher yield, early stabilization of production and lower height, compared with the local cultivars. The selection was released under the name 'Mangala' (Bavappa, 1977). Among the

indigenous collections, yield evaluation for a period of 10 years indicated continued high yield of 'Thirthahalli', with an increase of 49 per cent over the local types.

Studies on selection of seedling progenies showed that considerable yield increases could be obtained in plantations by judicious selection of seedlings at the time of planting as well as at subsequent stages (Bavappa and Ramachander, 1967a; Bavappa, 1970). It has also been established that in the case of seedlings, the number of leaves at the time of planting, the girth at the collar one year after planting and the number of nodes 2 years after planting have high heritability and have positive genotypic and phenotypic correlations with the yield. Exercising selection of seedlings for the above mentioned characters should not only bring down the age of first bearing of the population but should also increase the yield. The procedure for the mother palm selection has also been standardized by Bavappa and Ramachander (1967b, 1967c).

Arecanut is always propagated by seed. The age of the mother palm is an important factor for the selection of seed nuts. Collection of seed nuts should be confined to palms which commence bearing early, as well as those which have a high percentage of fruit set (Anonymous, 1967). Since the heritability of yield in arecanut is low (0.2 per cent), a substantial increase in yield cannot be expected by direct selection in a population (Bavappa and Ramachander, 1967c). However, the important criteria for mother palm selection are age at first bearing and regular bearing habit (Bavappa and Ramachander, 1967b, 1968).

Cultural practices. From the selected mother palms fully ripe heavy nuts are chosen, since these give a higher percentage of germination as well as better quality seedlings. The selected seed nuts are sown soon after harvest in soil or sand beds under partial shade, preferably after smearing with cow dung. The beds are irrigated daily. Germination commences about 40 days after sowing and the sprouts can be transplanted to the secondary nursery when the seedlings develop 2 or 3 leaves.

Beds of about 150 cm width and 15 cm height have been found convenient for transplanting the sprouts. The spacing of the sprouts in the nursery has significant influence on the growth of seedlings, and wider spacings of 45 cm are preferred. The seedlings from the primary nursery can also be raised in polythene bags. The percentage of quality seedlings is higher from shaded nurseries. The shade provided for the nursery may be either of coconut or arecanut leaves spread over a pandal (bower), or of trailing *Coccinia indica* W. & A. plants as an overhead bower.

Twelve to 18 month old seedlings are transplanted out to the main field. Seedlings with the maximum number of leaves (5 or more) and the minimum height are selected for planting.

The site selected for establishing an arecanut garden should have

adequate irrigation facilities for dry periods. It is essential that the site selected for an arecanut garden should have protection from the wind on the southern and western sides, by way of either a hillock or tall evergreen trees. Soil depth and the level of the water table are two important aspects to be considered when selecting a site for an arecanut plantation. Various methods of planting, namely square, rectangular, triangular and quincunx are presently used. Aligning the rows in a north–south direction and planting in the quincunx system lowers the incidence of sun scorching. Maximum yields are obtained from palms spaced at 2.7 × 2.7 m, planted at a depth of 19 cm.

The planting of seedlings in the permanent site is done either in May–June or September–October, depending upon the rainfall and soil conditions. In order to ensure perfect drainage, it is essential that a drainage channel is dug for every 2 rows of palms during the hot weather period beginning in October. The seedlings may be protected against direct exposure to the sun by providing artificial shade of either arecanut or coconut leaves, or by raising a shade crop of bananas.

Cultural practices followed by growers in different parts of India differ widely. In the Maidan and Malnad parts of Karnataka light digging is done twice a year, and in a few places even three times a year. According to Nambiar (1949), intercultivation increases productivity of palms by 10–20 per cent. Studies on arecanut have indicated that nitrogen at 100 g and K_2O at 140 g per palm each increase the nut production. Green leaves as a mulch at the rate of 12 kg per palm also increase nut production as well as the weight of nuts. The effect of phosphorus on any of the yield characteristics is insignificant. Based on the results of manurial trials, annual applications of 100 g N, 40 g P_2O_5 and 140 g K_2O in the form of fertilizers and 12 kg each of green leaves and compost per palm are recommended.

In places with high subsoil moisture and in areas where rainfall is well-distributed, irrigation is not practised. In certain parts of Kerala and Karnataka, arecanut gardens are irrigated during summer months by splashing water guided into channels. In recent years sprinkler and perfo methods of irrigation have also become popular. The frequency of irrigation varies between 5 and 10 days in different places.

Cocoa can be an ideal combination for mixed cropping with arecanut. The mean yield per arecanut palm in mixed cropping experiments is higher than that of arecanut palms grown as a monocrop. Among many perennial crops grown with arecanut, black pepper and cardamom are popular with farmers since these crop combinations help to augment the net income of the farm.

The stage of harvesting depends upon the type of produce to be prepared for the consumer market. There are two main types of produce, one prepared from the immature green nuts called *kalipak*, and the other from dried whole nuts called *chali*. Kerala and Karnataka are the main processing centres for *kalipak*. For *kalipak*, nuts of 6–7

months maturity are chosen, which are soft and can be pressed with a finger nail. The processing consists of dehusking, cutting the soft nuts into pieces, boiling cut pieces with water or the dilute extract from a previous boiling, *kali* coating and drying. Depending on the number of cuts, different types of *kalipak* can be made, representing pieces of various shapes and sizes. Both sun drying and oven drying are adopted for *kalipak* processing. A well-dried *kalipak* is expected to have a dark brown colour, glossy appearance, crisp chewing feel and well-toned astringency (Jayalakshmi and Mathew, 1982).

For preparation of *chali*, ripe nuts are dried in the sun for 35–40 days on dry level ground. The dried nuts are dehusked and marketed as whole nuts. The characteristics of a good *chali* produce are the absence of immature nuts, the lack of surface cracking, husk sticking and fungus and insect attack, and good cutting feel (Dhanaraj, Sankaran and Mathew, 1970). In Kerala, the fresh ripe fruits are preserved in water to allow the fermentation of the husk to proceed for some time. However, the nut inside is left in good condition and such nuts are known as *neetadaka*.

Pests and diseases. There are a number of major pests and diseases causing considerable damage to arecanut palms. The pests are the mites, *Oligonychus indicus* Hirst. and *Raoiella indica* Hirst.; the spindle bug. *Carvalhoia arecae* Mill C. China.; the inflorescence caterpillar, *Tirathaba mundella* Wek.; and the root grub *Leucopholis burmeisteri*.

Colonies of both *O. indicus* and *R. indica* coexist in the leaves and suck the leaf sap. The leaves turn bronze coloured and wither away. The mites can be effectively controlled by spraying the foliage with Kelthane, 1.86 ml/litre of water. Nymphs and adults of the spindle bug suck sap from the tender spindle and leaves. The infected portions develop necrotic patches which turn brown and subsequently dry up. In the case of severe infestation, the leaves are shredded. The pest can be controlled by keeping polythene packets containing 2 g phorate in the topmost two leaf axils. Caterpillars of *Tirathaba mundella* bore into the interior of the spathe and feed on the tender rachillae. They join together the terminal portion and feed inside. This pest can be controlled by spraying the inflorescence with 0.125 per cent malathion after force opening. The root grub feeds on roots and in some cases the entire bole region. If the roots are severely infested, the whole palm can fall. The infestation can be controlled by applying HCH (BHC), 5 per cent dust at 120 kg/ha.

The important diseases affecting arecanut palms are yellow leaf diseases, 'Mahali' and bud rot. The main symptom of yellow leaf disease is yellowing of the tips of leaflets, extending towards the lamina. The affected leaves develop necrosis. In advanced stages of the disease the leaves become smaller, stiff and pointed, and the palm becomes stunted. The kernels of affected nuts show discolouration. Mycoplasma-like organisms have been associated with this disease, which may be

managed by regular application of fertilizers, manuring with green leaf and compost and irrigation at four day intervals.

'Mahali' is caused by *Phytophthora arecae* (Col.) Pethy. The first visible symptom of the disease is the appearance of water-soaked lesions. The lesions gradually spread, covering the entire nut, which rots and is shed from the calyx. 'Mahali' can be effectively checked by spraying 1 per cent Bordeaux mixture once, before the onset of the heavy southwest monsoon rains, and a second application 40–45 days later. In the case of bud rot caused by *P. palmivora* Butler, the colour change of the spindle, from the natural light green colour to yellow, is the first symptom. The infection spreads inside the bud and the growing point of the stem also rots. The outer leaves then become yellow, droop and drop off one by one leaving a bare stem. Control is by scooping out the infected tissues and treating with 10 per cent Bordeaux paste. Spraying the surrounding healthy parts of the palm should also be carried out to prevent the spread of the disease.

Future outlook. An analysis of the increase in cultivated area, production and productivity of arecanut in India, starting from 1961–62, shows that the area under the crop increased at the rate of 4.3 per cent per annum, the production at 4.8 per cent and the productivity at 0.34 per cent. The increase has therefore partly been due to a total increase in area of 57.9 per cent (Bavappa, 1982). An average yield of 8 kg of ripe nuts per palm per year has been obtained by several progressive farmers in coastal Karnataka and an average yield of 14.5 kg per palm was achieved at a research station. This shows the need for concerted developmental efforts in the more favourable areas of arecanut cultivation through investment oriented programmes with all the input components such as high yielding varieties, optimum fertilizer applications, irrigation and plant protection measures (Figures 7.3 and 7.4). The reduction in cultivated area from 189200 ha during 1974–75 to 170000 ha during 1977–78 without any appreciable reduction in production indicates that it would be practically possible to reduce the area under this crop considerably and divert the land to other commercial crops. The future strategy for research and development should be to maximize the production and productivity of arecanut plantations, to find solutions for the more important maladies effecting the crop and to ensure market stability for the commodity. The future of arecanut as a plantation crop has to be centred on a farming system in which arecanut is a base crop, with cocoa, pepper, banana or coffee as mixed crops, or tapioca or sweet potato as intercrops (Figure 7.5).

Breeding for resistance to the Yellow Leaf Disease and effective control measures against Koleroga, *mahali*, or fruit rot caused by *Phytophthora palmivora* Butl. are two important aspects which need attention. The etiology of Yellow Leaf Disease is still not clearly understood. Several genera of fungi such as *Exosporium*, *Leptosphaeria*, *Phyllosticta* and *Trichoderma* have been reported to be

Figure 7.3 Sprinkler irrigation in an arecanut garden.

Figure 7.4 A climber secures his position on an arecanut palm for harvesting.

Figure 7.5 Intercropping arecanut with pepper and pineapple.

associated with its occurrence. Economically viable alternate uses for the different constituents of the nuts, and the production of other by-products will help to stabilize the arecanut industry.

Cashew, *Anacardium occidentale*

Origin and antiquity. Cashew (*Anacardium occidentale* L.) belongs to the family Anacardiaceae and is found growing in the coastal areas of many tropical countries. The commercial production of the crop is confined to India, Mozambique, Tanzania, Kenya and Brazil. In order of total production, Kerala, Karnataka, Tamil Nadu, Andhra Pradesh, Goa, Maharashtra, Orissa and West Bengal are the major cashew producing states in India. It is believed that cashew was originally introduced to India for checking soil erosion. Gradually it has gained commercial importance and is now one of the top foreign exchange earners for the country.

Cashew is believed to be a native of southeastern Brazil and was probably the first fruit tree from the New World to naturalize in the tropics of the Old World. It appears from published accounts that *A. occidentale* is the only species, among as many as 20 species of *Anacardium* occurring within Central and South America, which has been introduced to countries outside the New World. The French, Portuguese and Dutch seafarers described cashew in the 16th century, the first

illustrated description of cashew being given by a French naturalist, Thevet, in 1558 AD.

Acaju was the name given to cashew by the native Tapi Indians of Brazil. This subsequently became *acajou* in French and *caju* in Portuguese. Most of the names used for cashew in the Indian languages are derived from the Portuguese word *caju*.

The first record of cashew in India was given by de Costa (1578), who described its occurrence on the Malabar coast. Subsequently Linschoten (1598) described it in Goa. Johnson (1973) suggested that the cashew dispersal centre must have been Coçhin on the Malabar coast. From India it was carried eastward to Ambiona in Indonesia (Rumphius, 1962). Dispersal of the species in Southeast Asia appears to have been carried out by birds, bats, monkeys and man (Burkill, 1935; Johnson, 1973). Evidence of its existence in Southeast Asian countries only after the 16th century supports the theory that India was the centre of dispersal of cashew in the Old World (de Costa, 1578; Ridley, 1930). Though the crop was introduced to India during the 16th century, until the beginning of the 20th century only the 'apple' was considered valuable and the cashew kernel, the cashew nut of commerce, found favour among consumers only during the 20th century.

Production and productivity. About 95 per cent of the world production of cashew is from countries in Africa and Asia, mainly from India (42 per cent), Mozambique (34 per cent) and Tanzania (14 per cent). Small quantities also come from South America (Brazil) and various oceanic islands. Currently India, with a cultivated area of 481 000 ha and an annual production of 196 000 tonnes, ranks first in the world (1982–83). Kerala has the maximum area under the crop (148 000 ha), producing 84 000 tonnes annually. In terms of area, Tamil Nadu comes next to Kerala with 95 000 ha, though annual production is only about 10 000 tonnes. Karnataka, with an area of 53 000 ha produces about 15 200 tonnes of cashew annually. Andhra Pradesh, Maharashtra, Goa, Orissa and West Bengal are the other cashew growing states. However, it should be mentioned that the share of Kerala in the production of nuts is disproportionate to its area. The increase in cultivated area in Kerala during the past decade has been about 42 per cent while the increase in production has only been 17 per cent. It should also be pointed out, however, that the reliability of cashew statistics has been questioned on various occasions, since no systematic crop survey has been carried out for over a decade. Most of the newly planted cashew plantations in Kerala, created under the area expansion programme towards the later half of 1970s, are reaching full production level at present and there is every likelihood that the production as well as the productivity will show an upward trend in Kerala within the next 2–3 years. Though the productivity of cashew nuts in Goa is well below the national average, the Union Territory has a vital role in the cashew industry since the production of *fenni*, a liquor made from the 'apple',

forms an important cottage industry in Goa.

Climate and soil. The distribution of cashew extends from 27° N of the equator (south Florida) to 28° S of the equator (South Africa), showing essentially a tropical preference (Joubert, Thomas and Des, 1965). In the tropics, however, it is acclimatized to a wide range of climatic and soil conditions. The distribution of cashew is restricted to altitudes below 700 m. A fall in temperature below 20°C for a prolonged period is harmful to the crop. Cashew is very sensitive to cold when young but becomes hardy with age and can withstand light frosts for short periods. A minimum rainfall of 450 mm per annum is essential for good growth, though cashew can survive in areas with rainfall ranging from 300 mm up to 4000 mm.

A dry spell during flowering and fruit setting ensures a better harvest, but heavy rain during this period damages crop production. Cloudy weather during flowering enhances scorching of flowers, due to tea mosquito infestation.

Cashew is cultivated on a wide variety of soils in India, where it is grown only as a rainfed and neglected crop of marginal lands. It is suitable for fairly steep slopes with shallow topsoils. Because of its large canopy and surface root system the cashew tree protects the soil surface from erosion during heavy rainy seasons. Cashew is grown mainly on laterite and on red, coastal sands in the states of Kerala, Maharashtra, Goa, Karnataka, Tamil Nadu, Andhra Pradesh and Orissa. The most fertile of cashew growing soils are the forest soils of the western slopes of the Western Ghats in Kerala. Coastal sands on which cashew is often grown are very poor in fertility and yields are low unless the trees are fertilized regularly.

Genetic variability and varieties. Research on cashew in India can be considered to have commenced with the sanction of a few *ad hoc* schemes by ICAR from 1951–52 onwards in some of the southern states. A co-ordinated effort to intensify the research was initiated with the sanctioning of 'The All India Coordinated Spices and Cashewnut Improvement Project' in 1971. The introduction and evaluation of germplasm collections to select high yielding types, hybridization and selection to evolve hybrids with better performance, and agronomic trials to standardize agronomic requirements of the crop under different agroclimatic conditions were the areas of main interest in the All India Coordinated Project. Of the 20 species of *Anacardium* reported so far (Index Kewensis), *A. occidentale* is the only one introduced into India. According to de Candolle (1825), *A. occidentale* has two varieties, namely *americanum* and *indicum*. In *americanum* the peduncle is about 10 times bigger than the nuts whereas in *indicum* the peduncle is only about 3 times bigger than the nuts. In Brazil, cashews are given names on the basis of the colour, form, size, taste and consistency of the pulp of the peduncle (Lima *et al.*, 1952). However, Aiyadurai (1966) has reported the existence in India of cashew apples of varying

intensities of yellow, red and pink. Mukherjee (1956) recognized six types in West Bengal based on apple and nut characters, while Sebastine (1955) reported only four types from the Travancore–Cochin States.

At present a large degree of variability is discernible in different parts of the country due to the highly cross-pollinated nature of the crop and the natural selection pressures which have operated in the self-sown populations for over four centuries since introduction. The current germplasm accessions available at various cashew research stations in the country include seedling progenies from the original introduction, progenies from naturally occurring élite trees and selections emanating from the existing élite plantations. These collections include exotic types from Brazil, Malaysia, Sri Lanka, Tanzania, Nigeria, Mozambique, Kenya and Singapore (Anonymous, 1983).

A cultivar of *Anacardium occidentale*, Anacardium Ceylon N-4, a cashew clone, has been selected in Tanzania for its high yield potential, high kernel yield and tolerance to powdery mildew attacks, caused by *Oidium anacardii* Noack.

Considerable variation exists in germplasm collections for flowering behaviour, nut size, weight of kernel and shelling percentage. Rao and Hassan (1956) observed that high yielding trees normally have medium or small nuts. The importance of selection of types with medium nut size (120–130/kg), which give a higher percentage of germination and good export potential, has been emphasized by these workers. Variation in growth features in the collections maintained at Bapatla was reported by Dasarathi (1958). Nambiar (1977) suggested the possibility of shaping the canopies of cashew for better photosynthetic efficiency of the plants. In cashew about 85–90 per cent of the shoots of a bearing tree flower every year (Dasarathi, 1958). The number of flowers per panicle is between 200–1600, with 75–90 per cent staminate flowers (Rao and Hassan, 1957; Damodaran, Abraham and Alexander, 1966). The possibility of selecting lines with a relatively shorter flowering period, which would also ensure a shorter harvesting period, has been indicated by Dasarathi (1958) and Nambiar (1977). In a selection from Vengurla, 90 per cent of the fruits attained maturity in 45 days, against the 3 months recorded in most other accessions.

A comparative yield evaluation of 16 high yielding selections for a period of six years at Madakkathara, Bapatla, Vengurla, Vriddhachalam, Vittal and Bhuvaneswar indicated that differences between varieties were significant at all the centres except Madakkathara. The progenies of selections M 44/3 from Vriddhachalam were found to perform uniformly well during all years at all centres, indicating a stability in yield as well as adaptability to different agro-ecological conditions. Seedling progenies of M 76/1 and M 10/4 of Vriddhachalam and BLA 139/1 of Anakkayam also performed well at all centres. Based on these results, M 44/3, M 10/4 and BLA 139–1 were recommended for large-scale pre-release multiplication. Four selections from Bapatla (BPP 3, 4, 5

Figure 7.6 A high yielding cashew selection.

and 6), 2 selections from Vengurla (Vengurla 1 and 2) and one from Vriddhachalam (Vriddhachalam-1) have been recommended for cultivation in their respective states (Figure 7.6).

Hybridization programmes are in progress in different cashew research centres in India to exploit the variability in yield, size of nuts, synchronized flowering and shelling percentage. A yield of 10–14 kg nuts/tree/year was obtained in hybrids involving exotic accessions from Brazil as one of the parents at Anakkayam. Based on the yield performance of 4 hybrid combinations evaluated at Vengurla, Vengurla-1 hybrid (from Ansur 1 × Veture 56), 2 hybrids from Midnapure Red × Veture 56 and one from Ansur early × Mysore Kot 1/61 have been released as Vengurla 3, 4, 5 and 6 varieties, respectively. Two hybrids, H-2/11 and 2/12, from a cross between tree No. 1 and tree No. 297 at Bapatla have been released as BPP 1 and BPP 2.

Since cashew is a highly heterogeneous species, the élite trees identified, including selections and hybrids, can be multiplied only by vegetative propagation techniques. Various methods of clonal propagation have been attempted with considerable success, and this has helped to a certain extent in establishing uniformly high yielding cashew orchards. Layering is one of the earliest methods attempted in India and Tanzania. Air layering as well as ground layering have been found successful in the humid West Coastal regions of India. Patch budding (Phadnis, Choudhury and Banderkar, 1974), forket budding (Gunjate and Limaye,

1979), veneer grafting (Nagabhushanam and Rao, 1977; Phadnis *et al.*, 1974), side grafting, whip grafting, cleft grafting (Bhandary, Shetty and Shet, 1974) and epicotyl grafting (Nagabhushanam, 1982) have been successfully adopted in different regions. Research on vegetative propagation carried out at different centres has indicated the need to select the right technique suited to different agroclimatic conditions. Air-layering, budding and epicotyl grafting were found to be suitable throughout the year under controlled conditions. Low establishment of transplanted grafts reported from various states has mainly been attributed to lack of management (Nair *et al.*, 1979). However, there is an urgent need to standardize management practices for grafting (both for transplanted as well as for *in situ* grafts) to ensure better grafting success and field establishment (Anonymous, 1983).

Cultural practices. Availability of land seems to be the major problem for establishing large-scale plantations of cashew in India, because of competition from other crops. While selecting the land for cashew, soils prone to waterlogging and excessive salinity or alkalinity should be avoided. Otherwise soil depth, slope, stoniness, soil fertility and availability of water seem to impose very few limitations in the establishment of cashew plantations.

Cashew orchards are raised from seedlings or clonal materials depending upon the performance and stability in yield of the selections identified at various centres under the AICSCIP. In the case of élite trees as well as hybrid combinations, clonal material alone should be used for planting. Though vegetative propagation techniques for different agroclimatic regions have been standardized, poor field establishment of clonal materials and inadequate availability of planting material are the limitations faced by cashew growers at present. However, efforts are being made to establish clonal orchards at various centres during the VII Five Year Plan period.

Nuts selected for raising seedlings should be of good shape, medium size and high specific gravity. It is a common practice to select only those seeds which do not float in water. High yields are obtained from plants grown from nuts of average weight (112–120 nuts/kg). Nuts with a high specific gravity are also known to give higher kernel yields.

Seed nuts collected during March to April can be sown with the onset of the monsoon, either directly in the field or in polythene bags, for transplanting when the seedlings are 6–8 weeks old. The percentage germination decreases if nuts are stored for more than 4 months. After harvest, seed nuts should be dried for 2–3 days in the sun. Under West Coast conditions, a planting pit of 50 cm × 50 cm × 50 cm is recommended. Planting methods vary considerably in different regions. The seeds are best sown 2.5 cm deep in a slanting position. Seeds sown with their stalk end upwards are known to give a higher percentage of successful germinations. The seeds take about 3–4 weeks to germinate.

A spacing of 8 m × 8 m is recommended for cashew trees, although

a closer spacing of 4 m × 4 m initially and thinning out in stages to maintain a spacing of 8 m × 8 m by the tenth year is preferred. This enables higher returns during the first few years after the trees start to yield. In India, close planting at 3 m × 3 m and later thinning to 10 m × 10 m is practised in the Trichy district of Tamil Nadu.

Until recently cashew plantations received very little care and management, and large-scale plantings were rare. Regular maintenance operations and periodic land clearing are necessary to keep orchards free of weeds. Cashew is seldom pruned, but removal of dry and diseased branches is often necessary. In the sandy soils of the East Coast, the seedlings require irrigation during the summer months for the first few years.

With high yielding selections and hybrids identified, and vegetative propagation becoming more successful and popular, better management of plantations is required. It has been reported that a 30 year old cashew tree utilizes 2.80 kg N, 0.75 kg P_2O_5 and 1.26 kg K_2O. In order to obtain early and higher yields from new plantations, and regular and higher yields from mature trees, cashew requires regular fertilizer applications. The present fertilizer recommendations for cashew are 250 g N, 125 g P_2O_5 and 200 g K_2O/tree/year, to be applied in 2 split doses before and after the southwest monsoon. Fertilizers may be applied in small trenches or basins around the trees.

Intercropping received little attention before the systematic planting of cashew began on a large-scale. Intercropping is becoming popular in Andhra Pradesh and Orissa with the establishment of large cashew plantations by the Forest Departments. The main objective of intercropping is to obtain some return from the plantations during the initial years, before the cashew trees come into flowering and start bearing. In Andhra Pradesh, legumes such as horsegram, cowpea, or groundnut are raised in the interspaces. *Casuarina* is another crop planted along with cashew in Orissa. In Goa, *Eucalyptus* spp. and teak are successively grown during the initial years.

Harvest and collection of nuts is carried out over a period of 10–12 weeks. Where the 'apple' is not to be utilized, the fruits may be allowed to drop to the ground and the nuts collected periodically during the first 4–6 weeks. Most of the remaining nuts can be collected in one or two major harvests. Nuts are sun dried for 2–3 days before storing. Where the 'apple' is used for making *fenni*, great care is exercised in collecting the 'apples' at the right stage.

Pests and diseases. Two pests affecting cashew plants which can cause considerable damage are the tea mosquito, *Helopeltis antonii* Sig. and the stem borer *Plocaederus ferrugineus* L. The adults and nymphs of the tea mosquito bug suck the sap from the tender shoots, inflorescences, developing nuts and 'apples'. The infected shoot dries up, causing die-back symptoms and the entire inflorescence withers. The insects can be effectively controlled by spraying endosulfan (0.05 per cent) at the

time of emergence of flushes, at the emergence of panicles and at fruit set.

The grubs of the stem borer tunnel into the stem and roots. The earliest symptom of attack is the presence of holes in the collar region with gum and frass emerging from them. The infested trees show yellowing of leaves and drying of twigs before succumbing to the pest. Trees in the early stages of infestation can be saved by keeping a pad of cotton treated with monocrotophos in between the flap of live bark and the trunk, near the infested area, and applying HCH (BHC) 10 per cent dust around the base of the infested tree. Diseases do not cause serious problems in cashew.

Future outlook. While the national average yield of cashew is only about 2 kg/tree/year, the average yield in different states varies, and Kerala with the maximum area under production also has the maximum productivity of 5.5 kg/tree/year. An average yield of 43 kg/year has been obtained from a tree in a regular bearing 20 year-old plantation at Vengurla and a record yield of 125 kg has been reported from a single tree at Kottarakkara (Kerala) indicating the difference between the actual and potential yields. Bridging the gap in average yields between Kerala and the rest of the cashew growing states could make India not only self sufficient in raw nut production but would also help to stabilize India's position in international trade. The Committee on Cashew Cultivation (Bavappa, 1976) has identified the causes of low yields as non-adoption of improved management technology and genetic inferiority of the plants. They suggested that plant protection measures, especially against the tea mosquito and the stem borer, and the application of fertilizers, as the necessary short-term measures for increasing yields. By controlling the tea mosquito, the yield could be increased by about 30 per cent (Pillai, Dubey and Singh, 1976). By adoption of these short-term strategies, it should be possible to increase the national average yield of cashew to the level obtained in Kerala. In the new area expansion programme, if adequate care is taken to plant only superior planting material from the selections and hybrids already identified, and adequate scientific management is assured including regular fertilizer applications and plant protection measures, much higher yields are expected. The long-term action programmes required to increase the production and productivity of cashew in India can be categorized under the following headings:

(a) Expansion of cashew cultivation to new and non-traditional areas.
(b) Clonal multiplication of high yielding selections and hybrids to ensure adequate supply of planting material.
(c) Ensuring stability of remunerative prices to provide an adequate incentive for adopting new technology (Nair *et al.*, 1979).

Black pepper, *Piper nigrum*

Origin and antiquity. Black pepper (*Piper nigrum* L.) is one of the

oldest spices known to man and is a native of the Western Ghats in India, where it is still found growing in the wild state. The generic name *Piper* and the common name 'pepper' are probably derived from the Sanskrit word *pippali*, which is in fact the long pepper, *Piper longum* L. (Purseglove *et al.*, 1981a). Pepper has been in cultivation in India since time immemorial and it was one of the first spices to be introduced into Europe from the Orient.

Theophrastus (BC 372–287) recognized two types of pepper, black pepper and long pepper. The first record of pepper cultivation in India is found in *Topographia Christiana* written by a Greek monk Cosmas Indicopleustes, in the year 548 AD. However, trade between India and Rome was established even as early as 40 AD with the discovery of monsoons by Hippalus, and Roman built ships sailed to India to break the Arab monopoly of the spice trade. It is believed that the earliest Hindu settlers took pepper to Java at some time between BC 100 and 600 AD, and Marco Polo described the cultivation of pepper in Java in his memoirs. The economic growth and great wealth of some of the Mediterranean cities such as Venice and Genoa were largely due to the spice trade between the Orient and the Mediterranean countries. The demand for pepper in European countries was mainly responsible for the voyage of Columbus to the west, which culminated in the discovery of the Americas, and that of Vasco da Gama to the east, in which he circumnavigated Africa and reached Calicut on 20 May 1498. The later event in fact was the beginning of a series of voyages by the Portuguese and the Dutch, followed by colonization of India by the British. While the Dutch were credited with controlling the cultivation and trade of pepper in the East Indies, the British were responsible for the organized planting of pepper in Malaya during the 19th century (Purseglove *et al.*, 1981a).

Production and productivity. During 1947, India produced about 30 000 tonnes of black pepper and accounted for 80 per cent of world production. Through the successive Five Year Plan periods, the area under pepper in India increased from 80 000 ha in the early 1950s to 111 000 ha during 1982–83. Paradoxically, pepper production has remained almost static during the last 30 years and production for the year 1982–83 was 29 000 tonnes. World production of pepper during the period increased from 35 000 tonnes to 160 000 tonnes and therefore India's share of the total world production of black pepper dwindled to 18.2 per cent. Brazil, Malaysia and Indonesia in that order are the major pepper producing countries at present, producing an estimated 27.3, 25.6 and 25.6 per cent of world output respectively.

Kerala State alone contributes about 95 per cent of India's production; Karnataka produces about 3.5 per cent and the remaining pepper growing states together produce only negligible quantities. The present average yield of pepper is 261 kg/ha, which is one of the lowest in the world compared with 2727 kg in Brazil, 3000 kg in Malaysia and 1492 kg

in Sri Lanka (1980 figures for other countries). The low productivity of pepper in India has been attributed to a combination of factors such as the presence of a large number of unproductive senile and disease affected vines, the use of improper standards, imbalanced fertilizer use, inadequate plant protection measures, non-adoption of recommended agronomic practices and inadequate extension services, resulting in failure to transfer the technology available at research institutes.

Climate and soil. Pepper is a plant of the humid tropics requiring adequate rainfall and warmth for its growth. It is grown successfully between the latitudes of 20° N and 20° S and from sea level up to an altitude of 2400 m (Gentry, 1955). The crop can tolerate a temperature range between 10°C and 40°C, although the optimum range is between 20°C and 40°C. A well-distributed annual rainfall of 1250–2000 mm is considered essential for pepper, though in Kerala, the major pepper growing state, the annual precipitation is about 3000 mm. Although in its natural habitat pepper thrives in red laterite virgin soils, it can be grown successfully in a wide range of soils, except heavy clays and very sandy soils. For the cultivation of pepper, filtered shade provides the required microclimate. When pepper is grown on undulating land, the slope facing south should be avoided so that the vines are not subjected to sun scorching during summer.

Genetic variability and varieties. The genus *Piper*, which includes the cultivated black pepper *Piper nigrum* L., is the largest in the family *Piperaceae*, consisting of more than 2000 species occurring throughout the tropical and subtropical regions of the world (Usher, 1974). In India two independent centres of distribution are recognized – the trans-Gangetic region and the south-western region (Hooker, 1886). The submountainous tracts of the Western Ghats are believed to be the centre of diversity of *P. nigrum*. Even though 108 species of *Piper* have been reported from the Indian subcontinent, *P. betle* L. is the only species (other than *P. nigrum*) to be widely cultivated (Rahiman and Nair, 1983).

Piper nigrum is a perennial climber cultivated in India, Indonesia, Malaysia and Brazil and to a lesser extent in Sri Lanka and the West Indies (Howard, 1973). Systematic collection of germplasm from the forests of the Western Ghats was initiated after the establishment of CPCRI in 1970. At present the CPCRI Regional Station, Calicut, maintains a germplasm collection of 220 cultivated and 78 wild types. The cultivated types are mostly bisexual while in the wild types, dioecious plants occur (Rahiman *et al.*, 1979). Wild pepper shows considerable variation but through selection large numbers of monoecious clones have been produced in pepper growing countries. Clones such as Belantung, Muntok or Bangka, Lampong, Djambi and Sariki (Indonesia); Kuching (Malaysia); and Balancotta and Kalluvalli in India are the most important. Phnom-Pon and Kamchari cultivars are extensively grown in Kampuchea (Cambodia).

More than 100 cultivars of pepper are grown in India. These differ in size and colour of the berries, length and shape of the spikes, potential yield, and resistance to diseases. While most of the cultivars are monoecious, variations ranging from complete male to complete female plants have also been observed. Karimunda, Kottanadan, Narayakkodi, Kalluvally, Balankotta and Uthirancotta are the popular cultivars in Kerala, and Malligesara, Doddigya and Arasina Moratta are the popular cultivars in Karnataka. Panniyur-I, the only hybrid pepper in cultivation at present, has been reported to have a yield potential of 2–3 times that of other popular cultivars. It is also an early bearer and is fairly resistant to the destructive wilt disease (Figure 7.7) (Nambiar, 1974; Nair, 1978). However, the performance of this hybrid at higher elevations, with excessive shade and with higher doses of nitrogen, has been reported to be unsatisfactory (Nambiar, 1978).

Breeding work, to produce high yielding varieties combined with resistance to wilt disease, is in progress at the Calicut Centre of CPCRI. Some of the highly productive selections are being grown in comparative yield trials. A nematode resistant variety has been located and is under yield evaluation. Comparative tolerance to 'quick wilt' (foot rot) caused by *Phytophthora* spp., the pathogen causing the most serious disease of pepper, has been obtained by screening seedlings derived from open pollinated as well as irradiated seeds.

Cultural practices. In the Cannanore, Kasaragod and Idukki districts

Figure 7.7 Panniyur-I, a high yielding hybrid pepper.

of Kerala, where pepper is grown as a monocrop, all the undergrowth on selected virgin land is cleared and pits of about 0.5 m diameter are dug at a spacing of 3 m. Pits are filled with loose rainforest earth and leaf mould. Previous practice was to plant unrooted 5-noded stem cuttings, prior to the onset of the monsoon, in pits, about 30 cm away from the base of the standard. Gradually the planting of 3-noded rooted cuttings, which ensure better establishment, has become popular. Recently a rapid multiplication technique has also been popularized, in which single-noded, profusely rooted cuttings are planted. This ensures not only conservation of planting materials but also better field establishment. *Erythrina indica*, Lam. a leguminous tree and *Garuga pinnata* Roxb. are the popular standards used for training pepper vines in Kerala (Figure 7.8). Pepper vines are also grown as a subsidiary crop in coffee plantations in Kodagu and the upper Wynad areas and are trained onto shade trees such as silver oak (*Grevillea robusta* Cunn.) and dadap (*Erythrina lithosperma* Miq.). Recent experiments have shown that *Erythrina indica* is susceptible to nematode attack, (Koshy *et al.*, 1977) and also to white grubs. On-going trials at CPCRI have indicated that non-living standards such as RCC posts, granite posts and teak wood can be used to increase the yield in pepper and to avoid the problems faced in using live standards (Menon *et al.*, 1982).

The young sprouting vines planted with the onset of the monsoon need shading and irrigation for the first 2 summers. Periodic tying of

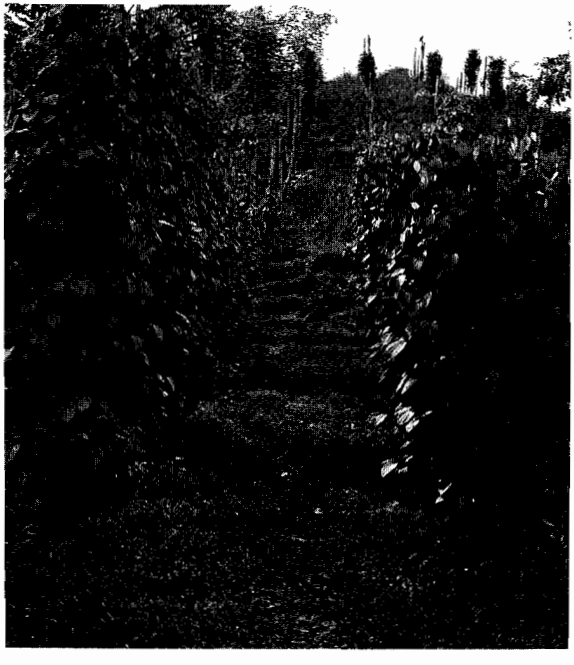

Figure 7.8 Pepper vines trained on to live and dead standards.

the growing vines to the standard for proper anchorage is also required. During the third year, the side branches of the standards should also be lopped to create a straight main stem and a uniform canopy. From the fourth year onwards, lopping of the branches of the standards should be done during April–May to regulate shade.

Intercultivation in pepper gardens is confined to 2 diggings during August–September and October–November, around the base of the vine to a diameter of about 2 m. The present trend is to grow pepper with minimum tillage around the base to avoid disease infection and spread.

In Kerala, pepper vines flower during May–June, and light rain at this time is considered essential for pollination and good seed set. From flowering to harvesting takes about 6–8 months. The harvesting season begins in November and continues until January. When one or two 'berries' (technically the fruit is a drupe) in a spike turn orange to red, all the fruiting spikes are harvested by hand picking, collected in gunny bags and taken to the threshing floor. The berries are then separated from the spikes either by hand or by trampling under foot. The berries are dried in the sun for 7–10 days till their moisture content is about 12 per cent and they develop the characteristic wrinkled appearance of black pepper.

Pests and diseases. In pepper the major pest is the 'pollu' beetle, *Longitarsus nigripennis* Motsch, and the major diseases are quick wilt and slow wilt.

The pollu beetle feeds on tender shoots, young leaves and spikes. The eggs are laid on the surface of tender berries. The grubs bore into the berries and feed on the fruit pulp. On average a single grub damages 3.4 berries. In some cases about 40 per cent of the berries are damaged. The beetle can be controlled by spraying endosulfan (0.05 percent) twice a year during June–July and September–October.

Quick wilt disease is caused by a soil borne fungus, *Phytophthora palmivora* (Butler) Butler. The disease occurs mainly during the south-west monsoon (June–September) and also to a lesser extent during the northeast monsoon. Though all parts of the vine are susceptible, infection in the region of the main stem and the collar results in the death of the vine. Among the control measures recommended are spraying with 1 per cent Bordeaux mixture, drenching the base with 0.2 per cent copper oxychloride and pasting the collar with 10 per cent Bordeaux mixture. Trials conducted with systemic fungicides have shown that metalaxyl is very effective.

Slow wilt disease of pepper is characterized by foliar yellowing and gradual defoliation. The root systems of affected plants show severe gall formation and root necrosis, accompanied by an overall gradual reduction in vigour and a decline in productivity. The plant ultimately dies. The burrowing nematode *Radopholus similis* Cobb has been implicated in the occurrence of slow wilt. Applications of phorate at

the rate of 5 g/vine, twice in a year, have been found to reduce the nematode population.

Future outlook. According to FAO, the importation of pepper by consuming countries increased from 59 000 tonnes in 1970 to 120 000 tonnes in 1978, and it is estimated that the international demand for pepper will go up at the rate of 4 per cent per annum. To keep pace with the growing international demand and to meet national consumption requirements, it is estimated that India has to produce annually more than 80 000 tonnes by 2000 AD. Thus there is an urgent need to increase pepper production and productivity in the shortest time possible. To improve productivity, both short-term as well as long-term programmes are envisaged. While the average yield/vine/year is only about 0.25 kg, an average yield of 1 kg/vine/year has been obtained by several progressive farmers. This productivity gap could be bridged by transferring the available technology such as the application of recommended fertilizers, the control of flea or pollu beetles (*Longitarsus nigripennis* Motsch.) and the adoption of prophylactic measures against quick wilt disease caused by *Phytophthora palmivora* (Butler) Butler. The work carried out at CPCRI has indicated that increases in yield up to 56 per cent can be obtained by the application of fertilizer at recommended dosages and a 30–40 per cent increase in yield can be achieved by controlling pests and diseases.

As a long-term measure, it is estimated that 50 per cent of the pepper vines in existing gardens require replanting and gap filling, which means replanting programmes for an area of about 50 000 ha. The planting material required for this purpose (about 123 million rooted cuttings) can be made available only in a phased programme by generating adequate single noded rooted cuttings of élite varieties such as Panniyur-I (a progeny from a cross between Cheriakanikadan and Uthirancotta), selected Karimunda and Kottanadan. A strategy should be evolved to establish rapid multiplication plots to supply rooted cuttings and also to provide subsidies for small and marginal farmers to meet at least the cost of planting materials and standards.

While the scope for raising pepper as a monocrop in Kerala is limited due to pressures on cultivated land, there is the possibility of growing pepper vines on coconut palms and other homestead trees. It was estimated in 1978 that Kerala has about 700 000 hectares under coconut, 68 000 ha under arecanut and 52 600 ha under coffee. The practice of growing pepper as a mixed crop in arecanut and coconut gardens is extremely limited at present and the immense potential of using these tree crops as standards should be exploited. There is also an urgent need to evolve a management technology for homestead gardens, since the existing package of practices are applicable only to medium- and large-scale pepper plantations. The technology for homestead gardens should include the production of varieties which are suited to different crop combinations and levels of available light

in a limited area, and to different fertilizer and plant protection measures. The varieties with a high yield potential such as Panniyur-I and Karimunda are highly susceptible to quick wilt disease. Research at CPCRI indicates that varieties resistant to quick wilt and slow wilt diseases are likely to be obtained within the next 3–4 years.

Research support for pepper so far has been limited and there is a need for it to be increased to undertake investigations on production physiology, economic and effective control measures against quick wilt and slow wilt diseases and the production of drought tolerant varieties. The rate of rapid multiplication of high yielding disease resistant varieties produced by research activities could be accelerated through the utilization of tissue culture techniques.

Cardamom, *Elettaria cardamomum*

The dried fruits of the perennial herb *Elettaria cardamomum* Maton, belonging to the natural order Scitamineae and the family Zingiberaceae, are the cardamom of commerce. The species is indigenous to the evergreen forests of Kerala and Karnataka as well as Sri Lanka, where it grows in the wild state. The large cardamom which substitutes for the true cardamom is obtained from *Aframomum* spp. as well as *Amomum* spp; which grow in natural conditions in Africa and India respectively (Purseglove *et al.*, 1981b).

Even as early as the 4th century BC, cardamom was reported to be an article of Greek trade, and at the time the inferior grade of the spices was known as *amomon* and the superior one as *kardamomon* (Rosengarten, 1969). Cardamom was one of the most popular Oriental spices in the Roman cuisine and by the first century AD, Rome was importing large quantities of cardamom from India. According to Ridley (1912) even though a spice was known to the Greeks and Romans as *amomon*, it is almost certain that this was not the cardamom of the present day. Burkill (1935) also doubts whether the Greeks and Romans had the true cardamom from *Elettaria*. The earliest record of cardamom in India is in an ayurvedic medical treatise compiled in BC 1000. In the 4th century, in the Tamil classic *Chilappathikaram*, a mention of the cardamom plant is made. Burkill (1935) concluded that cardamom had long been an article of trade at least from the time of Ibn Sena (980–1037 AD). The present day trade of cardamom from the Malabar coast was described by Barbosa, a Portuguese traveller, in 1514 AD.

India accounts for over 70 per cent of the world production of cardamom, with an estimated 6400 tonnes of cardamom capsules being produced during 1982–83. Guatemala, with an annual production of about 700 tonnes, Tanzania with 400 tonnes and Sri Lanka with 300 tonnes are the other important cardamom producing countries. It is also grown to some extent in Thailand and Indo-China.

Of the total estimated area of cardamom cultivation of 108000 ha in

India, more than 60 per cent is confined to Kerala, 31 per cent to Karnataka and 9 per cent to Tamil Nadu. In terms of production, Kerala is the leading state with about 75 per cent, with a productivity of 30 kg of dried capsules/ha, while the average yield for the whole of India is 48 kg/ha. The maximum productivity is in Tamil Nadu with 93 kg/ha. Unofficial reports indicate that some of the plantations in Karnataka and Kerala show wide variations in yield, and plantations producing about 300 kg/ha are not uncommon.

Cardamom grows in the evergreen forests of the Western Ghats at altitudes ranging from 600 m to 1500 m and at temperatures of 10–35°C. The canopies of the evergreen forests provide the shade requirements of the crop. If complete clearing of the natural forests is undertaken, overhead shade should be provided by planting quick-growing tree species. While the crop can tolerate heavy shade, maximum yields are obtained under regulated shade with filtered light. Moisture stress results in poor seed set and the crop prefers a well-distributed rainfall of up to 3000 mm per year. Humus-rich, loamy soils are preferred, though it can grow in a variety of soils. Cardamom is sensitive to high winds and suffers in exposed area (Purseglove *et al.*, 1981b). In certain parts of Wynad and Karnataka, cardamom is grown as an intercrop in arecanut and coffee plantations. The Idukki, Calicut and Palghat districts have the greatest areas under cardamom in Kerala, and Kodagu, Hassan and Chikmagalur are the three districts producing cardamom in Karnataka. The cultivation of this crop in Tamil Nadu is restricted to the Kanyakumari and Tirunelveli districts (Nambiar, 1978).

The genus *Elettaria* has 7 species occurring in India, Sri Lanka, Malaysia, Sumatra and Borneo (Holttum, 1950; Willis, 1966). *Elettaria cardamomum* Maton occurs both in wild and cultivated conditions, and 2 botanical varieties are recognized in the species based on the size of the fruit. The variety 'Major' occurs in the wild in Sri Lanka and is occasionally cultivated. The fruit is large, elongated and slightly arched and in trade it is known as 'long wild native cardamom'. The variety 'Minor' includes most of the cultivated races. The panicles in this variety are longer with numerous flowers, and may be procumbent, arching or erect. The fruits are smaller than in the Major variety with fewer, smaller and more aromatic seeds. 'Mysore', 'Malabar', 'Ceylon', 'Manjarabad', 'Bijapur', 'Vazhukka', 'Thara' and 'Nadan' are some of the cultivated types grown in different parts of Kerala and Karnataka. Mysore, Malabar and Vazhukka are the popular cultivars which have definite morphological characteristics. Most of the cardamom grown in Kerala belongs to the cultivar Mysore. It is robust and grows to 3–4 m in height. It produces erect panicles and capsules which are bold and long. The Malabar cultivar is comparatively smaller in size, and has pubescent or glabrous dorsal leaf surfaces. The panicles are of the spreading type and it produces roundish or egg shaped fruits (Figures 7.9 and 7.10). This cultivar is grown mostly in Karnataka State at an

Figure 7.9 Several erect leafy cardamom shoots developing from the underground stem. The fruiting panicle branches emerge directly from the root-stock.

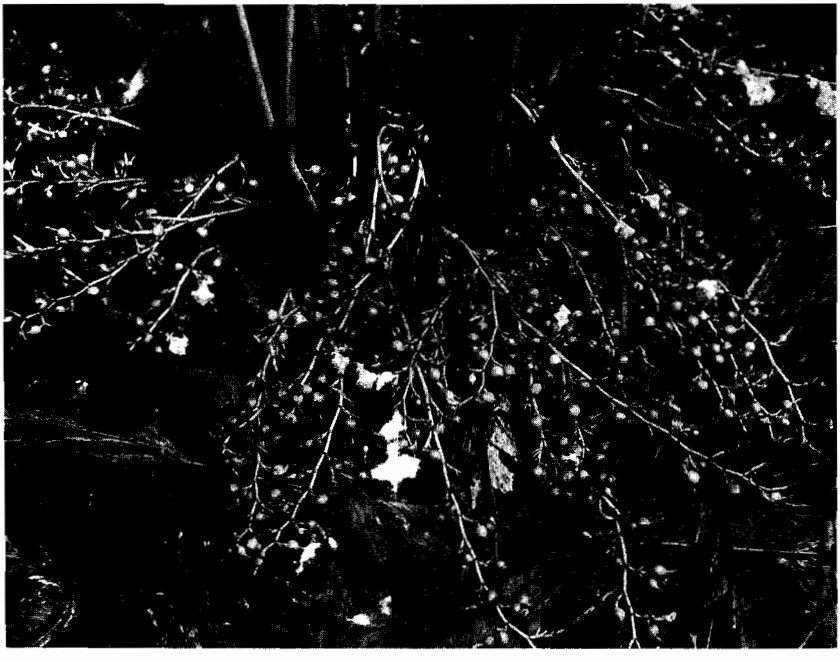

Figure 7.10 Basal portion of a cardamom clump with developing capsules.

elevation of 900–1200 m. Vazhukka, with semi-erect panicles and roundish, long capsules, is considered to be a natural hybrid between Mysore and Malabar.

Breeding work is in progress at Mudigere in Karnataka and at Pampadumpara in Kerala under the All India Coordinated Spices and Cashewnut Improvement Project. Based on the morphological characters, fruit size and shape and types of panicles, 16 different types have been identified at Mudigere. Selection work is also in progress at the Appangala Centre at CPCRI and 71 clumps selected from seedlings as well as clonal progenies are under field evaluation. Some of the selected clumps have yield potentials up to 3095 g wet weight of capsules per clump. Breeding work in progress to evolve a 'katte' or 'foorkey' resistant variety through irradiation has yielded 13 'katte' resistant mutants which are being evaluated for yield.

Cultural practices. For raising seedlings, seeds are collected from high yielding healthy plants with compact panicles. Fully matured and ripened capsules are immersed in water, seeds are extracted by gentle pressing, and the mucilaginous coating is then removed by washing in cold water. The seeds are mixed with ash and then dried in the shade for 2–3 days. In Karnataka sowing is done during the months of September–October while in Kerala and Tamil Nadu the time of sowing is November–December. For the nursery site, gently sloping or levelled land with access to water for irrigation is selected. The seeds are sown either in lines or are broadcast in raised beds, 1 m × 6 m in size, at the rate of 10 g of seeds/m^2. Immediately after sowing, the seeds are covered with a thin layer of soil rich in humus, and later with a layer of straw. Overhead shading should also be provided. Frequent irrigation without water stagnation is a prerequisite for good germination. Germination may begin within 30 days and continue for up to 90 days.

The seedlings remain in the primary nursery for about 6 months, after which they are transplanted to the secondary nursery where they are allowed to remain for one more year. In the secondary nursery, a spacing of 30 cm between plants is given and the density is reduced to about a tenth of that in the primary nursery. Mulching as well as overhead shading is also required in the secondary nursery.

The site selected for a cardamom plantation should be cleared of undergrowth and overhead shade should be regulated. The spacing recommended for the Mysore variety is 2 × 2 m to 3 × 3 m, and for the Malabar variety 1.5 × 1.5 m to 2 × 2 m. Pits of 60 cm × 60 cm × 30 cm are dug and filled with a mixture of compost and cattle manure about 2 months prior to the commencement of planting in May–June. Frequent weeding is required during the first year of growth. In older plantations 2–3 weedings/year, depending on weed growth, are required. Clearing away the old, dried shoots and keeping the clumps clean help reduce the incidence of diseases. Every year during September–October, trimming the shade trees to regulate shade is essential.

The recommended fertilizer dosages for cardamom is 75 kg N, 75 kg P_2O_5 and 150 kg K_2O per hectare per year. Fertilizers should be applied in 2 split doses in May–June and September–October. Cardamom starts flowering in its third year, commencing in April–May and continuing until August–September. The capsules are ready for harvest from July–August in Karnataka and August–September in Kerala and Tamil Nadu. The harvesting season continues until October–November. The harvested capsules are dried either in the sun or in specially built drying sheds heated by a slow fire from below, or in large kilns heated by flue pipes. The fruits are spread thinly and evenly on a platform. Frequent stirring is required to permit uniform drying and development of colour. With controlled heating, drying takes about 48 hours, while in natural conditions about 4–5 days are required. The dried capsules are rubbed by hand or with rough coir matting, and then winnowed to remove foreign matter. Dried and cleaned capsules are graded according to colour and size.

Pests and diseases. Thrips (*Sciothrips cardamomi*) and the shoot borer (*Dichocrocis punctiferalis* Guen.) are the major pests of cardamom. Thrips feed by lacerating the surface tissues of the plant parts including flowers and panicle stalks and sucking the exuding sap. The Mysore variety is more susceptible than the Malabar variety. The pest is controlled by spraying with quinalphos 0.03 per cent once between December–April and 3 more times during August–November. Shoot borer caterpillars bore into the pseudostem and feed on the internal contents. The central spindle dries up and becomes dead heart. The pest can be controlled by spraying quinalphos (0.025 per cent) or monocrotophos (0.05 per cent).

The important diseases of cardamom are 'katte' and 'azhukal'. Katte is a viral disease transmitted by the aphid, *Pentalonia nigronervosa* Coq. The first visible symptom appears on the youngest leaves as spindle-shaped slender chlorotic flecks, which develop into pale green discontinuous stripes. Within a year of infection there is a gradual reduction in leaf size and panicle length. Control is achieved by eradication of the source of inoculum and destruction of the vector by insecticide application. Azhukal disease is caused by *Phytophthora* spp. It affects leaves, tender shoots, panicles and capsules. The infected capsules become dull green-brown. They decay, emitting a foul smell, and are finally shed. The disease can be controlled by trashing, removal and destruction of the infected parts and spraying the shoots with 1 per cent Bordeaux mixture (2–3 times during the monsoon) and drenching the panicles with 1 per cent Bordeaux mixture at the rate of 3 litres/plant during July–August.

Future outlook. The yield of cardamom in India fluctuates widely depending on the season and this is partly reflected in the international price. While the economic life of a cardamom plantation is about 10–15 years for the cultivar Mysore and about 7–10 years for Malabar

(Sastri, 1952), most plantations have never been replanted and some are as old as 40 years or even more (Mukherji, 1973). Systematic planting is seldom undertaken by growers. Ecological imbalances due to continuous deforestation are also responsible for the decline of cardamom plantations. The concept of scientific cultivation of cardamom, with periodic replanting using high yielding clones, fertilizer application and regulation of shade, is essential for not only stabilizing but also increasing productivity. Cardamom is a highly cross fertilized species and the role of insects such as honey bees in pollination and the consequent increase in yield can be substantial. However, work in this regard is in the preliminary stages.

Diseases such as katte or marble mosaic disease (caused by a virus) and 'capsule rot' (*Phytophthora nicotianae* var. *nicotianae* E.M. Waterhouse) also adversely affect the yield of cardamom. While some success has been achieved in breeding katte resistant clones, resistance to capsule rot has not been achieved. Phytosanitary measures, including the 'katte clinic' approach effectively demonstrated by CPCRI, need to be popularized. Simultaneously the high yielding disease resistant clones presently being produced need to be rapidly multiplied through tissue culture.

Tea, *Camellia sinensis*

Origin and antiquity. Among the plantation crops, tea occupies a unique place, not only in terms of its foreign exchange earning capacity for India, but also in the ability to provide profitable and continuous employment for more than a million people.

Camellia sinensis (L.) O. Kuntze (syn. *Thea sinensis* L.) belongs to the family Theaceae (syn. Ternstroemiaceae) and has been known as a beverage since BC 3000. References are available in Chinese literature to the use of tea as a drink from as early as BC 2000. It is believed that the probable centre of origin of tea is on the banks of the Irrawaddy river, from where it spread to southeastern China, Indo-China and the northeastern regions of Assam (Purseglove, 1968). Major Robert Bruce in 1823 discovered tea in the wild in Assam. Tea is also reported to occur in the wild in upper Burma and upper Indo-China. However, the possibility of these plants being escapes from cultivation has been pointed out by Purseglove (1968).

There is another view that the origin of tea near the Irrawaddy river must have been a secondary centre, with the primary centre of origin located somewhere near the lower Tibetan mountains. The large leaved Assam tea is believed to have originated from small leaved Chinese plants (Wellensick, 1938). Experimental planting of tea in India was made during the first half of the 19th century from seeds obtained from China. However, with the discovery of tea in Assam, commercial plantings were made with the local types from 1835 onwards. Within 5 years of experimental cultivation of tea, plantations were established

in the Brahmaputra Valley of Assam, Darjeeling, the Nilgiris and the high ranges of Tranvancore. Today, tea grows from the Kangra valley in the north west of the country to the Ponmudi hills in the extreme south.

Production and productivity. The production of tea in India has increased by more than 100 per cent within the last 30 years. In 1945 the production of tea was 229 million kg, which increased to 400 million kg in 1972 and 570 million kg during 1982–83. The export of processed tea earns one sixth of the country's total foreign exchange. The remarkable rise in production of tea can be attributed to the scientific and systematic management of tea plantations in recent years.

Assam, with 199 400 ha of tea plantations accounts for 53 per cent of the total area cultivated and the total production. While the national productivity is 1510 kg/ha, the average productivity of the 3 southern states of Karnataka, Kerala and Tamil Nadu is much higher, at 1775 kg, and these 3 states together contribute about 23 per cent of the total production. The highest productivity for tea cultivation in India, as well as in the world, is 2000 kg/ha recorded in Tamil Nadu.

Climate and soil. Tea requires a temperature range of 14°C to 30°C with well-distributed rainfall of above 1500 mm per year. The major tea plantations are found at higher altitudes of 2000–2400 m, and though tea can be cultivated at lower elevations, the quality is reported to suffer. High humidity is beneficial for good growth of tea while frost adversely affects the growth. Drought for more than two months is injurious to the crop. Tea grows in a wide range of soils varying from the river alluvial soils of the Brahmaputra Valley and the 'bheel' soils of the Kangra Valley to the laterite loams of South India. Though tea is known as a calcifuge, it grows well in all soil types with a pH ranging from 4.5–6, though a pH of 4–5.5 is considered optimal.

Genetic variability and varieties. The genus *Camellia* includes 82 species (Sealey, 1958) of which *Camellia sinensis* is the only one of economic importance. Various botanical varieties have been recognized from time to time and all of them intercross freely. As such this type of classification does not seem to be justified (Purseglove, 1968). Tea cultivars are recognized in two main groups. These are China teas, *Camellia sinensis* var. *sinensis*, and Assam teas, *C. sinensis* var. *assamica*. The variety *sinensis* includes slow growing, dwarf trees with dark green leaves resistant to cold and adverse conditions, but with a low yield potential. *Assamica* tea trees are quick growing, with large drooping leaves adapted to tropical conditions. Besides these there is the large leaved triploid variety, *macrophylla*, from Japan which gives a bitter decoction. As tea is largely cross-pollinated and the commercial crop used to be raised from seed, numerous hybrids between the varieties are available and are grown in plantations.

The dwarf China tea, with its characteristic small leaves and multiple stem, was first introduced into India during the first half of the 19th

century (Barua, 1976). However, most of the imported teas grown in the northeastern region initially, were later replaced with the large leaved Assam tea after its discovery. At present the cultivation of China tea is found in the hill districts of Darjeeling and Himachal Pradesh. Natural hybridization between China tea and Assam tea has given rise to wide range of intermediate hybrid varieties with immense variation in morphological characteristics and quality. However, a third type of tea known as Indo-China or the 'southern form' later gained popularity and was crossed with Assam-China hybrids to give rise to a series of complex hybrid forms known as 'agro types', which formed the nucleus material for further selection. At present in addition to the basic types, various 'agro types' are also maintained in the germplasm collection at Tocklai Experimental Station as well as at UPASI Tea Research Institute. Tea is considered to be a species hybrid (Venkataramani, 1966). Distinct types are identified based on foliar characteristics, and are referred to as 'Jats' in North India (Eden, 1976). Due to the highly heterogeneous nature of plantations, the yield capacity is not always related to the size of the bush (Venkataramani, 1970). An orthotropic growth habit and early production of secondary laterals appear to be associated with higher yields in tea. The current crop improvement programme being followed at UPASI Tea Research Institute, as well as at Tocklai Experimental Station, aims to improve selection techniques and clonal propagation methods, to eliminate some of the variability in the crop.

Future outlook. Although India is the largest producer and exporter of tea in the world, the cost of production in India is highest in the world, mainly due to increasing labour costs. Within the last 25 years, a 40 per cent increase in the productivity of tea plantations has been achieved in South India and a 25 percent increase in northeastern parts of the country. However, there is a need to increase productivity to a greater extent to offset increasing labour costs. The tea plantations in India are very old and unless systematic replanting programmes are undertaken, the chances of increasing productivity are limited. The improved selections now available at the two tea research institutes for commercial cultivation should be utilized in a phased replanting programme, incorporating modern agronomic practices and plant protection methods to achieve still higher productivity levels.*

Coffee, *Coffea arabica*

Origin and antiquity. The roasted, ground, brewed beans of *Coffea arabica* L. which make a stimulating, refreshing beverage, were first discovered by man in Arabia, in about the middle of the 15th century. However, in Ethiopia dried coffee berries have been used as a masticatory since ancient times (Purseglove, 1968). The habit of drinking

*Cultural practices for tea are described in Chapter 8.

coffee spread from Arabia, through the Middle East, reaching Cairo and Constantinople in about 1550 AD. It is believed that the first drink from coffee was made by fermenting the seed pulp of the fruit and even today in Arabia a drink is prepared from dried coffee pulp. Coffee is reported to have reached England in 1650 AD and according to Purseglove (1968) there were more than 3000 coffee houses in England by 1675 AD. The first recorded coffee plantation was in Yemen in the 14th century, having been introduced there from Ethiopia. Yemen is presumed to be a secondary centre of dissemination.

The home of *Coffea arabica* is the Ethiopian plains where it occurs naturally at elevations between 1800–2400 m. *C. canephora* Pierre ex Froehner, the diploid coffee, is considered to have its primary centre of diversity in Central Africa and the Malagasy Republic (Ferwerda, 1976). Coffee is supposed to have been introduced into India and Sri Lanka towards the end of the 17th century. Baba Budan, a muslim pilgrim, is believe to have brought coffee with him from Arabia around 1616 AD, and planted it in Chikmagalur (Karnataka). However, the centre of distribution in India has been reported to be Anjarakandi near Cannanore, where coffee was established in 1790 AD, though organized plantations only began in South India in 1890 AD.

Production and productivity. *Coffea arabica* and *C. canephora* (syn. *C. robusta* Linden) are the two types of coffee grown on a commercial scale in India. The total area under coffee cultivation in India is 211 000 ha, with an annual production of 152 000 tonnes. In terms of production, India ranks eighth in the world and in terms of area cultivated it ranks seventh.

Coffee growing is confined mostly to the three southern States in India, namely Karnataka, Kerala and Tamil Nadu, which together account for 98 per cent of the area cultivated and almost the entire Indian production, a negligible quantity coming from States such as Andhra Pradesh, Orissa and Maharashtra. Kerala, with a total area under coffee of 54 per cent, contributes as much as 70 per cent to the production, mainly due to the high productivity of the plantations. An average yield in Kerala of 1720 kg/ha compares well with the productivity in the other coffee producing countries. The production in Tamil Nadu is not commensurate with the area, largely due to the prevalence of *arabica* coffee which has low productivity compared with *robusta* coffee (Anonymous, 1982). In India, *arabica* occupies 52 per cent of the area and the remaining area is under *robusta* types. While the area expansion has only been about 54 per cent during the last 2 decades, the production has increased by 100 per cent, largely due to improved varieties and better agronomic techniques, which have been made available to the planters.

Climate and soil. The coffee growing belt in the world lies between 25° N and 25° S of the equator. In India, coffee is grown on the lower slopes of the Western Ghats in the States of Karnataka, Kerala and

Tamil Nadu. *C. robusta* and *C. liberica* Bull. ex Hierm are suitable for lower altitudes (500–1000 m), while *C. arabica* thrives well at higher altitudes of 1000–1500 m. Similarly, the annual rainfall and temperature requirements for the 2 species differ significantly. While *arabica* coffee grows in areas with an annual rainfall of 1600–2500 mm, *robusta* prefers comparatively less rainfall in the range of 1000–1500 mm. *Arabica* coffee prefers cool and equable temperatures of 15–25°C, while hot humid temperatures of 20–30°C are ideal for *robusta* coffee. Depending on the elevation of the plantation, *arabica* coffee needs medium to light shade, whereas *robusta* coffee requires uniform thin shade.

Coffee plantations are generally situated on hill slopes, while open hills exposed to high winds are undesirable. Deep, well-drained, slightly acidic soils, rich in organic matter, are ideal for growing coffee. Although coffee can withstand acidic soils, a soil pH of around 6–6.5 is considered ideal.

The genus *Coffea* belongs to the family Rubiaceae, and contains several species variously listed as numbering between 25 and 100. Wellman (1961) listed 64 species, although most of these are now considered to be varieties only. The most important species from the economic standpoint are *C. arabica*, which produces 90 per cent of the world's coffee, *C. canephora* with 9 per cent and *C. liberica* Bull ex Hiern with 1 per cent. The seven other species of *Coffea* recorded in India are *C. bengalensis* Heyne & Willd., *C. fragrans* Wall., *C. travancorensis* W. et A., *C. wightiana* W. et A., *C. crassifolia* Gamble, *C. khasiana* Hooker. f., and *C. jenkinsii* Hook. f. (Hooker, 1886; Gamble, 1925). Among these, the first four species listed belong to the section Paracoffea (Narayanaswamy and Vishveswara, 1963). The centre of origin of this section is presumed to be Southeast Asia (Krug, 1959). The cultivated species, *C. arabica* and *C. canephora*, belong to the section Eucoffea, subsection Erythrocoffea.

Six commercially important cultivars of *C. arabica* are 'Oldchiks', 'Coorgs', 'Kents', S 288, S 795 and S 1934. The earliest variety developed in India was 'Chiks', the name being derived from Chikmagalur, the place where coffee was first introduced. Chiks is susceptible to diseases and pests and the area under this cultivar has dwindled since the 1970s. Coorgs, a selection from Chiks is resistant to borer. During the last 20 years, Kents has been planted extensively in India. Some of the other varieties grown in India are 'Maragogipe', 'Bourbon', 'Amarillo' (Garden Drop) and 'Blue Mountain'. Blue Mountain is an introduction from Jamaica with bluish heavy beans and superior quality.

The Coffee Research Institute at Balehonnur in the Chikmagalur district maintains 257 *arabica* selections and 37 selections of *robusta* and other species (Awathramani and Somiah, 1972). The primary breeding objective has been to screen germplasm and locate resistance

to coffee rust caused by *Hemileia vastatrix* Berk. & Br. (Srinivasan and Narayanaswamy, 1975) and transfer the resistance to high yielding selections. Eighty other plants from various *arabica* varieties selected for yield, resistance to leaf blight, and size and quality of beans have formed the nucleus of the material used at Balehonnur for various selections released for cultivation. The germplasm at the Coffee Research Institute also includes exotic collections of *robusta* from Indonesia, Uganda, Sri Lanka, the Malagasy Republic, the Ivory Coast, Guatemala and Ghana. CCRI No. 880, a collection from East Africa, is reported to give 6000 kg/ha in its 25th year, in contrast to the 520 kg/ha produced by local types (Vishveswara, 1970).

The dwarf coffee, *C. arabica* variety San Ramon, was introduced to India from Brazil in 1953. This variety, with its reduced plant height and wide leaves, is also tolerant of rust (Vishveswara, 1974). A series of hybridization programmes to combine the desirable characteristics of San Ramon and the resistance in exotic varieties such as 'Cioccie', 'Agaro', and 'Alghe' are in progress at the Coffee Research Institute, Balehonnur. Interspecific crosses and mutation breeding programmes are also being attempted to increase the variability, as well as the resistance to leaf blight (Vishveswara, 1975).

In Brazil the most important strains of *C. arabica* (such as CP 387–17 and MP 388–6–20), developed at Campinas, belong to the 'Mundo Novo' cultivar. They yield about two and a half times as much as the Typica variety, and 80 per cent more than the high yielding Bourbon variety.

Future outlook. Diseases and pests together cause about 25 per cent of the crop losses in coffee (Venkataram, 1980). Besides pest management practices, techniques for forecasting disease incidences must be produced to enable advanced action to be taken, thus increasing the productivity from existing gardens. The possibility of developing improved material through selection and hybridization has already been indicated by the Coffee Research Institute, Balehonnur. The production target suggested for India of 200 000 tonnes for 2000 AD should not be difficult to achieve (Anonymous, 1976) through high yielding varieties and better management practices, aiming at more than 6000 kg/ha, comparable to the production of CCRI No. 880. Selective hybridization involving some of these high yielding selections and stringent selection for yield and resistance are necessary. Another worthwhile appraoch could be through an aggressive breeding programme involving disease tolerant parents and selecting outstanding recombinants and propagating them through vegetative means. Tissue culture techniques could be effectively deployed for rapid multiplication of such plants. While the scope for area expansion is limited, the possibilities of increasing the population/ha by planting dwarf types such as 'Caturra', 'Mokka', 'San Bernardino', San Ramon and San Ramon-derived hybrids may have to be explored. Their low productivity and small bean size

are the main impediments to their use. The performance of coffee at present at lower elevations is not at all remunerative. It may be possible to produce varieties from accessions such as San Ramon which have the capacity to give economic yields at lower elevations. Some of the indigenous species such as *C. bengalensis* Heyne & Willd. and *C. travancorensis* Wight & Arn. are reported to be low in caffeine content (Vishveswara, 1971). It would be an attractive proposition to produce coffee varieties with a low caffeine content, but still retaining the flavour. The prospect of increasing the production and productivity of coffee in the near future seems to be brighter than it is for many other plantations crops.*

Rubber, *Hevea brasiliensis*

Origin and antiquity. *Hevea brasiliensis* Muell.-Arg. is a tall sturdy, quick growing perennial tree from which natural rubber, one of the most versatile industrial raw materials, is obtained. The bark of the tree exudes a white viscous liquid on injury which contains 30–50 per cent rubber hydrocarbons. Over 90 per cent of the world's production of natural rubber comes from the Para rubber tree – *H. brasiliensis*.

H. brasiliensis is a wild tropical rainforest tree of the Amazon basin, which was domesticated only a century ago. Prior to the discovery of the New World, Central and South American Indians used latex of certain plants for making bottles, footwear and for waterproofing fabrics. Columbus on his second voyage (1493–1496 AD) recorded the use of latex, probably from *Castilla elastica* Cerv. (Purseglove, 1968). La Condamine reported the use of rubber in Ecuador in 1736, probably obtained from *Castilla ulei* Warb., and its local name *heve* was used by Aublet to give the generic name *Hevea* (Purseglove, 1968).

After the discovery of the uses of latex from *Hevea* species, samples of rubber were brought back to Europe from the New World by several voyagers, arousing considerable interest. Priestley, a British chemist, discovered accidentally in 1770 that it would rub out pencil marks, hence the name rubber. This was followed by the discovery of various other uses, and the export of rubber gradually began from Brazil in the form of small articles like balls, bottles and toy figures.

The solvents of rubber, such as turpentine, ether, and rectified petroleum, were found by French chemists by 1763 and rubber tubing was made for the first time in 1791. The important discovery of vulcanization by Goodyear and Hancock in 1839 led to a sudden, great expansion in the demand for raw rubber, which in turn led to the establishment of rubber plantations. Hancock in 1824 suggested growing rubber in plantations and later in 1870 Sir Clements Markham of the British India Office suggested the establishment of rubber plantations in Asia in order to maintain the world supply. Three years later

*Cultural practices for coffee are described in Chapter 8.

through the efforts of Sir Joseph Hooker, a few seeds were collected by Farris in Brazil and sent to Kew (Purseglove, 1968).

Sir Joseph Hooker, the then Director, Royal Botanic Gardens, Kew commissioned H.A. Wickham to collect seeds of *Hevea* in Brazil. Almost all the rubber plantations of the Far East were derived from the first batch of seeds collected by Wickham from the Central Amazon basin. Rubber seedlings from the collections of Wickham were introduced to Sri Lanka in 1876 and the following year to the Singapore Botanic Gardens (for details see Chapter 3). Java obtained its first *Hevea* plants from Wickham's stock in 1896 and subsequent seeds from Brazil.

Currently rubber is grown in plantations in Indonesia, Malaysia, Thailand, China, India, Sri Lanka, Liberia, Nigeria, Indo-China, Zaire, the Ivory Coast, Cameroon, the Philippines, Burma and many other countries.

Production and productivity. In India, out of a total estimated area of 0.291 million hectares, Kerala state accounts for 0.256 million hectares. Besides Kerala, Tamil Nadu, Karnataka, and the Andaman and Nicobar Islands are the other rubber growing States in India. Rubber is also grown to a much lesser extent in Tripura, Goa, Assam and Meghalaya. The annual production of natural rubber in India was estimated to be 166 000 tonnes during 1982 (Anonymous, 1984). From an average yield of 150 kg of dry rubber/ha/year, India produces about 653 kg/ha at present, though yields as high as 4600 kg/ha have been achieved.

Climate and soil. The rubber tree grows on a variety of soils, provided they are deep and well-drained. A warm humid equable climate (21–35°C) and a fairly well distributed annual rainfall of more than 2000 mm are necessary for the optimum growth of Para rubber. In fact the average rainfall in rubber growing tracts varies from 2000–4000 mm. Most rubber plantations are found between 15° N and 10° S of the equator, where the climate is hot, humid and equable. Areas with great temperature fluctuations and pronounced dry seasons are not suited to the cultivation of rubber, although it is being grown increasingly in South India and Vietnam, in areas with a prolonged dry spell.

Genetic variability and varieties. The genus *Hevea* belongs to the family Euphorbiaceae and consists of nine species including *H. brasiliensis* (Schultes, 1977). Though breeding and selection in *Hevea* were carried out some 80 years ago, the development of bud-grafting by Cramer in 1917 was a great step towards a proper crop improvement programme. Standardization of the bud-grafting technique made it possible to multiply the best plants in a population instead of practising seedling selection, which is very time consuming (Figures 7.11 and 7.12).

Primary clones are mostly evolved from mother tree selections, while secondary clones are produced by hand pollination. PB 86, GL 1 and HC 55 are examples of primary clones in India. RRIM 600, RRII

Figure 7.11 A rubber budgraft.

Figure 7.12 Rubber polyclonal seedlings.

105 and RRIC 7 are secondary clones developed through hybridization (Nair, 1974). In India, a selection programme has achieved considerable success and is being conducted even now (Joseph, Saraswathy Amma and George, 1980). An intervarietal hybridization programme was started in 1954 with introduced clones (Nair and Panikkar, 1966) resulting in the production of the RRIM 100 series of clones (Nair and George, 1969). Subsequent crosses have resulted in the 200 and 300 series of clones, now under yield evaluation (Prem Kumari *et al.*, 1982). Success in *Hevea* breeding has thus been achieved through a combination of generative and vegetative methods of selection. The early selection of good trees and their propagation by bud grafting has been followed by controlled breeding between selected clones.

Cultural practices. In South India rubber seeds normally ripen during July–September, at which time they should be collected for raising seedlings. The clonal seeds collected from approved polyclonal seed gardens are the only recommended planting material. In India good quality polyclonal seed gardens have been established in the Kanyakumari district. Since the viability of rubber seeds is lost quickly, it is necessary to sow the seeds for germination immediately after collection. Soil beds of convenient size and shape, with a layer of river sand to about 5 cm thickness, are prepared for germination. The seeds are sown in a single layer, touching one another, and are pressed firmly into the bed with their flat surface just visible above the surface. The beds are irrigated frequently by sprinkling evenly during the morning and evening. Shade may be provided to prevent exposure to the sun. Seeds start to germinate within 6–7 days. Sprouts should be transplanted before the development of the shoot.

Budgrafting consists of the insertion of a sliver of bark containing a bud under the bark of stock seedlings, and taping with transparent plastic tape. When the tissues of the budpatch and the seedlings have become firmly united (3–4 weeks after budgrafting) the seedling's stem can be sawn off above the grafted bud, which then grows out to form a tall plant with the characteristics of the parent from which the bud was taken.

Most of the rubber plantations in South India are situated on slopes and undulating land. On hilly land, adequate soil conservation measures are necessary. Land preparation in the main field is completed before the onset of the monsoon, since the best time of planting is June–July. Planting is done along contour lines on undulating or hilly land. In hilly areas, terracing is advisable to aid soil conservation. Rubber is planted at densities of 445 trees/ha in the case of buddings and 445–520 trees/ha for seedlings. However, it is common practice to plant a higher density initially to provide for selective thinning at a later stage.

Seedlings raised in nurseries are transplanted after pruning the stem to a height of 45–60 cm from the collar. It is always desirable to plant stumps soon after pulling them from nursery beds. After planting, the

transplant should be inspected at intervals of about 10 days and only vigorous shoots should be allowed to grow. Sprouts from the budded stock should be removed and only one vigorous bud shoot should be allowed to develop. Side shoots up to 3 m from ground level should be pinched off.

A cover crop such as *Pueraria phaseoloides* (Roxb.) Benth., *Calopogonium mucunoides* Desv., or *Centrosema pubescens* Benth. should be established in new plantations immediately after clearing the area (one year prior to the planting if possible), to aid soil conservation.

It is essential to keep the base of the young rubber plants clear of weeds, in the field as well as in the nursery. Mulching with dry leaves or grass cuttings or a cover crop around the crop are recommended cultural practices for rubber nurseries. Mulching should be undertaken in nurseries and in plantations after fertilizer application and before the onset of summer. Usually November is the ideal month for mulching. Rubber plants are found to respond well to systematic manuring. Seedling nurseries are also manured to produce the maximum number of vigorous, healthy seedlings. In the nursery, the incorporation of two and a half tonnes of compost or farmyard manure and 350 kg of Mussoorie rock phosphate/ha, as a basal dressing, is recommended. The application of 2500 kg of a 10:10:4:1.5 NPKMg mixture/ha, 6–8 weeks after planting, is also recommended. The application of 550 kg of urea/ha 6–8 weeks after the first application, but before undertaking mulching, is also beneficial.

Rubber plants also require fertilizer application during the pre-tapping stage to accelerate growth and to reduce the unproductive phase of the crop. From the fifth year onwards, a complex fertilizer formulation containing 15:15:15 or 17:17:17 NPK at the rate of 200 kg or 170 kg/ha respectively, should be applied. For mature rubber trees being tapped, the application of NPK 10:10:10 at the rate of 300 kg/ha every year during March–April is required.

Weed control is an important cultural practice in rubber plantations. It is well established that proper control of weeds, and the establishment and maintenance of a leguminous ground cover crop during the initial years, not only reduces the unproductive phase of the crop but also saves considerable expenditure in the maintenance costs of rubber plantations. Four to five sessions of hand weeding are required during the first 2 years. During the third and fourth year after planting, more attention should be given to weeding in planting strips or terraces.

Chemical control of weeds is being increasingly used in rubber plantations in South India. It has, however, been found that a single weedicide is not effective in controlling weeds in rubber plantations and the use of combination weedicides is recommended, although the cost is higher.

Latex is obtained from the bark of the rubber tree by tapping. This is a process of controlled wounding during which the thin shavings of

bark are removed. Ethrel, 2, 4–D and 2, 4, 5–T are chemicals which can induce ethylene formation in plant tissues and can promote latex production when applied to the bark near the tapping cut.

Future outlook. Varieties are selected for their disease resistance, their ability to retain their foliage in the dry season, their resistance to wind damage and their yield potential. Breeding work in rubber has resulted in selection of varieties with a yield potential of over 4000 kg/ha in comparison to the 300–400 kg/ha obtained from plantations raised from the 'Wickham gene pool'.

Among the high yielding varieties are RRIM 501, 527, 600, 623 and 628, PB 5/51, PB 28/59, PB 86 (Malaysia); RRIC 36, PR 107, GI 1 and NAB 17 (Sri Lanka); AVROS 2037 (Sumatra); PR 261 (Java). A number of potentially very high yielding varieties (such as RRIM 703, 803) are being tested at the Rubber Research Institute of Malaysia. In West Africa, varieties presently grown are PB 86 and Gough garden (grown from seeds) while PB 5/51, BD 5, Harbel 1 and AVROS 49 are budded types.

Indications are available that some of these high yielding clones, using scientific cultural practices, may yield as much as 6000 kg/ha. A yield potential of 9000 to 10000 kg/ha has been predicted in Malaysia and it can be made a reality in the next decade or so if the selection of material, combined with intervarietal hybridization, progresses as predicted.

Work has already been initiated at the Rubber Research Institute of India on the crossing of Ceara (*Manihot glaziovii* Muell.-Arg.) and Para rubber. If this succeeds, the possibility of producing an early maturing rubber tree, which can be tapped within 2–3 years after planting as well as a variety suitable for high elevations, is very bright. One of the lines of breeding work contemplated in *Hevea* is the production of clones yielding coloured latex. The problem seems to be comparatively simple but the attention of plant breeders has not yet been drawn to this. Though work on tissue culture in rubber has been initiated, the problem seems to be the production of roots in the plantlet. While high yielding clones are already available, producing planting material of uniform plant height, and trunk and canopy development at maturity, may be advantageous in plantations for the introduction of mechanical devices for tapping. Clonal production of élite material through tissue culture may be an answer to these problems.

Though breeding for resistance has been initiated in rubber, absolute resistance to *Phytophthora* has not yet been obtained. It may be possible through simple breeding programmes to combine the comparative tolerance available in different clones, and to obtain improved resistance by transgressive segregation. Another possible breakthrough may come with the exploitation of dwarf clones, resulting from a cross between RRIM 605 and Ford 351. A dwarf rubber tree, half the normal height, resistant to wind damage, possibly early maturing

and convenient for spraying, could be a major development in *Hevea* improvement programmes.

References

Agnoloni, M. and **Givliani, F.** (1977) *Cashew Cultivation*, Library of Tropical Agriculture, Ministry of Foreign Affairs, Institute Agronomic Per L' Olheman, 168 pp.

Aiyadurai, S.G. (1966) *A review of research on spices and cashewnut in India*, ICAR, New Delhi, 228 pp.

Aiyer, A.K.Y.N. (1966) *Field crops of India*, 6th edition, Bangalore Printing and Publishing Co. Ltd., Bangalore, 564 pp.

Anonymous (1967) *Annual Report of the Central and Regional Arecanut Research Stations*, 1964–65, Central Arecanut Research Station, Vittal, India, 92 pp.

Anonymous (1976) *Report of the National Commission on Agriculture, Part VI. Crop production, sericulture and apiculture*, Govt. of India, Ministry of Agriculture and Irrigation, New Delhi, 501 pp.

Anonymous (1982) *Plantations in South India – past, present and future*, The United Planter's Association of South India, Coonoor, 44 pp.

Anonymous (1983) *All India Co-ordinated Spices and Cashewnut Improvement Project. Annual Report*, 1982–83, Central Plantation Crops Research Institute, Kasaragod.

Anonymous (1984) *Rubber and its cultivation*, The Rubber Board, Kottayam, 100 pp.

Awathramani, N.A. and **Somiah, M.M.** (1972) Quality of varieties of Arabica coffee: An assessment. *Coffee*, **36**:1–6.

Barua, D.N. (1976) Tea research in India, in *Golden Jubilee Souvenir*, UPASI, Coimbatore, India, 20–37.

Bavappa, K.V.A. (1963) *Morphological and cytological studies in Areca catechu L. and Areca triandra* Roxb., M.Sc. (Ag.) Thesis, University of Madras, India, 63 pp.

Bavappa, K.V.A. (1964) The correct botanical nomenclature of arecanut (Betel nut palm), *Sci. and Cult.* **30**:239–240.

Bavappa, K.V.A. (1970) Mother palm selection in arecanut cultivation, *Indian Fmg.*, **20**(3):31.

Bavappa, K.V.A. (1976) Short and long term strategies for increasing cashewnut production, in *Increasing production and productivity of cashew in India*, CPCRI, Kasaragod, 12–20.

Bavappa, K.V.A. (1977) 'Mangala' – a superior arecanut variety, *Arecanut and Spices Bull.*, **8**:55–56.

Bavappa, K.V.A. (1982) Future of arecanut, in *The Arecanut Palm. (Areca catechu L.)* (K.V.A. Bavappa, M.K. Nair and T. Premkumar eds.), CPCRI, Kasaragod, India, 319–325.

Bavappa, K.V.A. and **Gurusinghe, P.De.S.** (1982) Rapid multiplication of black pepper for commercial planting, *J. Plant. Crops*, **6**(2):92–95.

Bavappa, K.V.A. and **Ramachander, P.R.** (1967a) Improvement of arecanut palm, *Areca catechu* L. *J. Genet.*, **27**:93–100.

Bavappa, K.V.A. and **Ramachander, P.R.** (1967b) Selection of arecanut palm, *Trop. Agric.*, (Colombo), **123**:25–36.

Bavappa, K.V.A. and **Ramachander, P.R.** (1967c) Its worthwhile selecting areca seedlings with care, *Indian Fmg.*, **17**(2):20–21.

Bavappa, K.V.A. and **Ramachander, P.R.** (1968) How to select mother palms, *Indian Fmg.*, **18**(4):10–13.

Beccari, O. (1917) The origin and dispersal of *Cocos nucifera*, *Philipp. J. Sci.*, **12**:27–43.

Beccari, O. (1919) The palms of the Philippine Islands, *Philipp. J. Sci.*, **14**:295–367.

Bhandary, K.R., Shetty, K.P.V. and **Shet, M.** (1974) Propagation of cashew by wedge grafting, *J. Plant. Crops*, **2**:37.

Bhat, K.S. and **Khader, K.B.A.** (1982) Crop management, in *The Arecanut Palm* (*Areca catechu* L.) (K.V.A. Bavappa, M.K. Nair and T. Premkumar eds.), CPCRI, Kasaragod, India, 105–131.

Blatter, E.S.J. (1926) *The palm of British India and Ceylon*, Oxford University Press, Bombay, 600 pp.

Blume (1936) Rumphiasive commontations, *Botanica de Plantis Indiae Orientalis*, Leyden.

Bruman, H.J. (1945) Early coconut culture in Western Mexico, *Hispanic American Historical Review*, **25**:301–314.

Burkill, I.H. (1935) *A dictionary of the economic products of the Malay Peninsula* (Vol. 1), Crown Agents of the Colonies, London, 232 pp.

Child, R. (1974) *Coconuts*, 2nd Edition, Longman Group Ltd., London, 338 pp.

Corner, E.J.H. (1966) *The natural history of palms*, Weidenfeld and Nicolson, London, 393 pp.

Damodaran, V.K., Abraham, J. and **Alexander, K.M.** (1966) The morphology and biology of the cashew flower (*Anarcardium occidentale* L.) II Anthesis dehiscence, receptivity of the stigma, pollination, fruit set and fruit development, *Agric. Res. J. Kerala*, **4**:78–84.

Dasarathi, T.B. (1958) A study on the blossom biology and growth features of cashew nut (*Anacardium occidentale* L.), M.Sc. Thesis, Andhra University, Waltair (unpublished).

De Candolle, A.P. (1825) *Proxromus systematis Naturalis*, Paris, **2**:62.

De Candolle, A.P. (1886) *Origin of cultivated plants*, Hefner Publishing Co., New York, 428 pp.

De Costa, C. (1578) *Tratodo das Drogase Medicinas das Indias Orientais* (1964 Edn.), Junta de Universtigacees do ultramar, Lisbon, 336 pp.

Dhanaraj, S., Shankaran, A.N. and **Mathew, A.G.** (1970) Quality and market evaluation of processed arecanuts, *J. Food Sci. Technol.*, **7**:123–126.

Eden, T. (1976) *Tea* (3rd edition), Longman Green, London, 236 pp.

Edmondson, C.H. (1941) Viability of coconut seed after floating in the sea, *Occasional papers of Bermice*, P. Bishop Mus. Honolulu, Hawaii, **16**:293–304.

Ferwerda, F.P. (1976) Coffees, in *Evolution of Crop Plants* (N.W. Simmonds ed.), Longman Group Ltd., New York, 257–260.

Gamble, J.S. (1925) *Flora of the Presidency of Madras* (Repr. 1957), Vol. 2, Botanical Survey of India, Calcutta, 842–845.

Gentry, H.S. (1955) Introducing black pepper into America, *Econ. Bot.*, **9**:256–268.

Gode, P.K. (1961) *Studies in Indian cultural history*, Vol.I. Vishweshvarananda Vedic Research Institute, Hoshiarpur.

Gunjate, R.T. and **Limaye, V.P.** (1979) Ideas for successful propagation, *Intensive Agriculture*, **17**:11–14.

Harries, H.C. (1978) The evolution, dissemination and classification of *Cocos nucifera* L., *Bot. Rev.*, **44**:265–319.

Hill, A.W. (1929) The original home and mode of dispersal of the coconut, *Nature*, **124**:133–134, 151–153.

Holttum, R.E. (1950) The Zingiberaceae of the Malay Peninsula. *Gardener's Bull., Singapore*, **13**:1–249.

Hooker, J.D. (1886) *Flora of British India*, Vols. 1–7, L. Reeves and Co., London.

Howard, R.D. (1973) Notes on the Piperaceae of the Lesser Antilles, *J. Arnold, Arb.*, **54**:377–411.

Iyer, R.D., Rao, E.V.V.B. and **Govindankutty, M.P.** (1979) Super yielders in coconut, *Indian Fmg.*, **28**:3–5.

Jayalakshmi, A. and **Mathew, A.G.** (1982) Chemical composition and processing, in *The Arecanut Palm (Areca catechu* L.) (K.V.A, Bavappa, M.K. Nair, and T. Premkumar, eds.), CPCRI, Kasaragod, India, 225–244.

Johnson, D. (1973) The botany, origin and spread of cashew (*Anacardium occidentale* L.), *J. Plant. Crops*, **1**:1–7.

Joseph, G.M., Saraswathy Amma, C.K. and **George, P.J.** (1980) Crop improvement in *Hevea* through ortet selection in India, *Proc. International Rubber Conf.*, Kottayam, India.

Joubert, A.S. and **Thomas, D.** (1965) The Cashewnut, *Farming S. Agri.*, **40**:6–7.

Kaul, K.N. (1951) A palm fruit from Kapurdi (Jodhpur, Rajasthan Desert) *Cocos sahnii* sp. *Nov. Curr. Sc.*, **20**:138.

Koshy, P.K., Sosamma, V.K. and **Sundararaju, P.** (1977) Screening of plants used as pepper standards against root knot nematode, *Indian Phytopath.*, **30**:128–129.

Krug, C.A. (1959) *World Coffee Survey*, F.A.O., Rome.

Lima, O.G. de., Magalhaes, Neto, B., Farias, L., Albuquerque, I.L. De. and **Simocs-Filho, S.** (1952) Introducao as estudo dos cajus de perambuco (*Anacardium occidentale* L.), *Mon. ESC Quim. Pern. Univ. Recifi.*, **1**:1–20.

Linnaeus, C. (1753) *Species plantarum* Vol.I. London, 28–30.

Linschoten, J.H. (1598) *The voyage of John H.Van. Linschoten to the East Indies* (London, 1885).

Maramarosch K. and **Hunt P.** (1982) Lethal yellowing disease of coconut and other palms, in *Mycoplasma diseases of trees and shrubs* (K. Maramarosch and S.P. Raychaudhry, eds.), 185–210.

Martius, C.F.P. (1850) (1823–50) *Historia Naturalis Palmarum*, 3. Munich.

Mayuranathan, P.V. (1938) Original home of the coconut. *J. Bomb. Nat. Hist. Soc.*, **40**:174–182.

McCurrach, J.C. (1960) *Palms of the world*, Karpu and Brothers, New York, 200 pp.

Menon, K.S., Nair, M.K. and **Sharma, O.P.** (1982) Preliminary report on the performance of black pepper on non-living standards, *Indian Spices*, **19**:3–5.

Menon, K.P.V. and **Pandalai, K.M.** (1960) *The coconut palm* (A monograph) Indian Central Coconut Committee, Ernakulam, India, 384 pp.

Mukherjee, S.K. (1956) Variation in cashew (*Anacardium occidentale* L.), *Indian J. Hort.*, **13**(1):12–14.

Mukherji, O.K. (1973) Large cardamom, *World Crops*, **25**:31–33.

Murthy, K.N. and **Bavappa, K.V.A.** (1962) Species and ecotypes (cultivars) of arecanut, *Arecanut J.*, **13**:59–78.

Nagabhushanam, S. (1982) Epicotyl grafting in cashew, *Cashew Causerie*, **4**(1):8–9.

Nagabhushanam, S. and **Venkat Rao, P.** (1977) Propagation trials in cashew nut, *Indian Cashew J.*, **11**(3):7–11.

Naidu, G.V.B. (1962) *Arecanut in Mysore*, Union Printers, Bangalore, 225 pp.

Nair, B.V.K. and **George, P.J.** (1969) The Indian clones: RRII 100 series. *Rubber Board Bulletin*, **10**:115–140.

Nair, B.V.K. and **Panikkar, A.O.N.** (1966) Progress of investigation on improved rubber (*Hevea brasiliensis* Mull.-Arg.) planting materials in India, *Rubber Board Bulletin*, **8**:210–216.

Nair, C.K.N. (1974) National Rubber Research up to 2000 AD., *Proc. All India Summer Institute on Improvement and management of Plantation Crops.*, CPCRI, Kasaragod.

Nair, M.K. (1978) Current breeding programmes in pepper, *Proceedings of the National Seminar on Pepper,* CPCRI, Kasaragod, 9–10.

Nair, M.K., Rao, E.V.V.B., Nambiar, K.K.N. and **Nambiar, M.C.** (1979) *Cashew* (*Anacardium occidentale* L.) (Monograph on Plantation Crops – I), CPCRI, India, 169 pp.

Nambiar, K.K. (1949) *A survey of arecanut crops in Indian Union.*, Indian Central Arecanut Committee, Calicut, 35 pp.

Nambiar, M.C. (1977) Cashew, in *Ecophysiology of Tropical Crops*, Academic Press Inc., San Francisco, 461–478.

Nambiar, M.C. (1978) *Report on spice and essential crops of India*, FAO of United Nations, Rome.

Nambiar, P.K.V. (1974) Production of pepper, in *Development and prospects of spice industry in India*, CFTRI, Mysore. 16 pp.

Narayanaswamy, R.L. and **Vishveswara, S.** (1963) A note on the occurrence of three species of *Coffee* indigenous to India, *Coffee*, **5**:65–71.

Nayar, N.M. and **Annamalai, S.J.K.** (1982) Alternative uses of arecanut. in *The Arecanut Palm (Areca catechu* L.) (K.V.A. Bavappa, M.K. Nair, and T. Premkumar, eds.), CPCRI, Kasaragod, India, 263–280.

Nelliat, E.V. Gopalasundaram, P., Thomas Varghese, P., and **Sivaraman, K.** (1979) Mixed cropping in coconut, in *Multiple cropping in coconut and arecanut gardens*, CPCRI, Kasaragod, 28–34.

Ohler, J.G. (1979) *Cashews* (communication 71), Department of Agricultural Research, Royal Tropical Institute, Amsterdam, 260 pp.

Panda, K.C. (1982) Coconut types of Orissa, *Indian Coconut J.*, **13**: 10–18.

Pandalai, K.M. Sankarasubramoney, H., and **Menon, K.P.V.** (1953) Filter press mud as an ameliorant for coconut soils, *Indian Coconut J.*, **7**:20–25.

Patel, J.S. (1937) Coconut Breeding, *Proc. Ass. Econ. Biol., Coimbatore*, **5**:1–18.

Phandnis, N.A., Choudhury, K.G. and **Banderkar, D.G.** (1974) Studies in the raising of cashew (*Anacardium occidentale* L.) clonal material *in situ*, *Indian Cashew J.*, **8**(2):7–13.

Pillai, G.B., Dubey, O. P. and **Singh, V.** (1976) Pests of cashew and their control in India, A review of current status, *J. Plant. Crops*, **4**:37–50.

Premkumari D., George, P.J., Panikkar, A.O.N., Bhaskaran Nair, V.R. and **Sulochanamma, S.** (1982) Performance of RRII 300 series of clones in small scale trial, *Proc. PLACROSYM – V.*

Purseglove, J.W. (1968) *Tropical Crops–Dicotyledons*, Longmans Group Ltd., London, 719 pp.

Purseglove, J.W. (1972) *Tropical Crops – Monocotyledons*. Longmans Group Ltd., London, 607 pp.

Purseglove, J.W., Brown, E.G., Green, C.L. and **Robbins, S.R.J.** (1981a) *Spices* (Vol.I), Tropical Agriculture Series, Longman Inc., New York, 439 pp.

Purseglove, J.W., Brown, E.G., Green, C.L. and **Robbins, S.R.J.** (1981b) *Spices* (Vol.II), Tropical Agriculture Series, Longman Inc., New York, 440–813.

Raghavan, V. and **Baruah, H.K.** (1956) On certain aspects of the morphology of arecanut (*Areca catechu* L.), *J. Univ. Gauhati*, **7**: 23–40.

Rahiman, B.A. and **Nair, M.K.** (1983) Morphology and cytology of some *Piper* species from India, *J. Plant. Crops*, **11**:72–90.

Rahiman, B.A., Murthy, K.N., Nair, M.K. and **Nayar, N.M.** (1979) Distribution, morphology and ecology of *Piper* species in Karnataka, India, *J. Plant. Crops*, **7**:93–100.

Raju, C.R., Prakashkumar, P., Chandramohan M. and **Iyer, R.D.,** (1984) Coconut plantlets from leaf tissue culture, *J. Plant. Crops.*, **12**:75–91.

Ramachandran, M., Muralidharan, V.M. and **Balasubramanian, K.** (1977) A note on a new coconut variety – *Ayirankachi*, *Indian Coconut. J.*, **8**:4–6.

Rao, M.M. (1982) Introduction, in *The Arecanut Palm* (*Areca catechu* L.) (K.V.A. Bavappa, M.K, Nair, and T. Premkumar, eds.), CPCRI, Kasaragod, India, 1–7.

Rao, M.D.S. and **Koyamu, K.** (1952) Hybrid vigour in coconut seedlings, *Indian Coconut J.*, **5**:41–44.

Rao, V.N.M. and **Hassan, M.V.** (1956) A note on the variations in seed characters in cashew (*Anacardium occidentale* L.), *Indian J. Agric. Sci.*, **26**:211–216.

Rao, V.N.M. and **Hassan, M.V.** (1957) Preliminary studies on the floral biology of cashew, *Indian J. Agric. Sci.*, **27**:277–288.

Ridley, H.N. (1912) *Spices*, Macmillan and Co. Ltd. London, 449 pp.

Ridley, H.N. (1930) *The dispersal of plants through the world*, L. Reeve and Co. Ltd., Ashford, Kent. 481 pp.

Rosengarten, F. (Jr.) (1969) *The book of spices*, Wynnewood, Livingston Publishing Co., 489 pp.

Rosengarten, F. (Jr.) (1984) *The book of edible nuts*, Walker and Company, New York, 384 pp.

Rumphius, G.E. (1962) *Herbarium amboinanse Uitgevery en Drukkerij*, Hollandia, N.V. Bearn, 318 pp.

Sastri, B.N. ed. **(1952)** *The Wealth of India, Raw materials* (Vol. III), CSIR, New Delhi.

Satyabalan, K. (1956) A note on the performance of a Natural Cross Dwarf (female) × Tall (male) in coconut, *Indian Coconut J.*, **9**:166–173.

Satyabalan, K., Rathinam, T.C. and **Kunjan, P.V.** (1970) Hybrid vigour in nut and copra characters of coconut hybrids, *Indian J. Agric. Sci.*, **40**:1088–1093.

Schultes, R.E. (1977) An untapped source of natural rubber, *J. Rubb. Res. Inst. Sri Lanka*, **54**:227–257.

Sealy, J.B. (1958) *A revision of the genus Camellia*, Royal Horticultural Society, London.

Sebastine, K.M. (1955) The emigrant economic plants of India (1) *Anacardium occidentale* L. *Proc. Indian Acad. of Sci.*, **42**B,:239–248.

Srinivasan, K.H. and **Narayanaswamy, R.L.** (1975) A review of coffee breeding work done at the Government Experiment Station, Balaehonnur, *Indian Coffee*, **39**:311–321.

Swaminathan, M.S. (1983) Coconut Research – The next phase, in *Coconut Research and Development* (N.M. Nayar, ed.), Wiley Eastern Ltd., New Delhi.

Swaminathan, M.S. and **Nambiar, M.C.** (1961) Cytology and origin of the dwarf coconut palm, *Nature*, **192**:85–86.

Tammes, P.L.M. (1955) Review of coconut selection in Indonesia, *Euphytica*, **4**:17–29.

Thampan, P.K. (1981) *Handbook on coconut palm*, Oxford and IBH Publishing Co., New Delhi, 311 pp.

Usher, G. (1974) *A dictionary of plants used by man*, Constable and Co., London, 620 pp.

Vavilov, N.I. (1951) The origin, variation, immunity and breeding of cultivated plants, *Chronica Botanica*, **13**:1–366.

Velappan, E. and **George, C.K.** (1982) Development, in *The Arecanut Palm* (*Areca catechu* L.) (K.V.A. Bavappa, M.K. Nair, and T. Premkumar, eds.), CPCRI, Kasaragod, India, 305–318.

Venkataramani, K.S. (1966) Practical utilisation of plant variability in tea, in *Proc. UPASI Tea Sci. Dept., Thirteenth Annual Conference*, 3–7.

Venkataramani, K.S. (1970) Clonal selection, a method of improvement of tea planting materials, *UPASI Sci. Dep. Bull.*, **28**:65–74.

Venkataram, C.S. (1980) Plant protection in plantation crops through the 80's, *J. Plant. Crops*, **8**:1–12.

Vishveswara, S. (1970) Some aspects of Robusta coffee in India, *Indian Coffee*, **34**: 209–211.

Vishveswara, S. (1971) Breeding for quality in coffee, *Wynad Coffee Growers Association Souvenir*, 11–15.

Vishveswara, S. (1974) Performance of dwarfs in coffee, *Indian Coffee*, **38**:222–227.

Vishveswara, S. (1975) Coffee – Commercial qualities of some new selections, *Indian Coffee*, **39**:363–366.

Watt, G. (1889) *A dictionary of the economic products in India*, Vol.I. Periodicals Experts., Delhi, 557 pp.

Wellman, F.L. (1961) *Coffee – Botany, Cultivation and Utilisation*, Inter-science publication Inc., New York, 488 pp.

Wellinsick, S.J. (1938) Flower biology and crossing techniques in tea (Dutch with English summary), *Arch. Thucult.*, **12**:127–140.

Willis, J.C. (1966) *A dictionary of the flowering plants and ferns*, 7th edn. (Rev. by H.K. Airey Shaw), Cambridge Univ. Press., London.