MONOGRAPH ON PLANTATION CROPS - 1

CASHEW

(Anacardium occidentale L.*)*

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FOREWORD

Cashew is one of the important gifts of the "new" world to the "old" world. Although a native of tropical America, it became commercially important in its adopted homes in India, Tanzania and Mozambique, soon after its introduction over three centuries ago. More countries are adopting this wonderful plant which, however, has by and large remained as a poor man's crop but rich man's food. Because of the hardy and drought resistant nature, it is grown in a wide variety of soils under marginal conditions of management. Absence of plant protection, inadequate nutrition and above all, raising, the crop mainly from self-sown seeds have all resulted in low average yields. In spite of our producing cashewnuts worth over Rs. 1000 million per year, the average yield has remained at about 420 kg per hectare per year. Given an optimum population of about 200 trees per hectare and even an average yield per tree of five kg per year, as is already obtained in Kerala, it should be possible to obtain a minimum annual yield of 1 tonne of nuts per hectare. If this is achieved, the Indian cashew processing industry, whose great asset is the finger skills of rural women, can get all the raw material it needs even from the existing area of about 4,23,200 hectares.

Cashew is a fascinating plant for the geneticist and breeder. Its cross pollinated nature combined with scope for vegetative propagation makes it ideal for reaping full benefit both from additive gene action and heterosis. The genetic potential for raising the ceiling to yield is clear from the work already done under the All-India Co-ordinated Research Project on cashew sponsored by the Indian Council of Agricultural Research. A new strain Vengurla-2 has given an annual yield per tree of 43 kg when another genotype BLA 139/1 has given 34 Kg per tree at Anakkayam. Improved methods of vegetative propagation are now available and there

is hence scope for the large scale multiplication and cultivation of superior strains. Control measures have been standardised against major pests like stem and root borer, tea mosquito and leaf miner as well as against major diseases like die-back, damping-off and anthracnose. The economic value of improved soil fertility and plant nutrition has been demonstrated. Thus, there is now scope for taking up integrated programmes of improved cashew culture. I am hence happy that the scientists working on cashew in India have brought out this useful book. I hope this book will stimulate appropriate action by agencies connected with cashew research, development, processing and export.

I also hope that increased productivity and production of cashew will help to stimulate greater home consumption, particularly by children of the economically handicapped sections of the community. About 100 grams of cashewnuts per day can provide most of the protein needs of pre-school children. Therefore, it is essential to look upon this plant not merely as a foreign exchange earner or as a source of "Fenni" (cashew liquor) or of other products, but also as an important instrument in our fight against malnutrition in the poorer sections of our population.

M. S. Swaminathan

New Delhi,
1 March, 1979.

(M.S. SWAMINATHAN)

PREFACE

Cashew *(Anacardium occidentale* L.*)* a native of the tropical belt of Eastern Brazil has now naturalized itself to various ecological conditions and soils of Africa and India, and has at present a world production of 6,06,400 tonnes of raw nuts. The research on cashew started only about three decades back, mainly in India and Tanzania. Since the inception of cashew research in India, the main emphasis has been on crop improvement. However, the export potential of the cashew kernel gave the incentive for the industrial research and it has marched ahead the agricultural research. Therefore, today there is a wide gap between the installed processing capacity and internal production. Realising the need for intensifying agricultural research efforts, the Indian Council of Agricultural Research started the All India Co-ordinated Spices and Cashewnut Improvement Project in 1970.

The research results accumulated during the past three decades have been scattered. There appears to be no attempt so far made to compile all the available information except for the review by Shri S. G. Aiyadurai, over a decade ago (Aiyadurai, 1966). The present one is the first full scale attempt to compile the information available on crop improvement, management, protection and industrial aspects including marketing.

We express our profound gratitude to Dr. M. S. Swaminathan, Director-General, Indian Council of Agricultural Research, whose initiative and interest have given us the confidence to attempt this compilation. His forward to this compilation is a great inspiration and encouragement to us.

This work forms part of the publications being brought out in connection with the International Cashew Symposium being held at Cochin, Kerala from 12–15 March, 1979. The organisers of the Symposium thought that a gathering of cashew scientists, technologists and others concerned with cashew production and industry from all over the world would be an ideal forum to release such a compilation.

We have endeavoured to present in this publication the available information on various aspects of cashew research and development, and cashew based industry. However, we do not claim any exhaustive treatment, since we feel this is only a beginning. While the compilation also consists of information pertaining to other cashew growing regions of the world, emphasis is mainly given to the published research results from India. This is due to the fact that a recent book ("Cashew Cultivation" by Mario Agnoloni and Franco Giuliani) has covered the information pertaining to other cashew growing countries.

The contributors to various chapters are cashew workers with varied experience in their specialised fields. However, information received from such diverse sources could not be reproduced *in toto* in a book as this. The compiler of each chapter has been given a certain amount of freedom taking care that the continuity of the subject is not lost in reading.

We express our sincere thanks to all the contributors and compilers for their co-operation in sticking to the time schedule, which has helped in bringing out this compilation on the eve of the International Cashew Symposium. The facilities provided by Dr. N. M. Nayar, Director, Central Plantation Crops Research Institute, Kasaragod, are gratefully acknowledged. The colour transparency for the cover has also been kindly provided by him. We gratefully acknowledge the help rendered by many of our colleagues and among them we would like to mention specially Shri T. Prem Kumar for the invaluable help rendered at various stages of the work, Shri P. N. Ravindran for reading the manuscript and preparing a subject index, S/Shri P. A. Mathew and S. Devasahayam for the line drawings, S/Shri N. Ramachandran and M. Kochubabu for compiling the references, Dr. Y. R. Sarma for reading the proof and S/Shri V. L. Jacob, V. Ahmed Bava and T. K. Narayanan for typing the manuscript. We also appreciate the pains taken by St. Joseph's Press, Trivandrum, for bringing out this Publication in the short time available at their disposal.

Kasaragod,
5 March, 1979

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CHAPTER 1

INTRODUCTION

Cashew *(Anacardium occidentale* L.*)* belongs to the family Anacardiaceae which includes many economically important tropical and sub–tropical trees and shrubs. In most tropical countries it is found growing in the coastal areas. However, commercial production is mainly confined to India, Mozambique, Tanzania, Kenya and Brazil. Today the major cashew producing states in India are Kerala, Karnataka, Tamil Nadu, Andhra Pradesh, Goa, Maharashtra, Orissa, and West Bengal.

The cultivated cashew is a low spreading ever green tree of the tropics. It is presumed that cashew was originally introduced into India mainly for checking soil erosion. But gradually it gained commercial importance and now it is one of the ten top foreign exchange earners. In the earlier years of cashew production in India, the apple was considered valuable and it was only in the beginning of the twentieth century that the cashew kernel, the cashewnut of commerce, found favour among the consumers. Small quantities of cashew kernels were exported from India to USA even before the First World War.

History and origin

Cashew is believed to be native of South Eastern Brazil, from where it was introduced to India in the sixteenth century. It appears probable that it reached East African countries also by about the same time. No serious efforts appear to have been made to collect historical evidence nor any archaeological survey has been attempted to study the history of the cashew cultivation.

The French, Portuguese and Dutch seafarers described cashew from Brazil in the sixteenth century and the first illustrative description of cashew was given by a French naturalist Thevet in 1558 A. D. The fact that cashew is not mentioned in Spanish chronicles covering the exploration of the Caribbean Islands, probably shows that it was introduced after the arrival of the Spaniards (Johnson, 1973). Cashew was introduced to the Malabar Coast of India in the sixteenth century by the Spaniards, and probably served as a locus of dispersal to other centres in India and South East Asia (de Costa, 1578). The Spaniards who were aware of the use of cashew in medicine, foods and beverages, probably visualised the potential importance of this crop to India. From India it was carried eastward to Amboina in Indonesia (Rumphius, 1962); dispersal of the species to South East Asia appears to have been carried out by birds, bats, monkeys and human agents (Burkill, 1935; Johnson, 1973). It appears from the published accounts that *A. occidentale* is the only species which has been introduced outside the New World. Within Central and South America as many as 20 species of *Anacardium* are known to exist (Table 1.1).

TABLE 1.1. **Species of *Anacardium* Linn.***

Botanical name	Country
Anacardium brasiliense Barb. Rodr.	Brazil
A. curatellaefolium St. Hil (=*A. subcordatum* Presl.)	Brazil
A. encardium Noronha	Malaya
A. giganteum Hancock ex Engl.	Brazil
A. humile St. Hil (=*A. subterraneum* Liais)	Brazil
A. mediterraneum Vell. Fl. Flum	Brazil
A. nanum St. Hil (=*A. humile* Engl., *A. pumilum* Walp)	Brazil
A. occidentale Linn. (Cashewnut)	Brazil
A. rhinocarpus D. C. Prod.	Brazil
A. spruceanum Benth Ex. Engl.	Brazil
A. microsepalum Loes	Amazon region
A. corymbosum Barb. Rodr.	Brazil
A. excelsum Skeels (=*Rhinocarpus excelsa*)	Brazil
A. parvifolium Ducke	Amazon region
A. amilcarianum Machado	Brazil
A. kuhlmannianum Machado	Brazil
A. negrense Pires & Fro'es	Brazil
A. rondonianum Machado	Brazil
A. tenuifolium Ducke	Brazil
A. microcarpum Ducke	Amazon region

**Source :* Index Kewensis

The earliest record of cashew growing in South East Asia is that of de Loureiro (1790), although Johnson (1973) surmised that it was introduced to that continent by the Portuguese much earlier.

"Acaju" is the name given to cashew by the native Tapi Indians of Brazil and the French name "Acajou" is the nearest equivalent of the original. The Portuguese dropped the letter 'A', and "Acaju" became "Caju" in Portuguese. The Kashmiri, Punjabi, Hindi, Marathi, and Gujarathi lexicons in India also refer to the cashew as "Caju." It is probable that the use of the kernel spread from Goa to Maharashtra, thence to Gujarat, Rajasthan, Punjab and Kashmir and other Hindi speaking areas. In Kerala it is called "Parangi Andi" meaning foreign or "Portuguese nut". It is also known as "Kasu Andi", "Kasu" meaning money and "Andi" the nut. In Tamil it is known as "Mundiri" indicating the position and shape of the nut. In Oriya it is known as "Lanka Beeja" indicating that cashew reached Orissa by sea from Sri Lanka. The Bengalis know cashew as "Hijli badam" and Assamese refer to the nut as "Caju Badam." Thus, most of the names used in India are derived from the Portuguese "Caju" for cashew. This serves as a piece of evidence that the cashew originated in Brazil.

Cashew is found to tolerate wide range of ecological factors and it has become naturalised in extensive areas in tropical countries. Systematic cultivation of cashew, however, received attention only very recently and the available statistics on area and production etc. are conflicting and are of doubtful reliability. Even today most of the cashew collected and processed for world market are picked from self sown wild growth of cashew trees. World Bank has estimated that only about 2–3% of the annual world production is from systematically planted plantations and the bulk of the crop originates from wild growth in small peasant holdings.

Research in India

Research on cashew can be considered to have commenced with the sanctioning of a few *ad hoc* schemes by ICAR from 1951–52 onwards in the three centres of erstwhile states of Travancore, Madras and Bombay and later extended to Andhra Pradesh and Assam also. A co-ordinated effort to intensify the research was initiated with the sanctioning of the All India Co-ordinated Spices and Cashewnut Improvement Project in 1971. Introduction and evaluation of the germplasm collections to select high yielding types, hybridization and selection to evolve high yielding hybrids, agronomic trials to determine the agronomic requirements of the crop under different agro-ecological conditions were initiated and intensified under the Project. The plant protection measures to control the pests like tea mosquito, stem borer and thrips were standardised for large scale adoption in the field.

Cashew situation in India today

An analysis of production figures in India (see chapter 2) shows that the increase in production has not been proportionate to the increase in area. Cashew plantations are raised on marginal lands and even now receive very little attention from the growers. The area under cashew was increased from 1,03,581 ha in 1950–51 to 4,23,196 ha in 1976–77. During the same period the production increased from 58,968 tonnes to 1,79,305 tonnes. The reason for the low production can be attributed to a large proportion of the plantations consisting of self-sown seedlings or raised from unselected seedlings. Moreover, cashew is grown in marginal lands under poor management. Conceivably the production potential of these plantations is very low. A few years earlier small growers were not motivated in taking up cashew cultivation because of poor economic returns compared to other cash crops like pepper and cardamom. The situation has changed now. The price of cashew kernel has shot up steeply and adequate agrotechnology is available to increase cashew production. Thus cashew cultivation and production have reached a 'take off' stage entering a new phase in India and these two aspects of cashew industry may catch up with processing and export pace in the near future.

CHAPTER 2

PRODUCTION

Cashew is grown almost throughout the tropics, between the Tropics of Cancer and Capricon (Fig. 2.1). Most of the traditional cashew growing regions are characterised by semi-wild growth. Consequently, eventhough it fetches valuable foreign exchange to the national exchequer, most of the cashew collected and processed for world markets are picked from sporadically self-sown trees.

World production of cashew

Total world production of raw cashewnut during 1976 was 5.87 lakh tonnes (Table 2.1). About 95% of the production is from the countries in Africa and Asia, mainly from India (42%), Mozambique (34%) and Tanzania (14%). Contribution of Brazil, the original home of cashew, is less than 5% only. Other Asian countries growing cashew are the Philippines, Malaysia and Sri Lanka and together they account for only about one per cent of the total production (Table 2.1).

Mozambique ranks second in terms of production of raw cashewnuts with the annual average production being 1.97 lakh tonnes, for the last three years. It was introduced into the country during the fifteenth century by the Portuguese missionaries. The crop is now growing wild in the entire coastal belt of the country, more than 15,000 kilometres long and up to a breadth of 200 kilometres. As early as the 20's, harvesting and utilisation of raw cashewnut in Mozambique were oriented towards the demand on the part of Indian processors. From an average of 1,000 tonnes per annum during the 20's, exports of raw nuts from this country rose to 6,350 tonnes in 1930; 26,130 tonnes in 1935 and 31,700 tonnes in 1940. There was a rapid resumption in trade after the World War II and the exports climbed a peak of 1.26 lakh tonnes in 1964.

Tanzania is the third major cashew growing area in the world, with an average production of 1.15 lakh tonnes of raw nuts. Here also the crop was introduced at more or less the same time as in Mozambique. About 70 % of raw nuts are exported to India.

Brazil contributes about 4.4% and is the fourth largest producer. The production is mainly from wild and semi-wild cashew populations concentrated in the coastal areas of the north-eastern regions. In recent years large organised plantations have started contributing significantly to cashew output. Approximately 20 companies process cashew in Brazil of which all but three, rely upon manually operated machines. There is currently under-utilisation of capacity in the industry which can process 10,000 tonnes of raw nuts per year. This excess installed capacity in the processing industry has stimulated imports

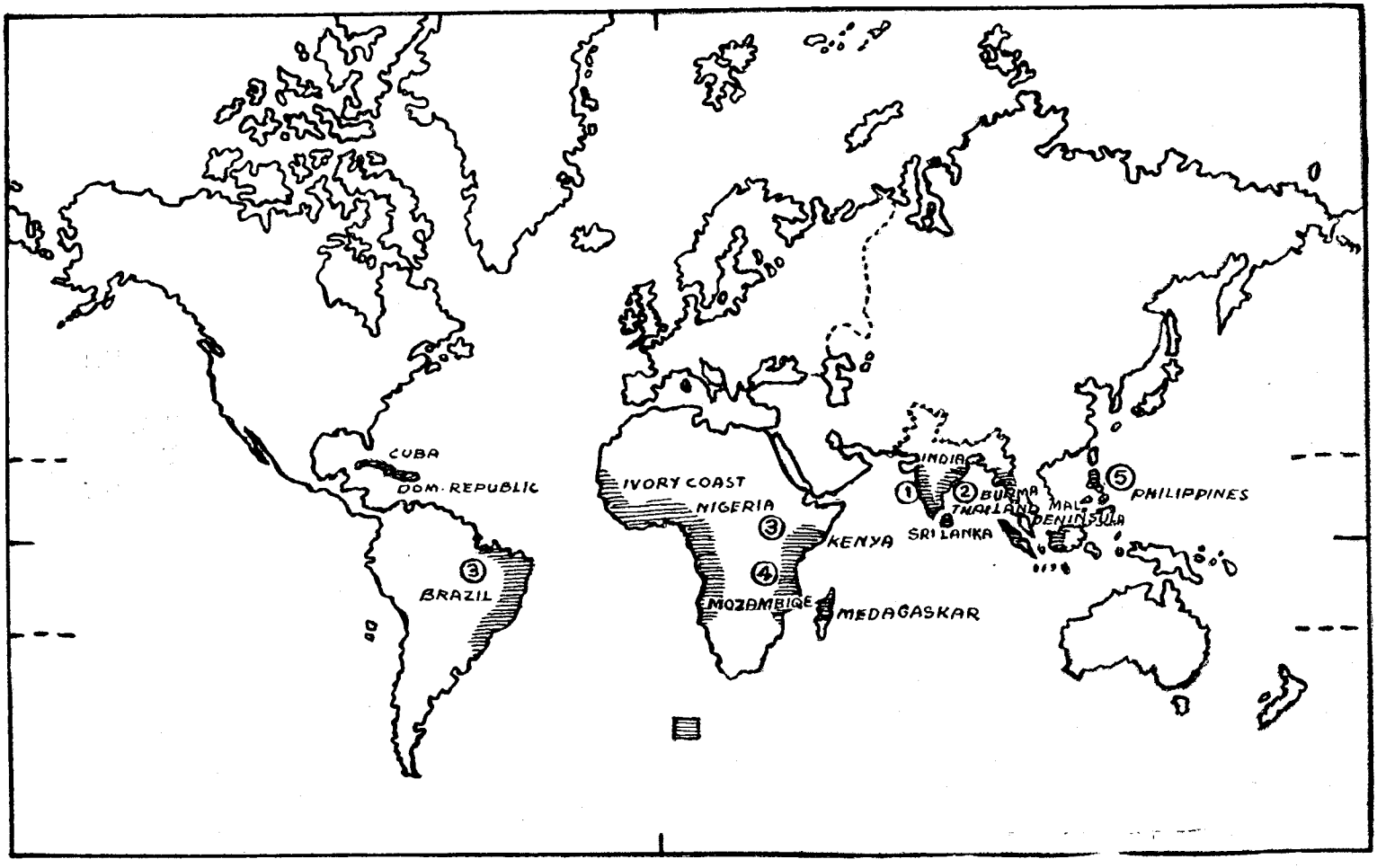


Fig. 2. 1. CASHEW GROWING AREAS OF THE WORLD

TABLE 2.1. **World Production of cashew ('000 metric tonnes)**

Country/Region	*Production of cashewnut*					*Compound growth rate (%)*
	Average 1961–65	*1974*	*1975*	*1976*	*Average 1974–76*	
Angola	1.0 (0.3)	1.4	1.4	1.4	1.4 (0.2)	2.5
Gumbissau	2.0 (0.5)	2.5	2.7	2.7	2.6 (0.4)	2.3
Kenya	7.1 (1.9)	16.0	16.4	20.0	17.5 (2.9)	7.8
Madagascar	2.0 (0.5)	2.0	2.0	2.0	2.0 (0.3)	0
Mozambique	131.2 (35.4)	213.4	180.0	200.0	197.8 (32.6)	3.5
Tanzania	63.4 (17.1)	147.7	115.2	83.4	115.4 (19.0)	5.1
AFRICA	206.7 (55.7)	382.9	317.7	309.5	336.7 (55.5)	4.2
Dominian Republic	0.8 (0.2)	0.8	0.8	0.8	0.8 (0.1)	0.3
N. C. AMERICA	0.8 (0.2)	0.8	0.8	0.8	0.8 (0.1)	0.3
Brazil	11.7 (3.1)	28.4	24.9	27.0	26.8 (4.4)	7.1
SOUTH AMERICA	11.7 (3.1)	28.4	24.9	27.0	26.8 (4.4)	7.1
India	145.2 (39.1)	230.0	235.0	243.3	236.1 (38.9)	4.1
Mal. Peninsula	0.2 (N)	0.6	0.6	0.6	0.6 (0.1)	9.6
The Philippines	6.0 (1.6)	4.9	4.9	4.9	4.9 (0.8)	1.6
Sri Lanka	0.4 (0.1)	0.5	0.5	0.5	0.5 (0.1)	1.6
ASIA	151.8 (40.9)	236.0	241.0	249.3	242.1 (39.9)	4.0
WORLD	371.0	648.1	584.4	586.6	606.4	4.2

Note: Figures in parentheses denote the production figures expressed as percentages of total production
Source of basic data : FAO Production Year Book, 1976

of raw cashewnuts from Mozambique and Tanzania for processing and eventual re-export. Thus Brazil has emerged as a tough competitor for India—for raw cashewnut import from African Countries and exports of kernel, especially to the American zone.

Kenya ranks fifth among the world's commercial cashew producing countries. The crop is grown primarily by small landholders in the southern humid part of the coast. The cashew belt extends for more than 150 kilometres along the coast. Most of Kenya's cashewnuts, till as late as 1975, were being exported to India. However, with the establishment of the first large scale processing unit in 1976, with an installed capacity of 15,000 tonnes of raw nuts per annum, Kenya's cashew export business has turned a new leaf as is evident from the diminishing shipments of raw nuts and an increasing volume of kernel sales. The kernel export, which was static around 160 tonnes for the last decade jumped to a record of 1,013 tonnes in 1976. The present raw nut production of 20,000 tonnes a year is expected to increase many fold as the new plantations start yielding.

During the period 1961–'65 to 1974–'76, the production of raw cashewnuts in the world was growing at the compound rate of 4.18% per annum compared to 4.15% growth for Africa and 3.97% for Asia. Among the major producing countries, growth rate was highest in Tanzania (5.12%), followed by India (4.13%) and Mozambique (3.48%). The rate of increase in production has been much higher in Malayan Peninsula (9.59%), Kenya (7.81%) and Brazil (7.10%), but this had no significant impact on total world production, because of their low share. In the Philippines a declining trend in production is noticed.

Cashew in India

The Directorate of Economics and Statistics (Ministry of Agriculture, Govt. of India, New Delhi) has been regularly publishing data on area, production and average yield of this crop for the period 1962–63 to 1969–70. From 1970–71 onwards, this has ceased to appear. State-wise data on area and production, compiled by the Directorate of Cashew Development, Cochin, based on the reports received from various state governments have been given in Table 2.2.

Over the years, the area under the crop in India has been steadily increasing, but corresponding increase has not been observed in the production of nuts. During 1976–77, the production of raw cashewnuts was 1.79 lakh tonnes from an area of 4.23 lakh ha. (FAO estimates of production from India is about 30% higher than this). This is probably because the new plantations have not started yielding yet.

Kerala has the maximum area under the crop (1.18 lakh ha accounting for 28% of the total), followed by Tamil Nadu (0.97 lakh ha or 23%) and Maharashtra (0.80 lakh ha or 19%). Other important cashew growing areas are Karnataka, Goa, Andhra Pradesh and Orissa. It is also grown in West Bengal, Tripura and Pondicherry. In terms of production, 72% (1.29 lakh tonnes) is from Kerala. Karnataka is the second largest producer, 8.5% (0.15 lakh tonnes) followed by Andhra Pradesh and Tamil Nadu. The

TABLE 2.2. **Area and production of cashew in India (1976–77)**

State/ Union Territory	*Area (hectares)*		*Production (in tonnes)*		*Yield (kg/ha)*
Andhra Pradesh	31,000	(7.3)	12,500	(7.0)	403
Goa	32,517	(7.7)	6,500	(3.6)	200
Karnataka	36,534	(8.6)	15,175	(8.5)	415
Kerala	118,139	(27.8)	129,021	(72.0)	1092
Maharashtra	79,808	(18.9)	3,634	(2.0)	45
Orissa	24,487	(5.8)	940	(0.5)	38
Pondicherry	322	(0.1)	42	(N)	130
Tamil Nadu	97,130	(23.0)	11,470	(6.4)	118
Tripura	753	(0.2)	23	(N)	31
West Bengal	2,506	(0.6)	N	(N)	N
ALL INDIA	423,196		179,305		423.6

Note : Figures in parentheses denote area/production expressed as percentages of the total
N : Nil or negligible
Source for basic data : Directorate of Cashew Development, Cochin, India

share of Kerala in production of nuts is disproportionate to its area figures. Though 19% of the area under the crop is accounted for by Maharashtra, its share in the total production is only 2%**. The production of nuts from all the states is likely to increase when the new plantations come to bearing.

In Kerala, during the past decade, the area expansion has been to the tune of 42% from 0.91 lakh ha in 1966–67 to 1.18 lakh ha in 1975–76, while the production increased from 1.15 lakh tonnes to 1.29 lakh tonnes, a rise of 17% only. Most of the large scale plantations have yet to reach the bearing stage. Cannanore district accounts for the maximum area under the crop (61,000 ha), followed by Malappuram (24,000 ha) and Palghat (13,000 ha) districts.

Karnataka, with a production of over 15,200 tonnes of raw nuts from an area of 36,500 ha, stands second among the different cashew producing states in India. The productivity of trees in the state is almost on par with the national average. During the

** During the late 60's, the estimated production of nuts from Maharashtra was around 24,000 tonnes. The reason for the reported fall in production is not known, though the area has considerably gone up.

past decade, area under the crop has shown a four–fold increase from 8,600 ha to 36,500 ha, whereas the production has gone up by three times only (5,000 tonnes to 15,200 tonnes). Fortyfive per cent of the area under the crop is young plantations in forest lands, which contributes to 34% of production. Out of the 16,400 ha under forest plantation, 10,250 ha (62.5%) is in Dakshina Kanara district, 5,500 ha (33.4%) in Shimoga district and small areas in Kolar and Uttara Kanara districts.

Andhra Pradesh is the third largest producer of raw nuts in the country. It has about 31,000 ha under cashew, producing 12,500 tonnes of raw nuts. The past decade has witnessed an increase of 70% in the area, whereas the production has remained almost static. Yield of trees is almost on par with the national average. Important cashew growing districts are East and West Godavari and Srikakulam.

Tamil Nadu produces 11,500 tonnes of raw nuts from an area of 97,000 ha and holds the fourth place for production in the country, and second in area. About 15 per cent of the production in the state is from forest plantations. South Arcot district has the maximum area under the crop and accounts for the maximum production also, followed by Tiruchirappalli. About 50 per cent of the area under cashew in the state is from the above two districts and their share in the production is over 60%.

World demand

The world demand of cashew kernels has increased in the last three decades. The export figures, rose from 17,200 tonnes in 1947 to 36,000 tonnes in 1957 and to 63,500 tonnes in 1967. It touched the peak during 1972, when the world export reached 1,02,000 tonnes. However, two subsequent crop failures in 1975 and 1976 have resulted in lower world exports in recent years. As a result of the continued short supply of raw cashew-nuts and the exceptionally high prices of cashew kernels, there has been a marked decline in world consumption during 1977.

The major importing and consuming countries of the cashew kernels are the USA and the USSR followed by Japan, Canada, UK, GDR, Australia and FRG. In fact these countries together make up more than 90% of the cashew imports. (Table 2.3).

World consumption has been increasing at an average annual rate of about 10.9% during the last decade. However, the expansion has not been uniform among the various importing countries. Japan has achieved the fastest growth rate in her imports (from 514 tonnes in 1968 to 6559 tonnes in 1976).

Exports from India

India is the largest exporter of cashew kernels and had the privilege of occupying a monopolistic position in the supply of cashew kernels in the international market till recently. At present India accounts for nearly 60% of the world export (Fig. 2.2). In 1947, India exported 16,900 tonnes of cashew kernel, which steadily increased to 34,577

TABLE 2.3. **Imports of cashew kernels by principal consuming countries (quantity in metric tonnes)**

Countries	*1948*	*1958*	*1968*	*1973*	*1974*	*1975*	*1976*
Australia	..	685	2024	2364	3448	3568	3489
Belgium	11	113	196	391	335	393	377
Canada	835	1507	2272	6703	5710	4865	6583
France	..	..	184	1164	647	835	1028
GDR*	..	50	2510	978	614	266	511
German Fed. Rep.	..	..	1174	3004	2261	2703	2986
Holland	..	..	777	2616	2441	3198	3194
Hong Kong*	..	230	521	548	832	858	532
Japan	..	..	514	3289	2332	4323	6559
Kuwait*	..	15	86	181	260	421	535
Newzealand	..	134	210	254	582	438	593
Singapore*	..	75	163	390	342	529	460
United Kingdom	3237	2717	3150	3420	3373	2303	4130
U.S.A.	15745	30286	42234	49003	39860	43683	50772
U.S.S.R.*	..	5095	17460	20700	31742	24797	15755
Total	19828	40907	73475	95005	94781	93180	97504

Source: Gill & Duffus Landauers Ltd., London
D G C I & S, Calcutta
*Exports from India only

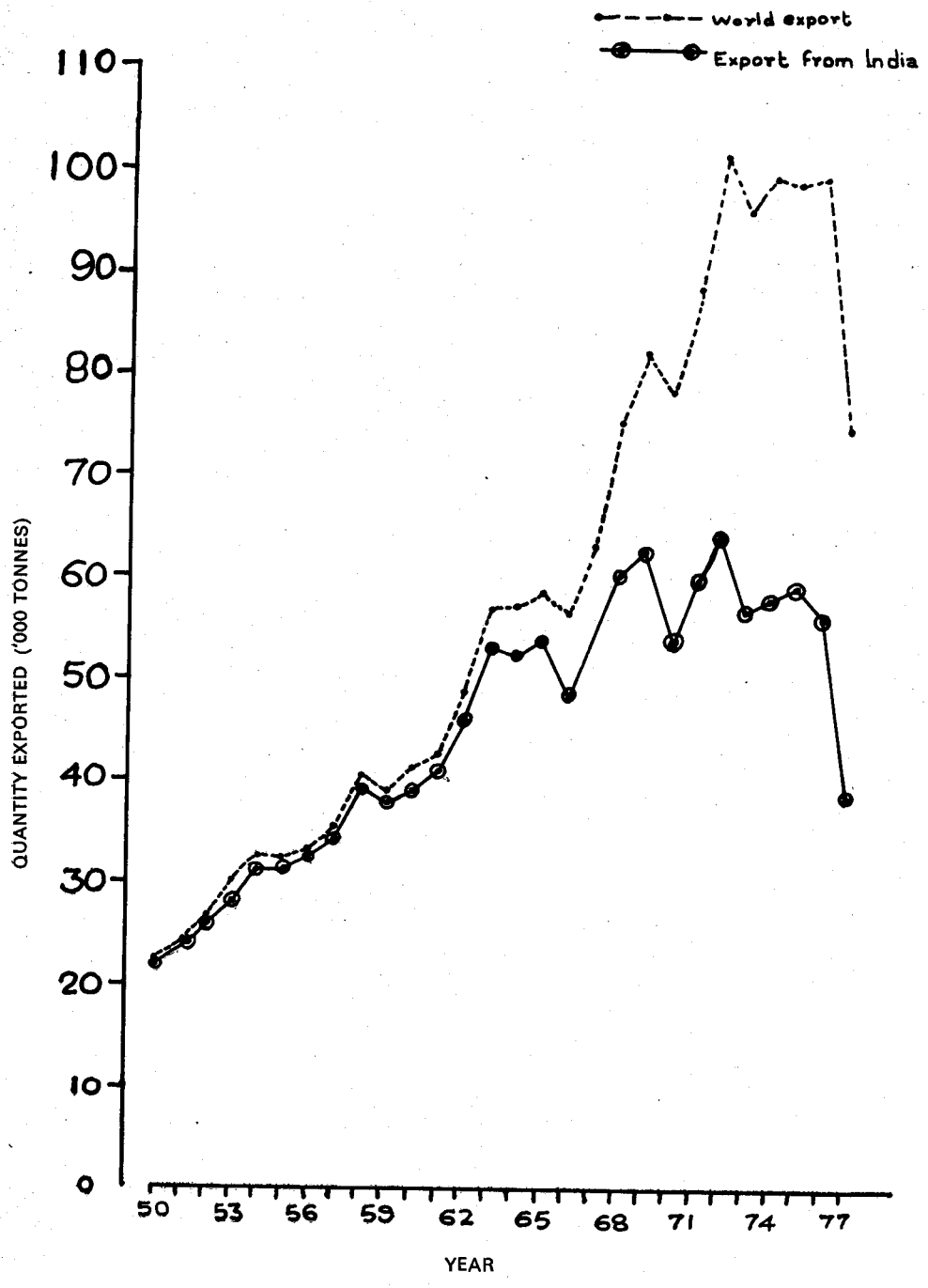


Fig. 2. 2. WORLD EXPORT OF CASHEW KERNELS

tonnes and 52,256 tonnes in 1957 and 1967 respectively and touched a peak of 64,500 tonnes in 1972. However, with the establishment of processing units in African Countries and entry of Brazil in the world market, the share of India has started declining. Exports from India fell from 59,000 tonnes in 1975 to 39,000 tonnes in 1977 (Table 2.4).

The largest consumers of Indian cashew kernels were from American zone, with the USA importing the lions share. However, the imports from India showed a fluctuating trend and touched the all time low of 8,800 tonnes in 1977.

The USSR, the second largest consumer of cashew kernels is presently the leading buyer from India. In fact, USSR imports are almost entirely from India. Though she entered the cashew market much later, USSR has experienced a spectacular growth in cashew consumption. The average exports from India to the USSR in the last few years have been around 20,000 tonnes annually.

Internal consumption

The available statistics on internal consumption is scanty. A crude way of arriving at the internal consumption is on the assumption that the difference between the kernels available for processing and the kernels exported will give the consumption figure (Table 2.5).

Right from its inception in the early twenties, the cashew industry has been mainly export oriented. The internal consumption tends to fluctuate.

Cashew crisis in India

The export oriented cashew industry in India had until early 1960's virtually a monopoly in the processing of cashewnuts and supply of kernels to international markets. However, the industry was solely dependent on imported raw nuts from East African countries. As is evident till early 1970's about 75% of the export requirements were met through the imported raw nuts.

Cashew industry had registered a phenomenal growth during the last half-a-century period. Relatively small capital investment required to establish the processing units, availability of skilled labour in abundance and steady increase in the imports of raw cashewnuts from East African countries had contributed to the rapid proliferation of processing units in Kerala. In recent years, the growing disparity in the wage structure in Kerala as compared to the adjoining states led the entrepreneurs to migrate from Kerala to neighbouring Tamil Nadu, creating new processing capacities and thereby aggravating the existing underemployment problem in the industry as a whole. Consequently the installed capacity of processing units was built up in the country which was sufficient to process more than twice the available raw material. Underemployment and seasonal employment have, therefore, been the constant features of the industry throughout. Practically no attention has been paid by the industry for enhancing the production of indigenous raw materials. Our main concern was only feeding the industry with imported raw nuts.

TABLE 2.4. Export of cashew kernels from India (quantity in '000 metric tonnes)

Country	1955–56		1960–61		1965–66		1970–71		1975		1976		1977	
U. S. A.	24.8	(79.1)	30.4	(69.8)	27.0	(52.7)	22.8	(45.3)	18.5	(31.2)	20.5	(36.8)	8.8	(22.8)
Canada	1.2	(3.7)	1.4	(3.2)	1.6	(3.1)	2.3	(4.6)	2.8	(4.8)	4.0	(7.1)	1.3	(3.3)
U. S. S. R.	..		4.2	(9.5)	11.5	(22.5)	14.4	(28.6)	24.8	(41.9)	15.8	(28.2)	19.1	(49.4)
G. D. R.	..		0.5	(1.2)	3.1	(66.0)	3.2	(6.4)	0.3	(0.4)	0.5	(0.9)	0.1	(0.4)
U. K.	3.1	(9.9)	3.0	(6.9)	2.5	(44.8)	1.8	(3.5)	0.8	(1.4)	1.0	(1.8)	0.4	(1.0)
F. R. G.	0.1	(0.3)	0.8	(1.8)	0.6	(1.2)	0.4	(0.7)	0.6	(1.0)	1.3	(2.3)	0.5	(1.2)
Japan	..		0.2	(0.4)	0.5	(1.0)	0.9	(1.8)	3.8	(6.4)	5.5	(9.8)	2.9	(7.6)
Singapore	..		0.1	(0.2)	..		0.3	(0.7)	0.5	(0.9)	0.5	(0.9)	0.2	(0.6)
Australia	0.6	(1.8)	1.1	(2.6)	1.4	(2.7)	1.1	(2.1)	2.2	(3.8)	2.4	(4.3)	1.9	(5.0)
Others	1.6	(5.2)	1.9	(4.4)	3.1	(6.0)	3.1	(6.0)	4.9	(8.2)	4.4	(7.9)	3.5	(8.7)
Grand Total	31.4	(100.0)	43.6	(100.0)	51.3	(100.0)	50.3	(100.0)	59.2	(100.0)	55.9	(100.0)	38.7	(100.0)
Value (in rupees crores)	12.92		18.91		27.40		52.07		105.53		110.25		143.22	

Note : Figures in parentheses express the quantity exported, as percentage of the total exports
Source : The Cashew Export Promotion Council, Cochin, India

TABLE 2.5. Internal consumption of cashew kernels (quantity in metric tonnes)

Year	Raw nuts			Kernel equivalent at 25 per cent recovery	Exports	Quantity available for internal consumption
	Imports	Indigenous production	Total			
1960	99,631	61,000	160,631	40,158	39,436	722
1965	175,489	61,000	236,489	59,122	53,793	5,329
1970	170,785	71,000	241,785	60,446	54,074	6,372
1975	126,724	97,000	223,724	55,931	59,174	—

Source : Cashew Export Promotion Council, Cochin. India

The impetus towards domestic processing in African Countries evolved with the development of mechanised processing system. The incentives to process their own raw nuts were strong to the African processors as it could lead to boosting up of the export earning, besides the generation of employment opportunities. As the conditions prevail today, with Mozambique achieving self sufficiency in processing her entire raw nut production, fast development of processing industry in Tanzania and Kenya and the emergence of Brazil and China with excess installed capacity and strong purchasing power, India has to compete for the dwindling availability of raw material in the international cashew market. India is, perhaps, fast approaching a stage where her industry has to depend entirely on indigenous production for its raw material requirements.

At present India has the installed capacity of about 4.5 lakh tonnes of raw cashew-nuts, while the triennial average of indigenous production and imported raw nuts together for the period 1975-77 has been of the order of about 2.3 lakh tonnes thereby leaving a gap of about 2.2 lakh tonnes between the supply and demand of raw nuts.

Development programmes during Sixth Plan period

As shown in the earlier section, the gap between the demand and supply of raw cashewnuts in the country is about 2.2 lakh tonnes. This gap could be bridged by the indigenous production through two measures: (i) expansion of area under cashew in both traditional as well as non-traditional regions, and (ii) adoption of improved management practices. Though various long and short term measures formulated for implementation during the Sixth Plan, the indigenous production is expected to go up to about 2.98 lakh tonnes.

Both Centrally Sponsored Schemes and State Sector Schemes intend to increase the area under cashew have been formulated to enhance the indigenous production. The details are presented in the Table 2.6.

TABLE 2.6. **Programmes for area expansion during Sixth Five Year Plan (area in '000 ha)**

State	*Centrally sponsored schemes*		*State sector schemes*	
	Non-departmental	*Departmental*	*Non-departmental*	*Departmental*
Andhra Pradesh	4.0	10.0	..	..
Goa	4.0	2.0	10.0	1.0
Karnataka	8.0	3.0	..	36.0
Kerala	18.0	8.0	..	..
Maharashtra	10.0	..	..	..
Orissa	8.0	24.0	..	14.0
Tamil Nadu	8.0	3.0	..	..
Total	60.0	50.0	10.0	51.0

Source : Directorate of Cashew Development, Cochin, India

According to the programmes, an additional area of 1.71 lakh ha are to be brought under cashew. The share of Central Sector being 1.10 lakh ha, the remaining 0.61 lakh ha will be covered by State Sector Schemes. In due course of time this programme is expected to yield an additional production of the order of 3420 tonnes.

Some of the other Centrally Sponsored Schemes are described below:

Scheme for laying out demonstration plots in growers' orchards for improved practices in cashewnut cultivation.

The scheme will continue during the Sixth Plan and envisages to bring out 15,000 plots under its programme. The aim of the scheme is to demonstrate the efficacy of improved agro-techniques developed at the Research Stations under the growers' conditions. Average cost of adoption of improved practices in one plot is estimated to be Rs. 500/–. All the inputs required will be supplied to selected cultivators in time to ensure the effective and timely application of the same. These plots are expected to add 1875 tonnes to the total production.

Scheme for improvement of cashew by vegetative propagation

The objective of the scheme is to improve the newly raised cashew plantations which are stocked with seedling progenies of low yielding nature by adopting the techniques of vegetative propagation *in-situ,* patch budding or veneer grafting or side grafting so as to convert them into trees of merit in respect of yield and quality. An area of 28000 ha is expected to be covered by this scheme during the current plan period.

Scheme for establishment of progeny orchards for cashew

This scheme envisages to establish clonal orchards of cashew raised from superior trees of merit evolved at the Research Stations and high yielding trees located in private orchards. An additional area of 640 ha is to be brought under progeny orchards.

The estimates of additional production are furnished in Table 2.7. The total indigenous production of raw cashewnut is expected to climb up to 2.98 lakh tonnes, the addition being about 1.12 lakh tonnes.

TABLE 2.7. **Estimates of additional production during Sixth Plan (quantity in metric tonnes)**

Schemes	*Additional Production*
Central Sector Schemes	
Area Expansion Programme (1,10,000 ha)	3,060*
Scheme for laying out demonstration plots in growers' orchards (15,000 plots cumulative)	1,875**
Scheme for improvement of cashew by vegetative propagation (28,000 ha)	1,200*
Scheme for establishment of progeny orchards (640 ha)	128*
Total	6,263 or 6,300
Base level production (1978–'79)	1,80,000
New plantations of IV and V Five Year Plans	62,300
Increase in production due to improved management of old orchards	50,000
Total	2,98,600

Source: Directorate of Cashew Development Cochin, India

* Additional production of 200 kg per hectare

** Additional production of 375 kg per hectare

CHAPTER 3

BOTANICAL DESCRIPTION

The family Anacardiaceae to which cashew *A. occidentale* belongs, comprises 60 genera and 400 species of tropical and sub-tropical trees and shrubs. Nearly 50 species under 22 genera are represented in the Indian sub-continent. The family has been treated under Sapindales by most phylogenists. (Rendle 1952; Khosla *et al.*, 1973). Hutchinson (1959) considered it as one of the advanced members of Sapindales. Hallier (1905) considered the family (Sub-Terebinthaceae) as ancestral to most amentiferous taxa and also to Aceraceae and derived from Rutaceae. According to Bailey (1958) *Anacardium* is a small genus of eight species indigenous to South America. However, Agnoloni and Giuliani (1977) recognized eleven species under the genus: *A. occidentale* Linn., *A. corymbosum* Barb. Rodr., *A. excelsum* (Bert. and Balb) Skeels, *A. giganteum* Hancock ex Engler, *A. humile* St. Hil., *A. microcarpum* Ducke, *A. microsepalum* Loesn, *A. parvifolium* Ducke, *A. pumilum* St. Hil, *A. tenuifolium* Ducke, and *A. spruceanum* Benth ex Engl.

According to De Candolle (1825), *A. occidentale* has two varieties *viz., Americanum* and *Indicum.* In *Americanum,* the peduncle is about ten times bigger than the nut whereas in *Indicum* the peduncle is only about three times bigger than the nut.

In Brazil, cashew is given names on the basis of colour, form, size, taste, and consistency of the pulp of the peduncle. Lima *et al.,* (1952) described 44 different types of cashew apples. There is a popular variety of cashew in Brazil called 'the six-month cashew' that flowers in less than one year (Gomes, 1944). Another variety flowers and fruits throughout the year (Mota, 1956), but the yield is low and the nut and peduncle are of poor quality. Two varieties based on the apple colours, red and yellow, have been identified in many cashew growing countries (Morada, 1941, Cordoba 1967, and Araque, 1968). However, from India, Aiyadurai (1966) has reported the existence of cashew apples in 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 Travancore–Cochin State.

Morphology

The cashew tree is a low spreading evergreen tree with a number of primary and secondary branches (Johnson, 1973). In a study of the germplasm at the CPCRI, Regional Station, Vittal, Kumaran *et al.,* (1976a) reported the number of primary branches in four year old trees to vary from 9 to 30 and secondary branches from 246 to 412. The branches are stout and the bark is thick, resinous, round and scaly. The wood is yellow in colour, moderately soft, light and having a relative density of 0.50 (Lima, 1954;

Tavares, 1959). The sapwood is pale brown when dry. The zone of the heartwood can easily be distinguished by the brown colour. The wood has an even texture with moderately close straight grains (Sebastine, 1955).

Root system

The root system of a mature cashew tree, when grown from the seed, consists of a very prominent tap root and a well developed and extensive network of lateral and sinker roots. Tsakiris and Northwood (1967) studied the root system of one and a half to six year old cashew trees. The lateral of a two and a half year old tree was found to be 4.6 m long, causing roots to interlace in trees planted at 6 m spacing and to meet in trees planted at 9 m.

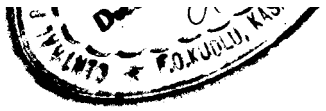
Agnoloni and Giuliani (1977) noticed that the simple, fragile tap root in the first phase of growth of the young plant takes a more complex structure of strong and extensive root both sideways and downwards. They also noticed that the primary root soon ceases to grow and atrophies, while at the same time the side roots develop progressively and extensively attaining an area double the size of the canopy by the time it is $1\frac{1}{2}$ years old. Rao *et al.*, (1957a) reported that in one or two months old seedlings, no lateral roots could be seen and that in the case of older seedlings, only lateral roots and fibrous roots developed. Shanmugavelu (1970) reported that better root system developed when the seeds were soaked in NAA at 100 ppm for 24 hr before sowing and seedlings sprayed with IBA at 100 ppm at weekly intervals.

Pattern of growth in a bearing tree

According to Argles (1969) two or three peak periods of growth are usually observed in a bearing cashew tree, eventhough under favourable conditions the stray shoot growth may occur almost every month.

The pattern of growth of a bearing tree consists of a generative flower flush and a vegetative flush. The vegetative flush, consisting of lateral shoots, always develops soon after the main crop has matured. Flowering is terminal and is universally preceded by the vegetative flush (Argles, 1969).

Dasarathi (1958) reported two types of branching in cashew, intensive and extensive. The intensive shoot grows to a length of about 25–30 cm and terminates in a panicle. Simultaneously, three to eight laterals arise within 10–15 cm of the apex. Some of these lateral shoots may also terminate in panicles in the same flowering season, repeating the same growth pattern, giving a well covered bushy appearance to the tree. In the extensive type, the shoot grows to a length of 20–30 cm and rests. A bud sprouting 5–8 cm below the apex leads to further growth. This process of growth continues for two or three years without any flowering. This kind of growth pattern produces a spreading tree. Eventhough both kinds of branching are observed in all trees, one type dominates in a tree. High yielding trees have more than 60% intensive branches whereas low yielders have less than 20%. Seventy five per cent of the shoots of the intensive types produce flowers as against 12% in extensive types.



Leaves

The leaves are alternate, simple, glabrous, obovate rounded, thickly coriaceous and entire, often notched at the apex, veins prominent, pinnately veined, lateral veins spreading with 10–20 pairs. The petioles are short, one to two cm long and the leaves are commonly crowded at the ends of the branches. Leaf size varies from 6 to 24 cm in length and 4 to 15 cm in width (Johnson, 1973; Kumaran *et al.*, 1976a).

Inflorescence and flowers

The cashew tree normally comes to flowering in three to five years. The inflorescence is an indeterminate panicle of polygamomonoecious type (Rao and Hassan, 1957; Damodaran *et al.*, 1965). Copeland (1961) described the inflorescence of cashew as a terminal panicle-like cluster. Each branch of the cluster bears a terminal flower subtended immediately by two or more bracts. From the axils of these bracts grow further bracted flower stalks. The average length of panicle varies from 14 to 21 cm and the number of flowers per panicle varies from 200 to 1600 (Damodaran *et al.*, 1966).

Flowers and sex ratio

According to Rao and Hassan (1957) nearly 96% of the flowers in a panicle are staminate. On the other hand Morada (1941) reported 90–99% staminate flowers. Bigger (1960) noted a ratio of 6:1 staminate to perfect flowers in cashew and only 10.2% of the perfect flowers produced mature fruits. Damodaran *et al.*, (1965) stated that the proportion of perfect flowers varied from as low as 0.45% to 24.9% in different trees.

Flowering season and phases

Maity (1960) recognized three growth flushes in a year and the rainy season flush to be less vigorous than the winter or spring season flushes. Rao and Hassan (1957) described two distinct growth flushes in southern parts of India, and emergence of panicles on shoots during October-January. Damodaran *et al.*, (1965) reported that the flower bud emergence in cashew commenced by the middle of September and continued until the end of February, the main season being October-November.

Chakravarty *et al.*, (1972) reported that in cashew vegetative shoots which appeared in April–May developed panicles in about 92% cases during the next flowering season, while those produced in December–January bore flowers in about 10% shoots in the same year.

Nambiar (1977) noted that the variation in the flowering season in cashew in different countries is related to altitude. The flowering season is from June to November in Tanzania with peak in August–September (Northwood, 1966). The peak flowering period in Brazil is August–September (Popenoe, 1924), in Mozambique it is in October and in the Philippines it is March (Galang and Lazo, 1936). In Central America (El Salvador), the flowering period is from December to March with a January–February peak, and in Malagasy, the peak period is in March–April. In West Africa also the flo-

wering period is from December to March with a peak in January–February. In Kenya, there are two flowering periods, one from September to November, and second from December to January (Agnoloni and Giuliani, 1977).

Seasonal variation in flowering was noticed even within the country. At Anakkayam (11°N) and Mangalore (13°N) in the West Coast the peak flowering is in early January and the peak harvest is in early April (Rao, 1956). At Bapatla (17°N) on the East Coast, peak flowering time is from mid January to mid February, and the crop is harvested by the end of April (Dasarathi, 1958) (Fig. 3.1). The harvesting season is

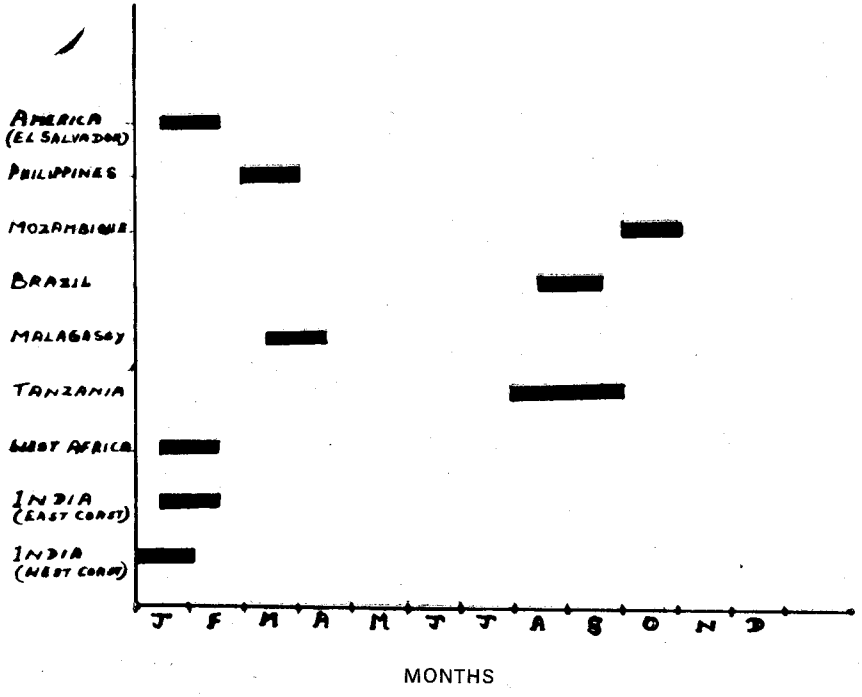


Fig. 3. 1. PEAK FLOWERING PERIODS IN CASHEW IN DIFFERENT PARTS OF THE WORLD

in summer in both above and below the equator. Nambiar (1977) suggested that the relationship between flowering and latitude probably reflects the effect of latitude on temperature. Dasarathi (1958) reported a strong influence of temperature on growth, flowering and fruiting of cashew. Cashew trees at higher altitudes, irrespective of latitude, show almost the same tendency for late flowering and fruiting (Nambiar, 1977).

Flowering appears in two or three distinct phases and those appearing in the intermediate stage are generally the most productive ones. Pavithran and Ravindranathan (1974) observed three distinct phases (i) the first male phase with 19 to 100% male flowers, (ii) the mixed phase with nil to 60% male flowers and nil to 20% hermaphrodite flowers and (iii) the second male phase with nil to 6.7% male flowers. Some other workers (Morada, 1941, Aiyadurai and Koyamu, 1957; Rao and Hassan, 1957; Damodaran *et al.*, 1965; Northwood, 1966; Kumaran *et al.*, 1976b) also have observed that the flowers produced early in a panicle are mostly male. The trees showed considerable variation

in the duration of different phases. The mean duration of flowering was recorded as 85.2 days in which the duration of first male phase was 2.4 days, mixed phase 69.4 days and second male phase 13 days. The percentage of male flowers in the first male phase was 74.7 and in the second male phase it was 1.9. The percentage of hermaphrodite flowers in the mixed phase was 22.2 and the mean fruit set was 4.6 (Anon, 1978) (Fig. 3.2).

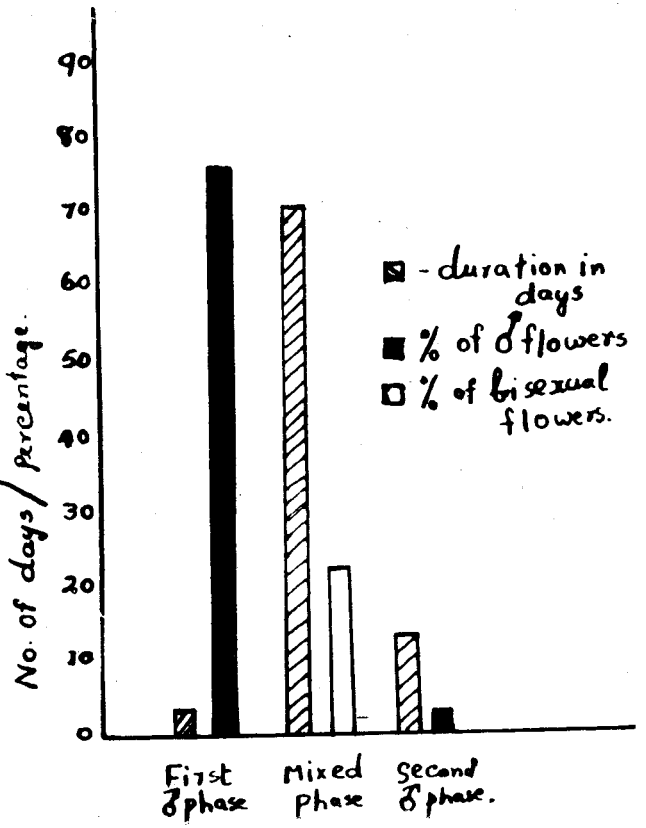


Fig. 3. 2. VARIATION IN THE FLOWERING BEHAVIOUR IN CASHEW

Structure of the flower

The flowers are small, white to light green at the time of opening, later turning to pink. Flowers are either bisexual or male and both occur intermixed in the same inflorescence. On the same tree, the perfect flowers are larger in size than the staminate (Damodaran *et al.*, 1965). The flower is typically pentamerous (Copeland, 1961 and Ascenso and Mota, 1972a). Each hermaphrodite flower stands upon an obconic pedicel and a few millimeter long. The summit of the pedicel, the receptacle, bears five separate oblong acute imbricate sepals, erect and overlapping so as to form a tube about as long as the pedicel (Copeland, 1961). Five linear acute petals, alternate with the

sepals, more than 10 mm long, spring from within the tube of sepals. At anthesis they are recurved, bringing the tips to the level of the receptacle. The outer surface of the sepals and petals are pubescent with simple hairs.

Both hermaphrodite and male flowers have 8–11 stamens of unequal size. Of these, one or two are large exerted fertile stamens of 6–8 mm length and the remaining are small sterile stamens (3–5 mm) (Copeland, 1961; Ascenso and Mota, 1972 a). The stamens are united at the base of the filament to form a tube about 2 mm long. The outer surface of the tube and the base of the filament above it are pubescent with minute glandular hairs.

The anthers are basifixed, dithecus, dehiscing through a slit between the two pollen sacs of each lobe. Compared to the large one, the small stamens contain only a few pollen grains. The pollen grains are three-grooved, with the exine between the grooves finely pitted and are binucleate at maturity,.

Ovary, style and stigma are present in both hermaphrodite and staminate flowers, although rudimentary in the latter. The size varies from one to two mm for staminate and 6 to 12 mm for hermaphrodite flowers. Ascenso and Mota (1972 b) suggested that the staminate flowers are derived from the ancestral hermaphrodite flowers by gradual reduction and loss of function of the gynoecium. The pistil is dorsiventral, ovary is superior, laterally compressed, with one end broader than the other and directed towards the large stamen. The ovary contains a single locule and a single apotropous ovule. The style is long and slender, springs from the distal margin of the ovary, tapering to a slightly expanded stigma (Fig. 3.3. a–f, 3.4, 3.5 and 3.6a, b).

Cytology

The chromosome number of *A. occidentale* was first recorded by Darlington and Janaki Ammal (1945) as $2n=42$. Khosla *et al.*, (1973) studied the cytology of Himalayan Anacardiaceae and reported $n=12$ in *A. occidentale*. Purseglove (1974) also reported a chromosome count of $2n=42$ for cashew.

Pollination, fertilization and fruit development

In India, the flowers open between 9 AM and 2 PM and the staminate flowers open earlier than the bisexual flowers (Rao and Hassan, 1957; Damodaran *et al.*, 1966). The stigma is receptive for about 24 hr before anthesis and continues to be so, for about 48 hr after anthesis. According to Northwood (1966) most of the flowers open between 6 AM and 6 PM in Tanzania, with a peak opening between 11 AM and 12.30 PM. The stigma is receptive as soon as the flowers open and anthesis takes place 1 to 5 hr later.

Pollen fertility was 94% in types studied by Damodaran *et al.*, (1966). Pollination is reported to be carried out by flies, bees and ants as well as by wind. Smith (1958) suggested that bees may be used to promote greater pollination. The occurrence of strong scented flowers and sticky pollen grains also emphasize the importance of insects over wind as pollinating agents.

Fig. 3. 3. FLORAL STRUCTURE

(a) Hermaphrodite flower
(b) L. S. of the hermaphrodite flower
(c) Hermaphrodite flower-after removing the perianth parts
(d) Staminate flower
(e) L. S. of the staminate flower
(f) Staminate flower - after removing the perianth parts

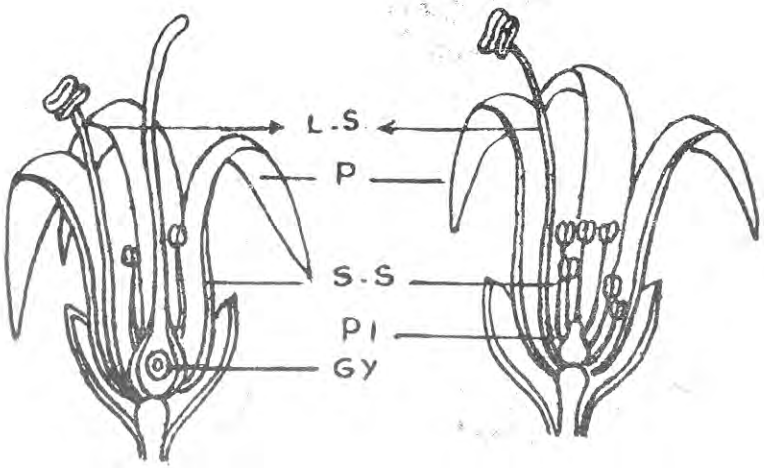


Fig. 3. 4. L. S. OF THE PERFECT FLOWER
L. S-Long stamen P. Petal. S. S. Short stamen

Fig. 3. 5. L. S. OF THE STAMINATE FLOWER
PI. Pistillode. GY. Gynoecium

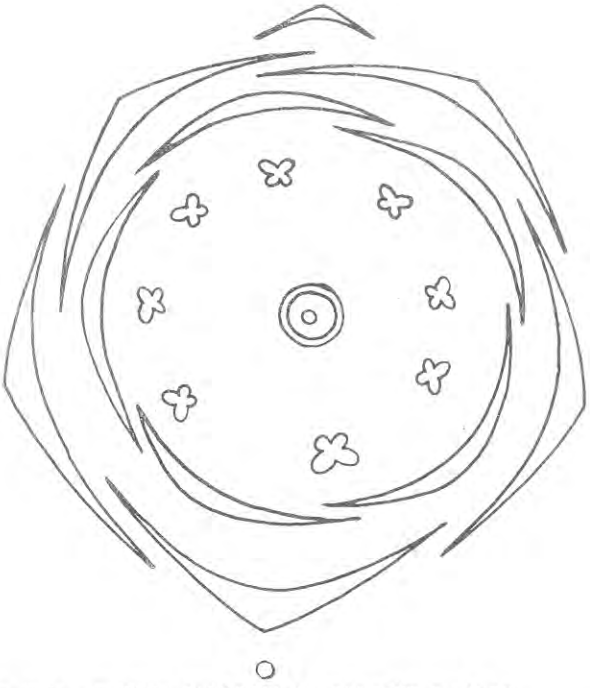


Fig. 3. 6a. FLORAL DIAGRAM OF PERFECT FLOWER

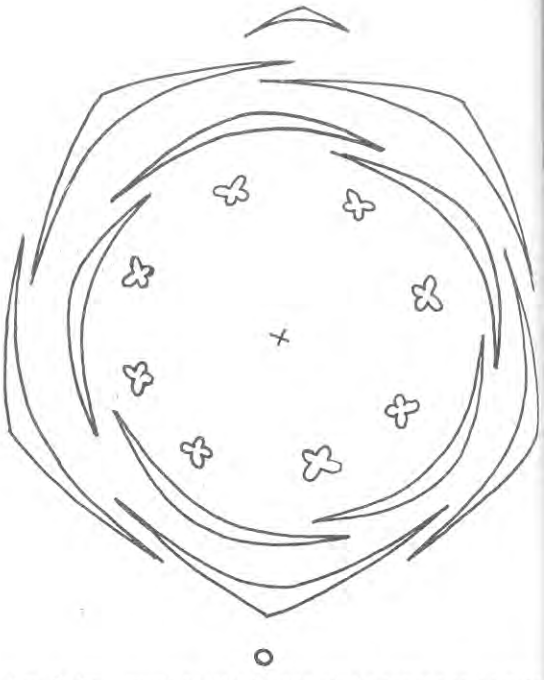


Fig. 3. 6b. FLORAL DIAGRAM OF STAMINATE FLOWE

Fruit setting

The cashew tree produces innumerable flowers of which less than 10% are perfect. Under normal conditions, nearly 85% of the flowers are fertilized of which only 4–6% reaches maturity, the remaining being shed away at various stages of development. Pillai and Pillai (1975) reported maximum shedding (more than 40%) at mustard stage, 20% at pea nut stage, and 20% at later stages. Northwood (1966) attributed fruit drop in cashew during the early stages of development to physiological reasons. Pillai and Pillai (1975) noted that insect attack also played an important role in immature fruit drop, apart from physiological reasons. Rao (1974) suggested that pollination in nature was inadequate since he obtained 55% fruit set by hand pollination, whereas Kumaran *et al.,* (1976a) obtained 61.3% fruit set by cross pollination. Moreover Northwood (1966) observed that when the inflorescences were bagged, they failed to produce nuts in the absence of hand pollination.

After fertilization, the ovary grows considerably bigger at the end, which contains the relatively large upward extension of the locule. This end curves upward in the position formerly occupied by the style with the effect that the curved mature fruit lies approximately in the axis of the flower (Copeland, 1961). At first, the ovule enlarges slowly, whereas the ovary grows faster, with the result the kernel does not fill the locule. The early growth of the ovule consists largely of the extension and curving upward of the chalazal end. Rao *et al.,* (1962) observed that the nut reached maximum size in 30 days, hardened in the ensuing 10 days and declined in size by 10% at harvest. Thompson (1969) also found that the embryo and pericarp developed to the maximum size when the nut is still green. From the fifth week onwards, when the growth of the nut ceases completely, the peduncle starts growing rapidly and outgrows the nut. This forms the apple. The fruit ripens fully in 60 days.

Apple and nut characters

The fruit of the cashew tree is grey coloured, kidney-shaped, borne on the fleshy thick hypocarp. The fruit contains a single kidney shaped seed with membranous adherent testa, semilunar cotyledons and short hooked radicle.

The fleshy peduncle, the cashew apple, is juicy and sweet when ripe. The apple varies in size, colour, juice content, and taste. Lima *et al.,* (1952) described 44 different types of apples while Aiyadurai (1966) reported the existence of yellow, red and pink coloured apples. Albuquerque *et al.,* (1960) noticed that the yellow apple tended to be heavier, softer and less astringent than red apples. Usually the apple is 10 times heavier than the nut. The apple is a rich source of vitamin C and sugar.

The cashew fruit is a kidney shaped drupaceous nut, greenish grey in colour. The nuts vary in size, shape and shelling percentage, (Rao and Hassan, 1956). A single nut is 3 to 5 cm in length and 2 to 3.5 cm in width. The weight of a single nut usually varies from 3 to 20 g. The shelling percentage varies from 15–30.

Structure of the fruit.

The fruit consists of the epicarp, mesocarp, endocarp, testa and kernel. The epicarp forms the epidermis and is coriaceous. The cells are elongated with hollows at frequent intervals. The mesocarp is the thickest of the three layers and is spongy and alveolar. In the mesocarp, which has a honey comb structure, there are ducts filled with a sticky, resinous corrosive oil, the cashewnut shell liquid (CNSL).

The endocarp is hard and is formed of a compact mass of sclerenchymatous cells. These three layers form the thick shell, i.e., the pericarp which forms 45 to 50% of the nut. The kernel with 2 cotyledons forms 20 to 22% of nut. Covering the seed is a brown membranous testa, which forms about 5% of the weight of the nut.

CHAPTER 4

CROP IMPROVEMENT

Cashew is grown over 4.0 lakh ha in India with an annual production above 1.7 lakh tonnes. However, the processing industry in the country is dependent today on imported raw nuts for nearly two-thirds of the total requirements. Kerala, with less than 30 per cent of the area, accounts for over 70 per cent of the total production with average yields above 1000 kg per ha. However, the average yields in other parts of the country are comparatively low (see chapter 2). Until recently, cashew plantations were generally raised on marginal lands and received little management. Though cashew can survive neglected conditions, economic yields can be obtained only from well managed plantations. It has been conclusively proved that average yields of 4 kg per tree can be obtained from the 5th year onwards with superior planting materials and good management from early years (Nambiar, 1976).

Cashew was introduced into India in the Goa region and on the Malabar coast during the sixteenth century and these two places served as centres of dispersal to other parts (de Costa, 1578, Van Linschosten, 1598). It is most likely that original introductions were nuts belonging to a few trees and thus had a very limited genetic base, from which all the present day cultivars in the country were evolved. This may be the probable reason for low variability in cultivated cashew in India. The same assumption may hold good for most of the cashew growing countries with probable exception of South American countries particularly Brazil, where it is supposed to have originated (Johnson, 1972). Variability observed at present with respect to plant canopy, leaves, flowering period, proportion of male and bisexual flowers, percentage of fruit set, size, shape, colour, smell, taste, and astringency of apple and size, shape and specific gravity of nuts (Morada, 1941; Rao and Hassan, 1957; Cordoba, 1967; Northwood, 1967; Morton, 1970) may be due to the segregation of inherent heterozygosity.

Since cashew is a highly cross-fertilized crop the most effective and shortest approach for its improvement will be to identify high yielding mother trees on the basis of yield records for a number of years and to perpetuate their progenies. There can be two methods of propagation, (i) through seeds after progeny testing and (ii) vegetatively. Progeny testing involves raising of progeny orchards from selected individual trees and evaluating the performance of the progeny. Such testing will be more reliable if carried out in replicated trials, preferably in multi-locations. Based on progeny performance, pre-potent mother trees could be identified for collection of seednuts. Seedlings raised from such seeds can be distributed to farmers. The other method will be clonal propagation of superior genotypes.

Crop improvement through introduction and selection

There are no reliable records of the introduction of cashew germplasm. The present collection includes mainly the seed progenies from original introductions made four centuries earlier. Attempts to gather information on morphological differences and productivity and to catalogue superior trees are only recent. Germplasm assemblage in different cashew research centres and promising types identified are presented in Table 4.1.

Success of any breeding programme depends on the selection procedure adopted. The characters under selection should be present in high frequency and should have high heritability. There have been attempts to correlate yield with ratio of bisexual flowers, short and synchronised flowering phase, flowering intensity, fruit per panicle, nut size, shelling percentage and morphological characters. Weight of nut has a positive correlation with height of seedlings and number of leaves and negative correlation with girth and internodal length (Anon, 1978).

Considerable variation in nut size and weight was observed by Northwood (1966) for a population of 128 three–year–old trees. The yield of the best trees in the population was more than twice the mean yield, indicating the scope for selection in breeding programme. He observed that trees which produced a large number of nuts had small nuts unsuitable for cashew trade. Observations conducted at Cashew Research Station, Ullal indicated that heavy yielding trees were more likely to bear medium sized nuts (120–130 nuts per kg.), and hence medium sized nuts should be preferred in selection. Medium sized nuts also had higher percentage of germination than either heavy or light nuts (Rao and Hassan, 1956; Shetty and Bhatkal, 1965). Northwood (1967) observed that the seedlings from high density groups grew better and had higher yields during the first three harvesting years, though this difference disappeared by the fourth year.

Galang and Lazo (1936) stressed the significance of growth features for an understanding of bearing tendency in cashew. They found that leaf area was associated with productivity. According to Morton (1970) trees exhibiting sprawly growth produced only a tangled mass of base and dead branches, and the maximum flowering is seen in trees with erect growing habit. This observation is in agreement with the extensive type of branching described by Dasarathi (1958).

Critical comparison of photosynthesis in cashew plants with different canopies is desirable to determine the optimum plant canopy with respect to high yield. The present practice of allowing unlimited canopy growth in the cashew tree will have to be reviewed critically. Some of the methods suggested for limiting the plant canopy to have maximum photosynthetic efficiency are (i) adopting a closer spacing (ii) pruning annually to restrict the plant canopy and (iii) pruning all the branches, which do not receive adequate sunlight (Nambiar, 1977).

Rao (1974b) found a positive correlation between yield and percentage of bisexual flowers, and he assigned the high percentage of staminate flowers as one of the reasons for poor yield in many cashew trees. He observed 3% of fruit set under open

TABLE 4.1. **Germplasm assemblage at different cashew research centres in India**

Research Station	No. of accessions			Promising plants identified		Remarks
	Exotic	Indigenous	Total	Sl. no.	Yield kg / yr.	
Bapatla	22	157	179	129	63.0	Exotic introductions include collections from Sri Lanka, South Africa, Mexico and Brazil
				56	47.0	
				1	41.0	
Vridhachalam	8	169	177	M 251	16.4	Among the 169 indigenous types, 160 are from Tamil Nadu and remaining from Karnataka, Andhra Pradesh, Kerala and Maharashtra
				M 26/2	15.9	
				A 3/4	15.0	
				M 16/3	14.8	
Vengurla	..	..	116	Vengurla 1	19.7	162 trees from 23 accessions produced more than 10 kg and 56 tree from 7 accessions produced over 15 kg nuts/ yr/tree.
Vittal	..	..	163			Plantation is about six year old only.
Mannuthy	39	151	190	NDR 2–1	19.5 *	Exotic introductions from Brazil, Tanzania, Malaysia, Nigeria and Tanganyika.
				VL 271	17.0 *	
				NLR 2–1	14.0 *	
				BLA 139–1	34.0 ±	
				BLA 273–1	21.4 ±	
				BLA 39–4	15.0 ±	

* Clonal progeny

± Seedling progeny

pollination, and 55% by hand pollination. He concluded that it was highly desirable t select types with a higher percentage of perfect flowers for increasing production i cashewnut.

A comparative yield trial of the high yielding selections has been in progress under the All India Co-ordinated Project at Mannuthy (Kerala), Bapatla (Andhra Pradesh), Vridhachalam (Tamil Nadu), Vengurla (Maharashtra), and Vittal (Karnataka) and the performance of the best five types are given in Figure 4.1. The yield was comparatively poor for all types under Bapatla conditions. At Vittal seedling progenies of Vridhachalam

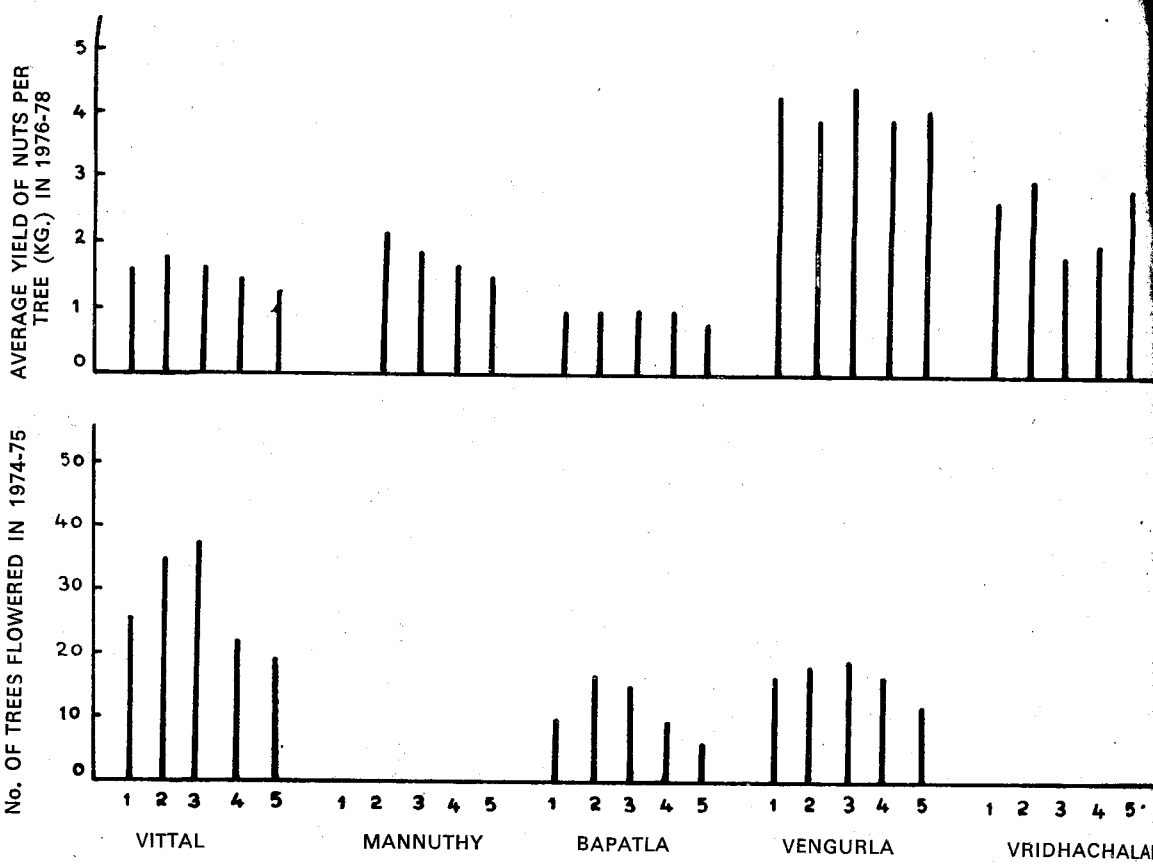


Fig. 4.1. PERFORMANCE OF SOME HIGH YIELDING CASHEW SELECTIONS IN MULTILOCATION TRIAL

(1. M 44/3; 2. M 76/1; 3. M 10/4; 4. M 6/1; 5. BLA 139/1)

selections, i. e. M 10/4 and M 44/3 gave the maximum yield. The same two selections from Vridhachalam have performed well at Vengurla also. At Anakkayam and Mannuthy among the clonal progenies of 16 high yielders, K 22–1 gave the maximum yield followed by BLA 39/4.

Hybridization

Breeding work has been in progress at many cashew research centres in India with the primary objective of increasing the yield. Selection of parents has been based on yield, size of nut, synchronised flowering phase and a high shelling percentage. Floral structure and details regarding dehiscence of anthers and receptivity of stigma are discussed elsewhere in this book (see chapter 3). The hybridization technique consists of clipping of all the staminate flowers in a panicle and emasculating preferably all the stamens or the single functional stamen from the bisexual flowers and bagging with a butter paper. Anthers from the desirable trees are collected on the following morning and pollen is dusted on the stigmatic surface of the emasculated bisexual flowers by a brush and the butter paper is replaced in position.

Limited hybridization work carried out at Anakkayam has shown that whenever one exotic parent was involved, the progeny showed marked improvement in yield than the hybrids obtained from crosses among local selections. This is exemplified in the cumulative mean yield from F_1 progenies involving indigenous types and Brazilean types (Table 4.2).

TABLE 4.2. **Performance of cashew hybrids at Anakkayam (Kerala)**

Type	*Cross combination*	*Year of planting*	*Yield of nuts (kg/tree)*		*% shelling*
			1978	*1974–78* (mean)	
H–3–19	T.30 x Brazil 18	1964	39	19	19.8
H–3–17	T.30 x Brazil 18	1963	21	16	26.2
H–3–12	T.30 x Brazil 18	1963	15	12	27.6
H–3–7	T.30 x Brazil 18	1963	18	11	27.3
H–4–7	T.30 A x Brazil 18	1963	14	11	25.2
H–1–4	T.12 A x T.27	1963	8	10	20.4

These results are obviously in agreement with well established concept of hybrid vigour, wherein vigour is manifested in crosses involving parents with greater genetic diversity. The performance of hybrids with self and open pollinated progenies was compared in a trial at Cashew Research Station, Anakkayam and the results showed that the hybrids had increased vigour with respect to girth, height, spread of canopy and mean yield (Table 4.3).

TABLE 4.3. **Growth measurements and yield data for selfed open pollinated trees in cashew**

Treatments	*Girth (cm) taken at three intervals*			*Ht. (cm) taken at three intervals*			*Spread in cm. taken at three intervals*			*Mean yield of nuts per tree in kg for*			
	1st	*2nd*	*3rd*	*1st*	*2nd*	*3rd*	*1st*	*2nd*	*3rd*	*1971–72*	*1972–73*	*1973–74*	*1974–75*
Selfed plants	40.00	58.8	59.8	345.42	456.00	505.00	345.08	428.40	486.60	0.550	0.627	0.286	1.298
Hybrids	50.83	61.9	62.2	442.83	466.60	512.20	412.08	437.80	489.90	1.263	2.391	1.072	2.450
Open pollinated	47.75	63.7	66.7	432.50	540.20	596.70	382.92	529.10	575.10	0.500	1.116	0.461	1.547

Hybridization and selection have also been in progress at various co-ordinating centres and the performance of some of the hybrids at Vengurla are given in Table 4.4.

TABLE 4.4. **Performance of F_1 cashew progenies at Vengurla (Maharashtra)**

Crosses	*No. of trees*	*Yield (kg nuts / tree)*			*Maximum yield in 1978*
		1976	*1977*	*1978*	
Mysore Kotekar 1/61 x WBDC VI	1	6.9	11.3	11.6	11.6
Ansur 1 x Vetore–56	2	9.0	10.4	13.7	17.2
WBDC V x Vetore–56	4	8.9	11.4	14.9	19.6
Midnapur Red x Vetore–56	9	11.0	11.1	16.9	23.2
Ansur Early x Mysore Kotekar 1/61	6	9.6	14.2	16.9	24.8
Mysore Kotekar 1/61 x Ansur Early	3	8.7	12.4	14.0	17.1
Mysore Kotekar 1/61 x Vetore–56	8	7.5	10.8	13.4	17.0
WBDC V x Ansur No. 1	14	7.9	8.7	14.8	21.7
WBDC V x Vetore–56	4	5.9	11.2	14.5	18.8
Midnapur Red x Ansur No. 1	8	5.7	10.4	14.5	18.8
Ansur No. 1 x WBDC V	6	7.3	10.3	13.9	18.1
Ansur No. 1 x WBDC VI	6	6.4	12.0	15.1	19.4
Ansur Early x Midnapur Red	4	8.6	12.1	13.2	15.4
Mysore Kotekar 1/61 x Ansur No. 1	2	8.2	11.8	15.3	15.3
Vetore–56 x WBDC VI	2	5.7	9.0	13.7	15.0
Vetore–56 x Mysore Kotekar 1/61	1	6.4	2.4	12.7	12.7

Hybrid evolved at Anakkayam H–3–19, involving Brazilean parent is outstanding with an average yields of 19 kg per tree/year followed by H–3–17 and H–3–12 from the same parentage.

At Vengurla out of 157 hybrids planted in 1970–72, 80 progenies gave yields ranging from 10 to 15 kg nuts per tree and five among these recorded more than 20 kg nuts per tree. The highest yield was obtained from tree No. 24 (Ansur early x Mysore Kotekar 1/61). The hybrids are also under comparative yield trials in other centres like Bapatla and Vridhachalam.

Vegetative propagation

Wide variation for nut and apple characteristics as well as yield of seedling progenies has led to the research on vegetative propagation of cashew in India and East Africa, with a view to transfer the desirable characteristics of the parent plants in their clonal progenies. Various methods of clonal propagation have been attempted with considerable success in cashew and this has helped to a certain extent to establish uniformly high yielding orchards. However, seasonal variation seems to play an important role in the success of multiplication.

Layering

Layering is one of the earliest methods attempted in India and Tanzania. It has been found successful in the humid west-coast region of India (Rao, 1958). Two methods of layering have been adopted in cashew (i) air layering, and (ii) ground layering.

i. *Air layering*

This is the most popular method followed for propagation in cashew. Shoots of pencil thickness of previous year's growth, preferably not bearing flowers, are used for layering. A ring of bark about 3 cm length from the selected shoot is removed carefully by giving two circular cuts at the top and bottom and joining these cuts with a longitudinal one (Fig. 4.2a). Cincturing is generally done slightly above the shoot and after removal of the bark ring. It is preferable to smear root promoting hormones on the ringed portion. A lump of saw dust, previously soaked in water is placed in a polythene film of 25 x 20 cm and after placing this around the cinctured portion, the film is wrapped closely (Fig. 4.2b). The ends of the film are carefully tied with a twine and left for rooting (Fig. 4.2c). The time for separation of the layer from the parent tree is determined by observing root formation through the transparent alkathene sheets. It may take about 60 to 80 days for rooting depending on the season of layering and age of the tree (Fig. 4.2d). The layers are separated from the mother tree by giving a notch at the first instance and deepening the cut after a gap of 10 days, and final separation after another 7 days. Though this method of separation has shown complete success, it is time consuming. From practical point of view, it is better to separate the layers completely by single cut after root formation is observed. The layers after separation from the mother tree are planted in suitable containers and kept under shade before transplanting to the mainfield.

Trials conducted at Fruit Research Station, Kodur (Andhra Pradesh) had shown that layering done during rainy season readily rooted within two months and has high percentage of success (Naik, 1949). Rao and Hassan (1957) observed maximum

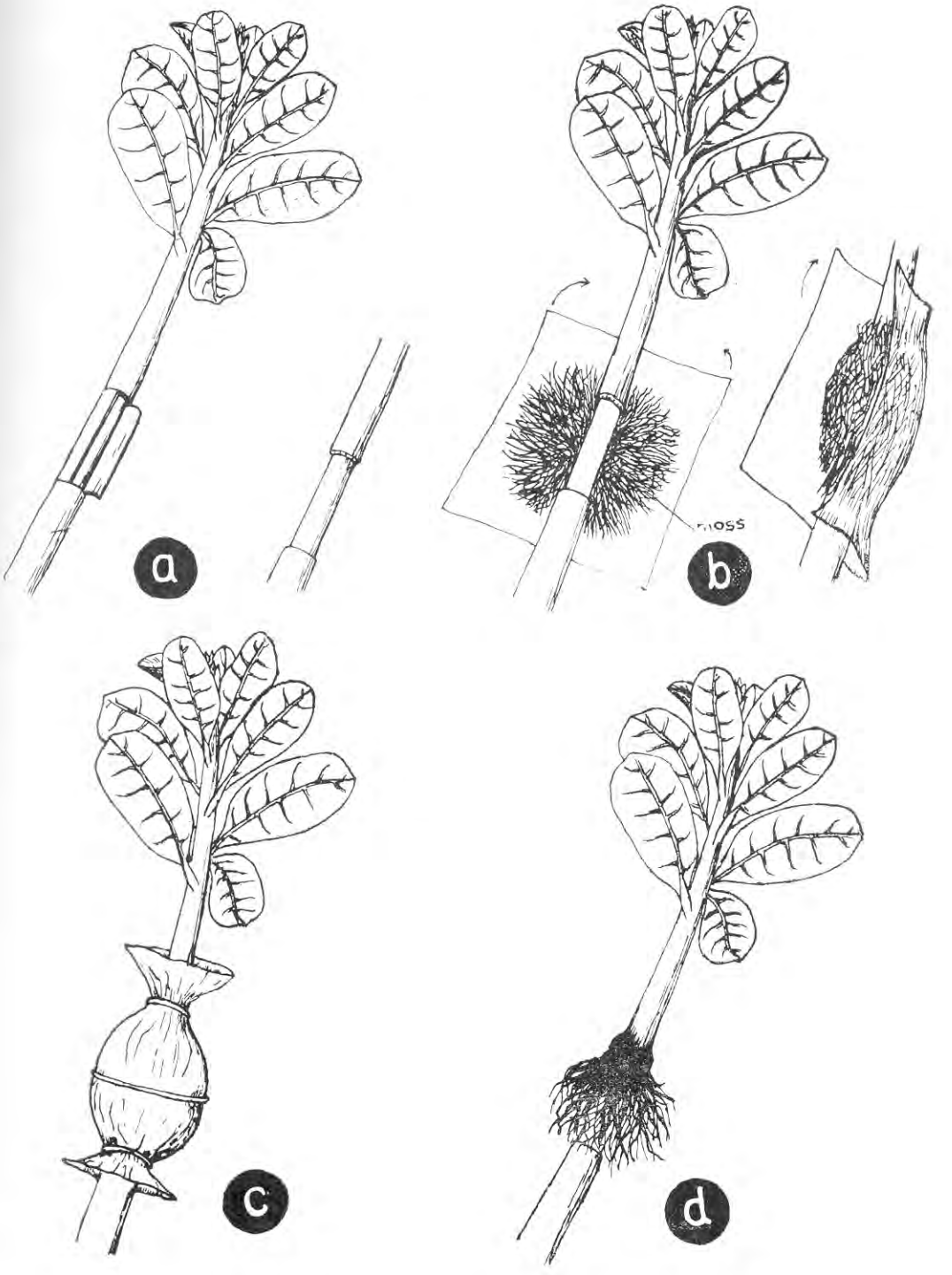


Fig. 4.2. a—d. AIR LAYERING

(a) Removal of a ring of bark
(b) Wrapping the ringed portion with a polythene film containing saw dust or moss
(c) Tying the wrapped portion with twine
(d) Rooted layer

rooting when layering was done during flowering season. Layering was also found successful to some extent even in the less humid regions of the East-Coast of India (Rao and Hassan, 1957). Maximum success of air layering at Ullal on the West-Coast of India was obtained during hot-weather period and when the trees were in full flush. Percentage of successful establishment of layers was dependent on seasonal variation in different regions in India (Rao, 1958; Aiyadurai, 1966, 1968). Significant improvement in layering and root formation was obtained by Chhonkar and Singh (1967), Acharyya and Dash (1972) and Sen and Chakravarthi (1972) on application of root promoting hormones in layers. Successful air layering in cashew was also reported by Abraham (1956), Damodaran (1970), Kurup and Viswanathan (1970); Rai (1970).

In Tanzania the best period for air layering was found to be the rainy season and horticultural vermiculite as the best rooting medium (Northwood, 1964). Northwood also found that two-year-old plants propagated from layers had a more spreading habit than the seedlings, and pruning was necessary to develop a desirable canopy. The fact that in India the best rooting was obtained during dry weather when trees are in vegetative growth, led Argles (1969, 1976) to suggest that these factors may be important in determining the success of air-layering.

ii. Ground layering

Though the method of mound layering has been tried in cinchona (Rao, 1959), mango (Mazumdar, 1963) and jack in Malaysia (Rowe-Dutton, 1976) it was not attempted till recently in cashew. Argles (1969) remarked "it is rather surprising that the method of layering known as stooling or mound layering does not appear to have been tried in cashew." A preliminary study of mound layering tried in cashew at CPCRI Regional Station, Vittal, has revealed that it is possible to obtain profuse rooting when the etiolated shoots are cinctured and treated with 10,000 ppm IBA.

The technique of ground layering consists of coppicing high yielding tree to the ground level and treating the nodes with fungicides to prevent infection. Numerous buds start sprouting from the ground level within two to three months. The shoots emerging from the stool are covered with sand and soil up to 15–20 cm (Fig. 4.3). After 30 to 40 days, the shoots which turn from green to brown are cinctured and treated with root-inducing hormones like IBA and again covered with sand. The cinctured shoots strike roots in 30 to 40 days. At this stage the sand mound around the stump is removed carefully and the plants are separated from the containers for planting. The process can be repeated with the remaining shoots or fresh supply of shoots obtained from the same stool.

Budding

Naik (1949) was the first to report from India about the successful budding in cashew. Phadnis *et al.*, (1974) found that patch budding was superior to veneer grafting on one year old root stock plants, during September-November. Palaniswamy and Hameed (1976) in Tamil Nadu obtained 71% success with patch budding in July. Large scale trials in budding has been carried out by the Department of Forests, Government

of Goa and Bhattee (1977), in his recent report claimed success varying from 5 to 58 per cent with bud grafting done on two year old seedlings in September-October. Better success was obtained when budding was attempted on $2\frac{1}{2}$ year old seedlings raised in polythene bags.

The budding technique consists of selecting a mature shoot from previous year's growth and pre-curing it by clipping the lamina of the leaves into halves and leaving them like that for about a week to activate the axillary buds. The stock for budding is prepared by removing side growth upto 20–25 cm from the base. It is necessary to select stock plant corresponding to the thickness of the bud wood. The pre-cured bud sticks are severed from the tree, just before the operation to avoid desiccation. The budding operation consists of removing a rectangular patch (about 1 x 6 cm) of bark with bud from the bud wood by giving two transverse and two vertical cuts. A corresponding patch of bark is removed from the stock plant. The patch removed from the scion is then fixed on position in the stock and wrapped with a plastic film either fully covering the patch or covering the patch in such a way that a small patch of bud is left uncovered (Ascenso and Milheiro, 1973). If the take is perfect, the bud starts sprouting within a month (Fig. 4.4).

Fig. 4.3. MOUND LAYERING

Fig. 4.4. PATCH BUDDING

Another method of budding adopted in cashew is called 'Forkert budding' (Fig. 4.5a – 4.5f). Instead of removing a portion of the stock plant, in this method the bark is loosened by giving two vertical incisions, connecting the two with a transverse cut at the bottom (Fig. 4.5a). The flap is lifted upwards and the bud is inserted into the flap (Fig. 4.5c). The bud so covered with the flap, is wrapped with plastic film (Fig. 4.5d). The wrapper is removed after three weeks and if the bud is found green the flap of the bud is cut to expose the bud for further development. A slightly modified method of forkert

budding has been developed by the Department of Forest, Goa. The budding is done in two month old cashew seedlings raised in polythene bags during the months of March–April. After budding the whole portion is completely covered with polythene tape. The cover is opened after three weeks and the flap of the bud is cut as described above. A success of 80% has been claimed in this method (Gunjate and Limaye, 1979).

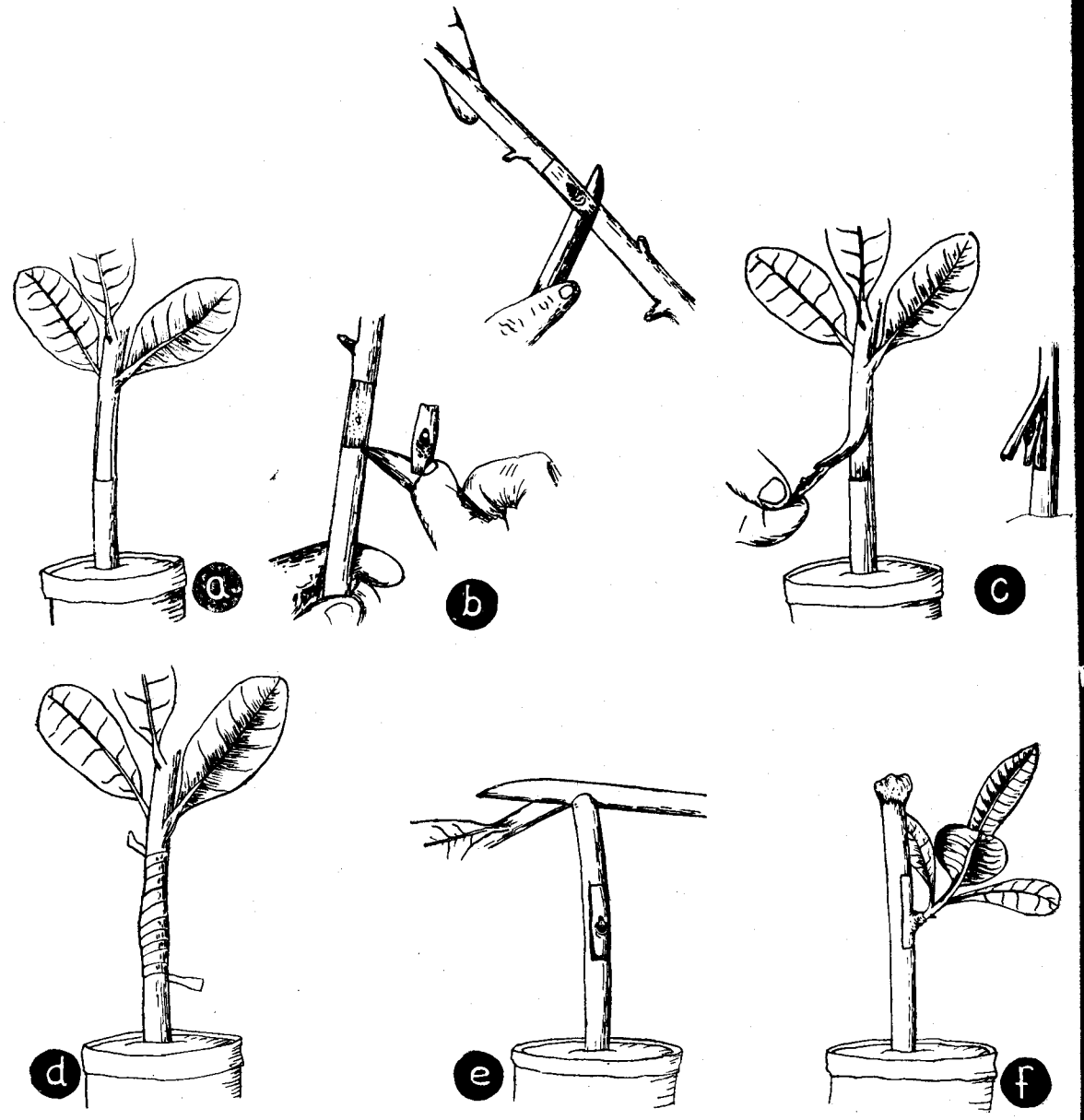


Fig. 4.5 a—f. BUDDING IN CASHEW

(a) Preparing the stock with two vertical and one transverse cut
(b) Removing the bud patch from the scion
(c) Insertion of bud patch under the flap
(d) Tying the bud
(e) Topping the stock plant after successful 'take'
(f) The successfully sprouted bud

Grafting

In cashew different grafting techniques like veneer grafting, side grafting, wedge grafting, cleft grafting, tip grafting etc., have been tried with different degrees of success. Compared to budding, grafting is labour consuming as the seedlings in the pots are to be carried to the scion and platforms are to be erected at different heights to support stocks and the budded seedlings are to be watered till the grafting becomes successful.

Veneer grafting

Vigorous growing seedlings of about six months old are ideal for veneer grafting in cashew. Pre-curing of scion stick is necessary, about 7–10 days prior to grafting (Fig.4.6a, b). The pre-cured scions are detached and kept in moistened saw-dust till the grafting operation is initiated to avoid desiccation. Each scion is prepared with a long cut (3–4 cm) along one side and a very short one at the base from opposite side to get proper fitting on the stock matrix. A smaller cut is made on the root stock about 10–15 cm above the base of the stock plant. It is necessary that the cuts on the scion as well as on the root–stock are of the same length and width (Fig.4.6c). After placing them in a correct position both are securely tied with polythene film (Fig.4.6d, e). In the case of successful take the union takes place in 3–4 weeks and the stock can be cut back in a slanting position in gradual steps (Fig.4.6f).

A maximum take of 49% in September and 36% in August has been claimed with the *in situ* veneer grafting on 15–20 month old seedlings at Cashew Research Station, Bapatla (Nagabhushanam and Venkata Rao, 1977). Phadnis *et al.*, (1974) found more percentage of success in veneer grafting done during early rainy season on 5 month old seedlings than on one year old seedlings. At Anakkayam in Kerala maximum success in veneer grafting was obtained during the south–west monsoon (Anon., 1978).

Side grafting

In mango and other perennial fruit trees, side grafting is generally done to inferior seedlings growing *in situ.* In this method cashew seedlings are raised *in situ* and when they are 2–3 year old are side grafted. Two vertical parallel cuts of about 4–6 cm length corresponding to the thickness of the scion are made on the trunk of the stock plant and detached from the trunk. Scion is prepared with a lengthy shallow cut on one side and another small slice on the opposite side to facilitate pushing the scion into the groove on the trunk portion of the stock. The cut end of the scion is carefully pushed into the groove and covered with the rind flap before wrapping with plastic film. When the terminal bud of the scion starts growing within a month, the top of the stock plant is generally loped in stages to push up the growth of the scion.

Whip grafting

In whip grafting pre–cured scion is given a slanting cut of 5–8 cm on one side and a smaller cut is given on the apical portion of the stock–seedling. The cut surfaces of both scion and stock are matched together and tightly wrapped with a polythene

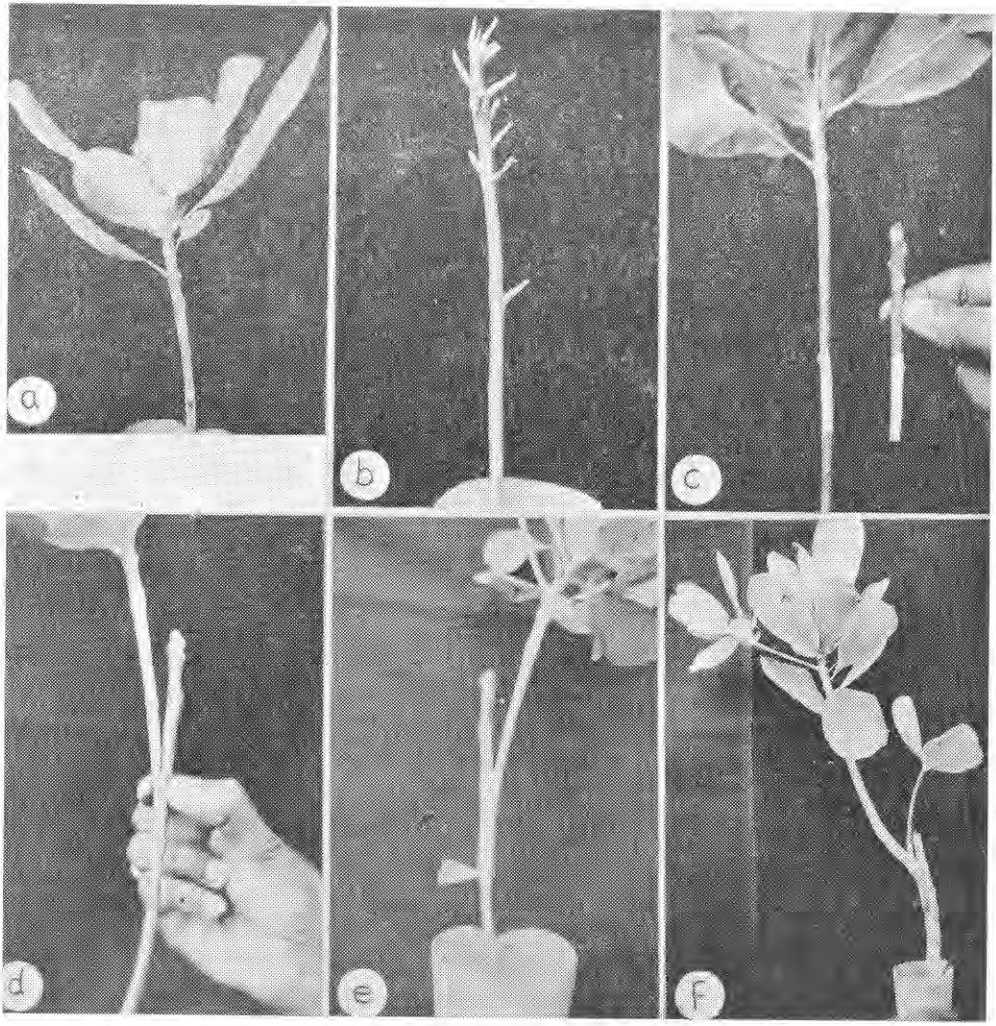


Fig. 4.6a—f. VENEER GRAFTING

(a) A cashew shoot before defoliation
(b) Defoliated shoot
(c) Stock and scion prepared for union
(d) Positioning scion on root stock
(e) Tying the graft joint with polythene film
(f) Successful graft

film. If the take is perfect the terminal bud of scion sprouts within three weeks time. Care should be taken to see that the basal portion of the stock does not give sprouts.

Cleft grafting

In cleft grafting the pre–cured scion stock of pencil thickness are selected and two slanting cuts on either side of the scion are made to form a wedge. The seedlings to be grafted should be given a clean cut from the base horizontally at the centre to facilitate insertion of wedge shaped scion. The joint is tied with polythene film as usual and allowed for healing. Bhandary *et al.,* (1974) tried this method successfully on cashew seedlings raised in polythene bags with pre-cured or fresh scion. However, they observed that after 2 months, 63% grafts prepared with thin scion (0.3 cm) with or without defoliation were successful whereas those prepared with thick scion (0.4 cm) gave 14–20% success. However, this method followed in this case should be considered as a combination of wedge and stone grafting since the stock seedlings used were of 21 days old.

Tip grafting

This is done on 5–12 months old stock of 0.6 – 1.0 m height and of 1 –1.5 cm diameter at the base with scion from the current seasons shoot taken one month after commencement of flowering. The tips of shoots are whip grafted and tied in plastic film and the terminal buds are covered in a separate sheet of plastic. This method was successfully tried for the first time in Mozambique where 59.0 – 96.0% survival after transplanting has been claimed. (Lefebre, 1971). Slight modification of this method with mini grafting is also reported from Mozambique. In this method scions of 3–5 cm thick with terminal buds which are about to open were used. The leaves on the stock were retained and the graft was tied with PVC tape until the union was complete. Almost 100% success has been achieved by this technique (Ascenso and Milheiro, 1973).

Future programme

A perusal of the history of origin and subsequent geographical distribution of cashew shows that variability in cultivated cashew has been very low. Hence, it is important to introduce germplasm from South-East Brazil. New introductions should be evaluated against local types and if found superior could be directly propagated as new varieties or may be utilised in suitable hybridization programmes.

It is also necessary to have an effective selection programme based on a biometrical base. Heritability of desirable characters like intensive type of branching short and synchronised flowering period, proportion of bisexual flowers, medium nut size, high shelling percenage etc. should be worked out and correlation with these and other characters is to be established. Possibilities of both vegetative and seed propagation of cashew are of considerable advantage in estimating both additive and non-additive components of heritability. After establishing selection criteria based on correlation and heritability, a short term approach would be to survey the existing plantations within and outside the country and identify the best genotypes. Substantial progress have been made in vegetative propagation techniques for rapid multiplication of selected elite trees and establish new plantations with superior genotypes.

An indication of high combining ability of introduced genotypes with the local type is available from the limited studies on the hybrids under the All India Co-ordinated Spices and Cashewnut Improvement Project. Large scale hybridization should be undertaken to evolve new hybrid combinations. Since cashew is clonally propagated, new combinations can be immediately fixed and there is no need for continuance of seed propagation for fresh planting as in the case of solely seed propagated crops. However, while selected hybrid combinations with favourable gene interaction can be maintained through vegetative reproduction, synthetic varieties also could be developed through seeds. Different genotypes can be tested for their combining ability and good combination can be used to develop synthetics. Parallel lines of synthetics can be maintained for vegetative propagation and simultaneously mass-pedigree selection programme can be used to improve synthetics.

CHAPTER 5

CROP MANAGEMENT

Ecological adaptation

Cashew is essentially a crop of the tropics and its distribution extending upto latitudes 27°N (South Florida) 28°S (South Africa) (Joubert and Thomas, 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 where temperature does not fall below 20°C for prolonged periods.

Climate

The main factor that seems to limit the distribution of cashew within the tropical belt is its inability to tolerate prolonged periods of extremes of cold and frost. The tree is very sensitive to cold when young but becomes fairly hardy with age and can withstand light frost for short periods.

It requires a minimum of 50 cm rainfall per annum, but can stand extremes of rainfall from 30 cm to 400 cm as obtaining on the East and West Coasts of India. The mean annual rainfall in the cashew growing regions on the East and West Coasts of India are presented in Table 5.1.

The South West (S.W.) monsoon season on the West Coast is preceded by a prolonged dry spell of five to six months. The coolest months are December–January when the average minimum temperature varies around 20°C. On the East Coast during North East (N.E.) monsoon maximum rainfall is received. Average minimum temperature varies around 17°C during January–April in this region. The maximum temperature during the summer months varies around 32–34° C on the West Coast and around 34–38° C on the East Coast (Table 5.1).

Sunlight

Cashew is a sun-loving tree and probably does not tolerate excessive shade. Sunshine on the West Coast of India averages above 9 hr/day from December to May with reduced sunshine during the S.W. and N.E. monsoons from June to November. On the East Coast the reduction in sunshine hours/day during the monsoon season is less marked than that on the West Coast.

The climatic factors influence cashew as follows:

i. Dry spell during flowering and fruit setting ensures better harvest.

ii. Cloudy weather during flowering enhances scorching of flowers due to tea mosquito infestation.

iii. Heavy rain during flowering and fruit set damages production.

iv. High temperatures (39°—42°C) during the marble stage of fruit development cause fruit drop.

v. Cashew performs better when the period of drought is shorter.

TABLE 5.1. **Monthly rainfall and temperature in the cashew tracts of India**

Month	Kasaragod (W. Coast)*				Vridhachalam (E. Coast)**			
	Rain fall		Temp. °C		Rain fall		Temp. °C	
	Qty. (mm)	No. of rainy days	Maximum	Minimum	Qty. (mm)	No. of rainy days	Maximum	Minimum
January	0.8	0.1	32.6	19.7	29.2	0.6	30.7	17.3
February	0.0	0.0	33.6	23.0	8.0	0.6	31.6	17.5
March	3.1	1.0	33.6	24.0	10.7	0.6	33.9	17.2
April	43.6	2.1	33.8	24.9	22.1	1.3	37.1	17.0
May	281.9	9.3	32.3	24.7	54.6	3.8	37.5	16.7
June	965.9	20.2	30.0	23.6	43.0	4.7	37.5	23.3
July	1098.0	38.9	29.6	23.4	94.7	6.5	35.6	21.9
August	644.0	21.8	29.4	23.6	144.8	10.0	34.6	22.9
September	319.8	11.9	30.3	24.0	122.6	8.0	34.4	21.9
October	193.6	10.1	30.0	23.8	228.3	11.3	32.4	21.3
November	76.5	4.3	31.6	26.8	189.8	9.1	30.2	21.6
December	19.3	1.6	32.0	21.8	134.4	6.5	28.9	19.9

* Mean of 20 years data
** Mean of 10 years data

Soils

Cashew is cultivated on a wide variety of soils and lands in India. Cashew literature in India is replete with the statement " Cashew is a crop of the marginal lands", the assumption being that cashew was not a cultivated crop in the country. It is important that the term 'soils' is not used to describe different classes of lands when the adaptability of a crop is discussed. Until recently there was practically no research effort in cashew to evolve new varieties with high yield potential or to assess the yield potential of existing cultivars under different soil fertility levels. However, what is generally true of other crops should also be true of cashew. It will perform better on Class I and II lands than on Class IV and V lands if only we could utilise these lands for cashew because it comes up well at all altitudes upto 700 m on all soils. It is known only as a rainfed and neglected crop at present although seedlings are often watered during the initial years in Andhra Pradesh and Tamil Nadu and fertilisers are applied regularly in new plantations. It is suitable for fairly steep slopes with shallow top soils because

its large canopy and surface root system protect the soil very well from run off and erosion during the heavy monsoon rains. Cashew is not a very common sight on water-logged or saline soils. It was observed that cashew plants succumbed to floods where water did not recede for 45 days after the 1977 floods in Andhra Pradesh, following a cyclone (Fig. 5.1).

Fig. 5.1. CASHEW TREES SUCCUMBED TO FLOODS IN ANDHRA PRADESH

In India cashew is grown mainly on laterite, red and coastal sands in the states of Kerala, Maharashtra, Goa, Karnataka, Tamil Nadu, Andhra Pradesh, Orissa and West Bengal. To a limited extent it is also grown on black soils in Tamil Nadu and Andhra Pradesh. The fertility status of these soils varies widely. The most fertile among cashew soils is the forest soils on the western slopes of the Western Ghats in Kerala. They are often virgin soils rich in organic matter on which cashew was planted with minimum tillage and little land clearing. More recently Agriculture/Horticulture/Forest Departments of different states have been planting cashew in forest areas. The coastal sands on which cashew is often grown is very poor in fertility and yields are low unless the trees are fertilised regularly. The laterite soils vary considerably in depth, texture and other physical and chemical properties. It is difficult to classify soils/lands according to their suitability for cashew but Mahopatra and Bhujan (1974) have suggested a 'rating chart' for land selection for cashew in Orissa (Table 5.2). With more refinement and detailed soil survey data such criteria may be evolved for other states also.

TABLE 5.2. **Guidelines for selection of land for cashew***

	Very good	*Good*	*Fair*	*Poor*	*Unsuitable*
	Class I	*Class II*	*Class III*	*Class IV*	*Class V*
1. SOIL CHARACTERISTICS					
1.1. Depth of soil	>1.5 m	90 cm–1 m	45 cm–90 cm	23 cm–45 cm	<23 cm
1.2. Texture	Loam Sandy loam	Loamy sand Silty loam Coastal sand	Clay loam Silty clay loam Sandy clay loam Loamy skeletal	Gravelly clay loam Gravelly silty loam Gravelly sandy loam	Gravelly clay Sandy clay Silty clay Clay
1.3. Reaction	Very slightly acidic to neutral (pH 6.3 to 7.3	Slightly acidic (pH 6 to 6.3)	Medium acidic (pH 5.6 to 5.9)	Strongly acidic (pH 5.1 to 5.5) or mildly alkaline (pH 7.4 to 7.8)	Very strongly acidic (pH less than 5) or alkaline (pH more than 7.8)
2. LAND FEATURES					
2.1. Slope (%)	<3	3–5	5–15	15–25	>25
2.2. Water table (m)	2–5	1.5–2 (coastal belt)	8–10	10–13	>13
2.3. Erosion condition	None to slight (e_0)	Slight (e_1) (sheet erosion)	Moderate (e_2) (Rill and sheet erosion)	Severe (e_3) (Gully erosion)	Very severe (e_4) (Gully and ravine erosion)
2.4. Drainage	Well drained	Well drained to some what exce	Moderately well	Excessively	

2.5. Physiography	Coastal plains	Alluvial plain	Plateaus	Denuded hill slopes with shallow soils	Swamps
	Delta reaches Shield plains	Natural levees Upland plains	Hills domes, mounds	Ridges Steeply undulating terrain with severe erosion	Valley, bottoms Escarpments
	Inland lateritic region adjoining coastal plain	Coastal ridges			Steeply sloping mountains Creek plain
3. CLIMATE & ENVIRONMENTAL FACTORS					
3.1. Altitude (m)	<20	20–120	120–450	450–750	<750
3.2. Rainfall (cm/year)	150–250	130–150	110–130	90–110	<250
3.3. Proximity to sea (miles)	<50	50–100	100–150	150–200	<200
3.4. *Temperature* (°F)					
3.4.1. Maximum in summer	90–100	100–103	103–106	106–110	<110
3.4.2. Minimum in winter	60	57–60	53–56	48–52	<48
3.5. Humidity (%)	70–80	65–70	60–65	50–60	<50 or <80
3.6. Occurrence of frost	None (once in 20 years)	None (once in 15 years)	Very rare (once in 10 years)	Occasional (once in 5 years)	Very often to frequent (every year)

* (*Source*: Mahopatra and Bhujan, 1974

Selection of site

Selection of land for large scale plantations of cashew poses an entirely different set of problems in India today than in other countries where new areas are being brought under the crop. Availability of land seems to be the only problem now because of the competition from other crops. While selecting the land for cashew, soils with water-logging and excessive salinity/alkalinity should be avoided. Otherwise, soil depth, slope, stoniness, soil fertility and availability of water seems to impose very little limitation, because cashew is a hardy plant. However, it should be noted that these factors would definitely affect the regular spacing of trees, often limiting the number of plants per ha in large plantations and ultimately the yield. With better plant types and successful vegetative propagation methods and better utilization of cashew apple and byproducts, cashew orchards could well be the norm of the future.

Planting material

There are no large scale plantations of released high yielding varieties or cultivars of cashew in the country today, because cashew research started only recently. The most important consideration today in selecting the planting material is to ensure that only progenies of high yielding mother tree are perpetuated.

Cashew orchards can be raised from seedlings or clonal material. Though vegetative propagation provides the most reliable progeny in a cross-pollinated crop like cashew. The available technology and research set up are not adequate to meet the projected demand for planting material in the immediate future. A few high yielding selections have been identified at different cashew research stations but planting materials from these trees are not yet available to the farmers in large numbers.

Where seeds and seedlings from research stations or State Departments of Agriculture are not available, the farmers must raise their own nurseries. The preparation of layers and grafts is discussed elsewhere in this book (see chapter 4). It is desirable that mother trees are identified on the basis of yield records and progeny testing. Where yield records are not available, certain characters believed to be characteristic of high yielding trees may be used as guidelines. High yielding trees are reported to have a compact canopy with an intensive branching pattern characterised by a high percentage of flower bearing laterals, a larger proportion of bisexual flowers and a nut set of more than five nuts per panicle (Nambiar, 1976).

Selection of seednuts

The nuts selected for raising seedlings should be of good shape, medium size and high specific gravity (Turner, 1956; Auckland, 1961; Northwood, 1967). It is a common practice to select only those seeds which do not float in water. According to Agnoloni and Giuliani (1977) (i) shape of the nut is a genetic trait, (ii) high yields are obtained from plants grown from nuts of average weight (112–125 nuts/kg), (iii) germination is related to the specific gravity of the nut and (iv) yield of kernels is high in the case of nuts with high specific gravity.

Seed treatment and sowing

Seednuts collected during March–April can be sown in June with the onset of monsoon directly in the field or in polythene bags for transplanting when the seedlings are six to eight weeks old. The germination percentage decreases if the nuts are stored beyond four months (Rao *et. al.,* 1957). However, the viability of nut did not alter much for two years after picking when the seeds were kept in dry condition (Rocchethi and Panerai, 1970). The seednuts should be dried for two to three days in the sun after harvest. Seedlings obtained by sowing fresh nuts are reported to be poor in vigour. Seeds are generally sown in the field with the onset of the South West monsoon. Planting in pits (50cm x 50cm x 50 cm) is recommended (by the Central Plantation Crops Research Institute) for the West Coast. But the planting method varies considerably in different tracts. Three or four seedlings may be sown in each pit. Rao *et al.,* (1957) reported that the seeds are best sown 2.5cm deep in a slanting position. Though the percentage of germination was higher when the seeds were sown with stalk end upwards, the cotyledons were exposed as soon as the seeds sprouted (Ascenso and Milheiro, 1972; Ibikunel and Komalafe, 1973). The seeds take about three weeks for germination.

Spacing

A spacing of 7m x 7m to 8m x 8m is recommended (by the Central Plantation Crops Research Institute). However, spacings from 4m x 4m upto 10m x 10m are adopted in different tracts. In many countries a close spacing of 4m x 4m to 6m x 6m is adopted at planting but by the tenth year the population is thinned to a spacing of 8m x 8m to 12m x 12m. This enables higher returns during the first few years after the trees start yielding when the canopy spread of each tree is limited. As the tree grows in volume the final thinning is done. In India such close planting at 3m x 3m and later thinning to 10m x 10 m are practiced in Trichy district of Tamil Nadu (Shanmugavelu, and Rao, 1977).

Care and management of cashew orchards

Till recently cashew plantations received very little care and management and large-scale plantings were rare. When an orchard is raised on a large area, however regular maintenance operations and periodic land clearing is necessary to keep the orchard free of weeds and wild growth especially on the hill slopes of West-Coast where forest growth has been cleared for planting cashew. Weeding is necessary to conserve available soil moisture for the cashew seedlings during dry months. Gap filling will be necessary during the initial years. Repairing terraces and clearing of planting pits also require labour. Unlike other fruit trees like mango, cashew is seldom pruned but removal of dry and diseased branches is often necessary. Thinning is done where an initial closer planting is adopted as the canopy grows in volume.

In sandy soil on the Bast Coast the seedlings are watered during the summer months after the South West monsoon. The frequency and quantity of irrigation vary. Degree of response of cashew trees to irrigation during the summer months when the tree flowers and bears fruits is yet to be worked out. However, with better classes of land being utilised for the crop and higher returns in the future, irrigation could be profitable.

After the trees start bearing, weeding, fertiliser application, sprays against insects and diseases, and harvesting are done regularly in maintaining a cashew orchard (Table 5.3). Crop protection measures are discussed in detail chapter 6 and 7.

TABLE 5.3. **Calendar of operations for cashew plantations in India**

December–January	On the West Coast flowering starts in December and continues throughout January. The cashew will begin to flower on the East Coast in January. The most important operation during flowering is spraying against tea mosquito with endosulfan, or quinalphos, where it is suspected to cause severe damage. The insecticide also controls thrips infestation. In large scale plantations in forest areas, clearing of weed growth may be important.
February–April	Harvesting season begins on the West Coast as well as the East Coast in February. Harvesting and collection of fallen nuts are done periodically. Harvesting of cashew apple is important only in Goa where it is used for making fenni. Seednuts should be collected separately from previously identified high yielding mother trees. Air layers are prepared during February–March for planting in June–July.
May	Half the annual dose of fertilisers are applied in the basins of individual trees before the onset of South West monsoon on the West Coast as well as the East Coast. The Central Plantation Crops Research Institute now recommends an annual application of 250gN, and 125g each of P_2O_5 and K_2O per tree. For raising new plantations land preparation should begin as soon as the pre-monsoon showers are received. Clearing of weed growth, digging of pits and terracing or bunding on slopy lands are operations to be completed before heavy rains start. Sowing of inter/cover crops can be done after pre-monsoon showers are received. Seed nuts are sown in alkathene bags after soaking in water for 2–3 days. These will germinate in 15–20 days.
June–July	Sowing of seeds in the fields as well as planting of seedlings and clonal progenies are done in June-July depending on the onset of South-West monsoon. Where rains are heavy and continuous, planting is done after the monsoon peak is over. Die-back affected trees are to be sprayed with Bordeaux mixture (1%) after lopping off the affected branches below the point of infection. The cut surface should be treated with Bordeaux paste. In nurseries, drainage must be ensured to prevent damping-off in seedlings. Nursery beds must be drenched with Bordeaux mixture (1%) if disease symptoms are noticed.
August–September	The second dose of fertilisers are applied after the monsoon rains subside. Cattle manure or green manure is also applied after the rains.
October–November	New flushes are produced during October and early flowering trees start flowering. It is necessary to keep a watch on the appearance of insect pests and give insecticide sprays against tea mosquito. Spraying with endosulfan to control tea mosquito will also control leaf miner, leaf and blossom webber and other pests.

Manuring

Cashew has been seldom manured regularly in India. This situation was probably justified because cashew was not cultivated with intensive management until recently. Reasons for poor productivity were rarely the concern of cashew growers, especially when the genetic potential of the self-sown crop was unknown.

With high yielding selections and hybrids being identified, and vegetative methods of propagation becoming more successful and popular, this situation is slowly changing. As the genetic potential is assured and as there is a growing demand for raw nuts within the country, a higher productivity is required for new cashew orchards. Mohapatra *et al.*, (1973) studying the nutrient removal in a 30-year-old cashew tree found that annual utilisation was 2.80 kg N, 0.75 kg P_2O_5 and 1.26 kg K_2O. Recent research findings do indicate that cashew requires regular fertiliser application to ensure (i) early and higher yields in new plantations, and (ii) regular high yields from mature trees (Nambiar, 1976). The present recommendations of the Central Plantation Crops Research Institute are 250 g N, 125g P_2O_5 and 125 g K_2O per tree annually to be applied in two split doses before and after the South West monsoon. The fertilisers may be applied in small trenches or basins around the trees.

Intercropping

Intercropping received little attention when there was no systematic planting of cashew on a large scale. With recent establishment of large cashew plantations by forest departments and cultivation of cashew in new areas in Andhra Pradesh and Orissa intercropping is becoming common. The main aim of intercropping is to obtain some return from the plantations during the initial years until cashew comes to flowering and starts bearing. After the cashew canopy covers the area, it leaves no scope for intercropping because of the dense nature and complete shading of the interspace. Further the heavy leaf fall in cashew is not conducive for any field crops.

In Andhra Pradesh legumes like horse gram, cowpea, or groundnut are raised in the interspace. Casuarina is another crop planted along with cashew in Andhra Pradesh and Orissa. Casuarina is planted at a spacing of 1m x 1m or 1.5m x 1.5m. In Goa, eucalyptus and teak are successfully grown during the initial years. On the west coast intercropping new plantations is often not practical on hill slopes because of terracing and the need for soil conservation. In West Godavari district in Andhra Pradesh and Orissa it is reported that cashew, casuarina and coconut constitute a popular crop combination.

Harvest

Harvesting and collection of nuts are done over a period of 10–12 weeks. Where apple is not collected, the fruit may be allowed to fall to the ground and nuts collected periodically during the first 4–6 weeks. Later most of the nuts can be collected in one or two major harvests. Towards the end of the season, nuts can again be collected from the ground. Where it is important to keep yield records, nuts collected from individual trees may be kept separately and weighed periodically. Also seed nuts from selected mother trees may be collected separately. The nuts are sun dried for two or three days before storing.

TABLE 5.4. **Cost of establishing and maintaining cashew plantation per hectare**

Year after planting	Land clearing, terracing & weeding		Digging pits & planting		Cost of seedlings		Mulching & watering in dry months		Fertiliser application including cost of	Plant protection including cost of	Harvest	Total
	Labour (mandays)	Cost (Rs)	Labour (mandays)	Cost (Rs)	No.	Cost (Rs)	Labour (women days)	Cost	fertilisers (Rs)*	chemicals (Rs)**	(Rs.)	(Rs.)
First	20	160	15	120	200	50	30	180	75	58	..	643
Second	15	120	..	..	40	10	..	..	150	115	..	395
Third	15	120	..	..	20	5	..	..	225	172	24	546
Fourth	15	120	..	..	..	..	..	..	300	230	80	730
Fifth	10	80	..	..	..	..	..	..	300	230	240	850
Sixth	10	80	..	..	..	..	..	..	300	230	320	930

* Vide Table 5.4a.

** Vide Table 5.4b.

Where apple is made use of in fenni making, great care is exercised in collecting the apples at the right stage.

Cost of cultivation and profits

Bavappa (1976) worked out the cost for maintaining one hectare cashew orchard from the sixth year onwards to be Rs. 1100/– and the total cost for the first six years for establishing the orchard to be Rs. 4896/–. The data presented in Table 5.4 shows that the cost of maintaining a cashew orchard will be around Rs. 950/– from the 6th year onwards at present cost of fertilisers. However, these costs do not include the cost of farm machinery and sprayers. Thus, if we consider the annual recurring cost to be Rs.930/- and the cost of raw nuts to vary around rupees four to six per kg, the 'break-even' yield would be less than 160–240 kg of nuts/ha or 1.5 kg/tree after the trees have started bearing regularly. The average yields in Kerala have been reported to be above 5 kg/ha for several years now. Most of these trees are unfertilised and of unknown genetic stock. With selected planting materials and regular fertiliser, application average yield should be above 10kg/tree of which 1.5 kg nuts/tree could meet the maintenance cost of the orchard and the profit would be the cost of 8.5 kg nuts/tree or nearly 1.5 tonness raw nuts/ha fetching Rs. 6000–9000/ha.

TABLE 5.4a. **Cost of fertilisers and fertiliser application for cashew orchard**

Nutrient	*Dose (g per tree)*	*Cost* Rs. / kg nutrient*	*Cost Rs / ha*
N	250	3.37	148.28
P_2O_5	125	3.34	73.48
K_2O	125	1.34	29.48
	Total		251.24
	Cost of application (20% of the cost of fertilisers)		50.25
	Total		301.49 or 300.00

TABLE 5.4b. **Cost of insecticide sprays for the contol of tea mosquito in cashew orchards**

	Quantity/ha	*Cost/ha (Rs.)*
Endosulfan 35 EC	750 ml	45.00
Petrol for minimicron sprayer	3 ml	10.80
2 T oil	120 ml	1.45
Labour 1½ mandays		12.00
Total.		69.25
Plus 10% incidental expenses		6.92
Cost of 3 sprays		228.51 or 230.00

As the management becomes more intensive other inputs like irrigation and higher rates of fertilisers will have to be taken into account but yields can also be expected to be higher. Further, better utilisation of cashew apple and alternate use of cashewnut shell liquid and byproducts should ensure higher returns to cashew cultivators, enhancing their profits.

CHAPTER 6

PESTS

Cashew, *Anacardium occidentale* L. is known to be infested in India by more than sixty species of insects during different stages of its growth and development. The important records of insect pests affecting cashew were those of Ayyar (1932, 1940 1941 and 1942). The vast literature on cashew pests has been reviewed by Abraham (1958), Beccari and Gerini (1968), Pillai *et al.,* (1976) and Ohler (1977). The pests so far recorded on cashew in the field and processed kernels in storage are given in Appendix 6.1.

When the extent of damage done by the pests is taken into consideration, stem and root borers (*Plocaederus ferrugineus*) tea mosquito *(Helopeltis antonii),* leaf miner *(Acrocercops syngramma)* and leaf and blossom webber *(Lamida moncusalis)* are considered to be the major pests of cashew in India. From Tanzania, Northwood and Kayumbo (1970) reported that the important pests included sucking bugs *(Helopeltis schoutedeni* and *H. anacardii),* the theraptus bug *(Pseudotheraptus wayi),* the thrips *(Selenothrips rubrocinctus),* the bark borer *(Mecocorynus loripes),* and the defoliating caterpillar *(Nudaurelia bellina).* Brief descriptions of the pests, life histories, their nature and extent of damage, and control measures are discussed here.

Stem and root borers

Plocaederus ferrugineus L. (Coleoptera: Cerambycidae) the stem borer of cashew is capable of killing the tree outright. The symptoms of infestation include presence of small holes in the collar region, gummosis, extrusion of frass through holes, yellowing and shedding of leaves, drying of twigs and final death of the tree (Pillai, 1975; Pillai *et al.,* 1976).

The adult is a medium sized reddish brown longicorn beetle, the head and thorax of which are dark brown or almost black. It lays eggs in the crevices of loose bark in the trunk or exposed portions of roots of cashew trees. The grubs that hatch out bore into the fresh tissues of the bark and feed on the subepidermal and sapwood tissues and make tunnels in irregular directions. As a result of injury to the cells, a resinous materia oozes out, which on exposure to air gets hardened. The tunnels made by the grubs in the sapwood are broad and irregular, deepest in the middle and shallow at the sides, and fully packed with frass and fibrous tissues. When the vascular tissues are damaged, the ascent of plant sap is arrested and the leaves become yellow and are shed. During later stages, the twigs dry up and finally the tree dies. The fully grown grub descends to the root zone through tunnels in the sap wood and bores through the heart wood forms a chamber tightly packed with fibrous tissues and frass providing protection for the calcareous cocoon. Biology of the pest has been studied (Pillai *et al.,* 1976). Incubation period lasted for 4–6 days, grub phase 6–7 months and pupal period 20 days (when cocoon was not formed) and 60 days (inside cocoons) in laboratory cages.

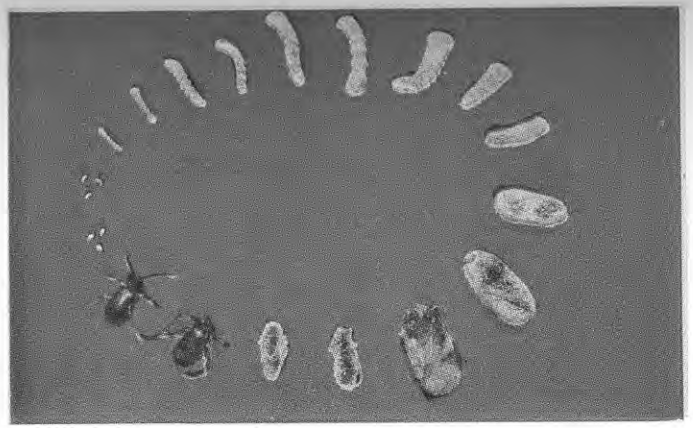
Two other species of longicorn beetles, *P. obesus* Gahan and *Batocera rufomaculata* De G. were also observed infesting cashew trees. *P. obesus* is a chestnut brown beetle with black pubescence. The adult is 40 mm long and the fully grown grub measures 75 mm. The excavations made by the grubs are wider than those of *P. ferrugineus. B. rufomaculata* is dark brown with fine greyish vestiture, pronotum with two kidney shaped orange yellow spots, white scutellum, and elytra with numerous black tubercles and yellowish spots of varying number and shape. The fully grown grub is 100 mm long. The larval excavations in early stages are extensive, irregular and deep, and packed with coarse fibres and scrapes of wood and bark. The pupae are bigger than those of *P. ferrugineus* and *P. obesus.*

Besides the longicorn beetles listed above, the grubs of the bark and sapwood borers like *Xylothrips flavipes* Ill. (Bostrychidae). *Lampetis fastuosa* F. and *Belionota prasina* Thumb. (Buprestidae), *Xystrocera globosa* Ol. (Cerambycidae) and *Coptops aedificator* F. (Lamiinae) also are seen associated with stem borer infested trees. Infestation by these insects will aggravate the condition of stem and root borer-infested trees.

Aspergillus sp. isolated from dead grubs was not found to be pathogenic (Basu Choudhuri, 1969). Basu Choudhuri (1973) reported the green muscardine fungus *Metarhizium anisopliae* Metch. (Sorokin) from *P. ferrugineus* grubs and gave the details of its host-range, symptomatology, epidemiology and pathogenicity. However, the tests carried out at CPCRI, Kasaragod with *M. anisopliae,* isolate from *Oryctes rhinoceros* grubs, showed that this was not very effective, particularly when the inoculum was applied by mixing with cashew bark, the feeding material of grubs. Similar trials with the entomogenous bacteria, *Bacillus thuringiensis* Berl. and *B. popilliae* Dutky also did not give encouraging results. However the nematode-*cum*-bacterium culture, DD–136 *(Neoaplectana carpocapsae* and *Achromobacter nematophilus*), at an inoculum dose of 100 nemas / gram body weight of host grubs, effected 50–60% mortality of grubs within 24 days, when the inoculum was mixed with the feed, the cashew bark, in laboratory. This is yet to be tried under field conditions (Pillai *et al.,* 1976).

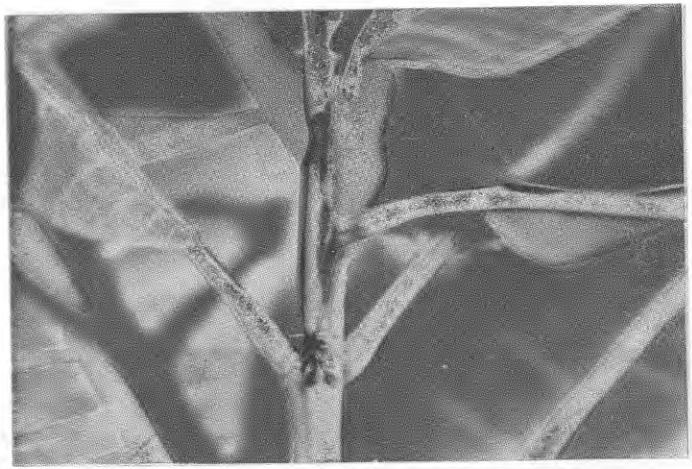
Field trials on the curative chemical control of stem and root borers revealed that success of the curative treatment depended much on the stage and intensity of infestation. Eventhough most of the insecticides tried were effective in controlling the grubs, the trees in the middle and advanced stages of infestation could not be saved. If the infestation was detected in the early stage itself, even swabbing with BHC 0.1% after removal of the affected tissues with immature stages of the pest, was quite effective. The dead trees and those which are beyond recovery should be removed from the plantation, lest they serve as reservoir for the multiplication of these pests, and the associated bark and sap wood borers. Some sort of an integrated approach including the phytosanitary measures is quite necessary for tackling stem and root borer infestation in cashew.

The bark borer *Indarbela tetraonis* Mo. (Lepidoptera: Arbelidae) is another pest present in almost all plantations irrespective of age of the trees (Pillai *et al.,* 1976) The adult moth lays eggs on the branches and the trunk. The caterpillars make small holes and tunnel through the superficial tissues of the bark on which they feed. They are seen inside the galleries made of silken threads reinforced with scrapes of tissues

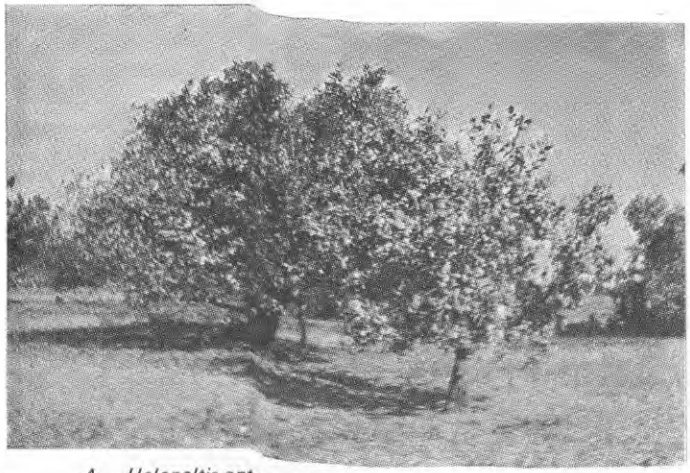


1. Stem and root borer *(Plocaederus ferrugineus* L.) —Different stages of development

2. Stem borer infested cashew tree



3. *Helopeltis antonii Sign.* infested tender shoot



4. *Helopeltis antonii* Sign. infested cashew tree

and frass. They cause damage sometimes to the cambial tissues of small branches resulting in their drying. When the trunk and older branches are affected the tree presents a dirty appearance because of the presence of galleries and frass on the branches. Mechanical removal of the larval galleries and swabbing with BHC 0.1% will control the pest.

Analeptes trifasciata Fab.(Coleoptera: Cerambycidae) is widely distributed in Africa but particularly more serious in the western coastal belts. The recorded hosts of this longicorn beetle, besides cashew, include Sterculiaceae, Rubiaceae and Moraceae in Ivory Coast; Bombacaceae, Anonaceae and Verbenaceae in Ghana; *Adansonia digitata* L. and *Ceiba pentandra* Gaertn. in Nigeria and *Eucalyptus* sp. in Kenya and Uganda. The adult beetle lays eggs singly in incisions at the bases of branches immediately above the characteristic rings made by them. The grubs complete their life cycle in tunnels hollowed out inside the dead wood of the ringed branches and fallen ones. The infestation can be serious in young plantations.

Paranaleptes reticulata Thomas (Coleoptera: Cerambycidae) also causes more or less the same type of damage as that of *Analeptes,* though generally the branches attacked are much smaller. This insect too has numerous host plants such as *C. pentandra, Hibiscus* sp., *Plumeria acuminata, Bougainvillea* sp., etc.

Mecocorynus loripes Ches. (Coleoptera: Curculionidae) is the most serious pest in the cashew growing tracts of East Africa. Its incidence is considered to be more in Kenya and Mozambique. The adult is a dark grey weevil which lays eggs in the crevices of the bark. The grub period lasts for 60–75 days. The pupation takes place in burrows hollowed out in the xylem. The insect causes damage to the roots, trunk and branches. Intense attack quite often leads to the death of the tree.

The other Coleopteran borers on cashew include *Apate terebrans* Pall. (Bostrychidae), *Ceratosomus reidii* Kirby and *Marshallus* sp. (Curculionidae) reported from Brazil and *Apata* sp. and *Heterobostrychus* sp. (Bostrychidae), *Coptops aedificator* F. (Cerambycidae) and *Stephanoderes macrolobii* Egg. (Scolytidae) from West Africa (Agnoloni and Giuliani, 1977).

Tea mosquito

The tea mosquito, *Helopeltis antonii* Sign. (Heteroptera: Miridae) causes more economic losses to the crop than any other pests of cashew. The adults and immature stages of this mirid bug suck sap from tender shoots, leaves, floral branches, developing nuts, and apples. The injury made by the suctorial mouth parts of the insect causes the tender shoot to exude the resinous gummy substance. The tissues round the point of entry of stylets become necrotised and brown or black scabs formed, presumably due to the action of the phytotoxin present in the saliva of the insect injected to the plant tissues at the time of feeding. The adjoining lesions coalesce and finally the affected shoot/panicle dries up. Abraham (1958) estimated the average damage to tender shoots to be about 25% and to tender nuts as 15%. When the floral branches are infested it results in inflorescence blight which accounts for about 30% loss (Anon., 1966).

The immature nuts infested by this pest develop characteristic eruptive spots and finally shrivel and fall off.

Sathiamma (1977) observed that a final instar nymph of tea mosquito produces 114 lesions (range 78–235), a female bug 97 lesions (range 16–238) and a male 25 lesions (range 11–59) during 24 hr. Water soaked lesions appear at the feeding sites 10–15 minutes after feeding. These become prominent within 3–6 hr. The water soaked lesions turn pinkish brown in 24 hr and scabby and black in 2–3 days (Nambiar *et al.*, 1973). The initial lesions are about 2.0 mm long and 1.3 mm wide on leaves and 9.2 mm long and 1.9 mm wide on stems. Lesions on fruits appear as brownish or blackish circular spots of 2.6–3.7 mm diameter. It was also estimated that on an average 14.0% shoots were infested (range 5.2–32.8%). The panicle damage may be partial (the secondary rachii only affected) or full (main rachis and secondary rachii infested). On an average 48.5% panicles were found attacked (24.2% partial and 24.3% full). Fully affected panicles dry up. Fruit damage was estimated to be 32.0%. Tea mosquito damages young cashew trees throughout the year as they produce flushes almost continuously (Sathiamma, 1978). However, older trees do not show any damage during June–September when they will be without new flushes (Pillai *et al.*, 1976). Similar observations have been made for *H. anacardii* Miller on cashew in Tanganyika also (Swaine 1959).

Remamony and Abraham (1977) observed *Pachypeltis maesarum* Kirkaldy (Heteroptera: Miridae) in company with *H. antonii.* The percentage of *P. maesarum* in the mixed populations ranged from 22 – 52 as revealed from random samples. Under confinement in cages, the adults and nymphs were found to infest tender stems, young leaves and inflorescences. The affected leaves curl up and show necrotic lesions around the feeding punctures. The infested twigs and inflorescences dry up rapidly.

The tea mosquito has a wide host range including tea, guava, cacao, mahogany, cinchona, red gum, apple, grapes, and neem trees (Rao, 1915; Puttarudriah and Appanna, 1955). Eventhough adequate data on the extent of crop losses caused by this pest are lacking, it was observed that the incidence was very severe in most of the cashew growing tracts on the West Coast. Contrary to the earlier belief that tea mosquito is not a major problem on the East Coast, recent observations revealed its incidence in severe proportions in Tamil Nadu, particularly in Cuddalore, Vridhachalam and Pudukkottai areas.

The adult bug is reddish brown with a black head, red thorax, and black and white abdomen. A knobbed process arises from the dorsal aspect of the thorax. The bug lays eggs singly deep inside the tissues of tender shoots or floral branches. A pair of fine thread-like chorionic processes projecting outside is indicative of the presence of eggs inside the tissues. The eggs are reniform and creamy white. The incubation period lasts 6–7 days and nymphal period comprising five instars is completed in 10 days. The build up of population synchronises with the emergence of new flushes after cessation of monsoon showers. The pest population reaches its peak when the trees are in full blossom.

Damodaran and Nair (1969) assessed the relative efficacy of eleven insecticides in controlling *H. antonii* and found that two sprayings with DDT 0.2% at 15 days interval starting as soon as the pest attack was noticed, gave the best results, followed by Sevin (0.1%), endrin (0.03%) and dieldrin (0.05%). Systemic insecticides were not as effective as contact insecticides in controlling the pest.

Chemical control trials carried out at Kasaragod revealed that endosulfan 0.05%, applied as high volume spray, or 0.1% as low volume spray, at the time of emergence of new flushes, panicles and fruit set, was effective in controlling tea mosquito population and reducing the resultant crop losses. Endosulfan treated plots recorded 10.7% infestation of inflorescences as against 32.5% in the untreated control plots. The average yield of nuts per tree in the treated plots was 2.5 kg as against 1.3 kg in the untreated control (Pillai and Abraham, 1975).

Three rounds of sprayings are recommended taking into consideration the trends in population fluctuation of the pest. Moreover, the third round of spraying given at the time of fruit-set will take care of not only tea mosquito infestation, but also other insects which are responsible for immature fruit drop in cashew. Infestation by tea mosquito, flower thrips and fruit borers accounted for 12.3% fruit drop during the mustard stage, 16.4% during pea nut stage and 1.1% during later stages (Pillai and Pillai, 1975). They also found that immature fruit drop was quite high at the mustard, pea nut and later stages.

The time of spraying is very important for the effective control of a pest like tea mosquito. The spraying has to be done well in advance before the insect has inflicted injury to the crop. As the flowering in cashew is protracted, the insecticide that is used for spraying inflorescences should be one which does not affect the pollinating insects adversely. A study of the insects associated with cashew inflorescences revealed that the honey bees *Apis indica* and *Apis florea,* the dipteran fly *Thoracitis abdominalis,* ceratinid bees, wasps (Vespidae, Scoliidae, and Xylocopidae) and ants (Formicidae) were the major species of insects visiting cashew inflorescences. The exact role played by each species of these insects in the pollination of cashew is yet to be confirmed.

Three species of *Helopeltis* are associated with cashew in different cashew growing tracts of the world (Swaine, 1959, Northwood and Kayumbo, 1970). Of these, *H. schoutedeni* Reuter (=*H.bergrothi* Reuter) is the most wide spread species occurring in Africa, extending from Togo and Nigeria to Tanzania and Mozambique, while *H. anacardii* Miller is essentially confined to the coastal cashew regions of Africa. *H. antonii* Sign.,on the other hand, is distributed in India and neighbouring countries, Brazil etc.

Leaf miner

Infestation by the leaf miner *Acrocercops syngramma* M. (Lepidoptera: Gracillariidae) is commonly observed in the post-harvest and post-monsoon flushes. Young trees are more prone to the attack of this pest. The injury by the caterpillars which mine through tender leaves become visible as tortuous markings first. Later on, the thin epidermal peel of the mined areas swell up as blistered patches. When the infested

tender leaf matures the damage will be manifested as big holes. As many as eight pillars have been observed on a single leaf. Abraham (1958) estimated the loss to be 26% in severely infested tracts, whereas Basu Choudhuri (1962) observed 75–80% leaves were damaged.

The adult is a silvery grey moth which lays eggs in tender leaves. Freshly hatched caterpillars are pale white and the fully grown ones reddish brown. They make their way out of the mined areas and fall to the soil and pupate.

Spraying phosphamidon or fenitrothion 0.05% at the time of emergence of new flushes is effective in controlling the pest. Spraying with endosulfan 0.05% against tea mosquito infesting new flushes will take care of this pest also.

A chalcidid parasite (unidentified) has been recorded from *A. syngramma*.

Leaf and blossom webber

Two species of leaf and shoot webbing caterpillars *Lamida (=Macalla) moncusalis* Walker and *Orthaga exvinacea* Hamps have been recorded as pests on cashew. Of these, the former has attained the status of a major pest in recent years in the East Coast tracts, particularly in the coastal districts of Andhra Pradesh (Ayyanna, Narayana and Rao, 1977). The pest is assuming severe proportions in the cashew plantations of Tamil Nadu and Orissa also. The symptoms of infestation include the presence of silken webs reinforced with pieces of plant parts on the terminal portions of tender shoots and blossom and the drying of webbed shoots.

L. moncusalis male is dark, fuscous and female paler and more olive green. Rao et al., (1973) studied the comparative biology of the insect on cashew and mango and found that the life cycle was completed in 37 days on cashew and 41 days in mango. Murthy *et al.*, (1974) reported that the egg, larval, prepupal, pupal and adult stages lasted for 5–6, 16–21, 1–2, 8–11 and 3–6 days respectively.

Spraying 0.2% BHC or 0.05% fenitrothion or endosulfan at the time of emergence of new flushes immediately after the monsoon was recommended for the control of the pest. Ayyanna, Subbaratnam and Rao (1977) found that Carbaryl 0.15% and malathion 0.15% were most effective against the pest with endosulfan 0.05% and fenitrothion 0.15% being the next best.

Two species of *Apanteles* and an unidentified species of Braconid have been reported as natural parasites of this pest.

Less serious enemies of cashew

The less serious pests are the defoliating caterpillars, shoot tip caterpillars, leaf thrips, leaf beetles and weevils, flower thrips, apple and nut borers, and nut crinkler.

Defoliating caterpillars

Cricula trifenestrata H. (Lepidoptera: Saturnidae) is a sporadic pest which causes extensive damage by defoliation of isolated trees in certain localities. The body

of the caterpillar is beset with urticating hairs and spines. The full grown larva is stout, dark brown and about 50–65 mm long. Pupation takes place inside dark silken cocoon spun amongst the leaves often in masses. The adult is a reddish brown moth with three clear concentric spots on wings.

Metanastria hyrtaca Cram. (Lepidoptera: Lasiocampidae) is also a sporadic pest attacking isolated cashew trees. Nair *et al.,* (1974) studied the biology of the pest in Kerala. The moth lays eggs in clusters on the lower surface of leaves. The eggs hatch in nine days. The larval period lasts 33 days for males and 35 days for females. There are five larval instars. The duration of different instars also varied for males and females. The pupal period lasts 12 days. The early instar caterpillars are gregarious feeders on tender foliage and the full grown caterpillars feed voraciously on mature leaves as well. They congregate on the tree trunk during day time and are active during night only.

Rao *et al.,* (1976) studied the biology of the pest in Andhra Pradesh. The pest appeared in June-July with the emergence of new flushes in cashew and continued up to December. Its fecundity ranged from 26 to 128. Incubation period lasted for 8–12 days with an average of 9.8 days, larval period comprising 5–7 instars ranged from 21–47 days and pupal period (including prepupal period of 2–3 days) for 12–18 days with an average of 14.7 days. The total life cycle from egg to adult took 54–76 days with an average of 66 days. An interesting feature noticed was that it took 75–109 days to complete the life cycle in sapota as against 54–76 days in cashew.

Perilampus microgastrii Ferr. (Perilampidae) was reared from parasitised larva collected from the field (Pillai *et al.,* 1976).

Misra and Basu Choudhuri (1974) recorded *Lymantria obfuscata* Walker (Lepidoptera: Lymantriidae) as a new pest of cashew from South India. The caterpillars feed voraciously on foliage during night, but are inactive during day time. They congregate in large numbers, on the ground under dry leaves, near the base of the tree in crevices of bark, or on lower parts of well shaded branches. Its life cycle lasts 45–51 days during April-May. Field and laboratory observations revealed that the pest completed five generations and started a sixth one in an year under South Indian conditions. Some Tachinids have been reported as parasites of this pest (Misra and Basu Choudhuri, 1974).

The slug caterpillar *Latoia (Parasa) lepida* Cram. (Lepidoptera: Eucleidae) and the looper *Oenospila flavifuscata* W. (Lepidoptera: Geometridae) were also reported as sporadic pests of cashew. Recently *Estigmene lactinae* C. (Arctiidae) (Sreeramulu *et al.,* 1975), *Diacrisia obliqua* Walker (Arctiidae) and *Stathmopoda* sp. near *paraealbata* Meyr. (Stathmopodidae) were also recorded as pests infesting cashew foliage (Pillai *et al.,* 1976).

Rao *et al.,* (1977) studied the biology of the leaf eating caterpillar *Thalassodes quadraris* Guen. (Lepidoptera: Geometridae), recorded as a cashew pest in Guntur and Prakasam districts of Andhra Pradesh. The adult is a medium sized moth, apple green in colour with a pale oblique line running across the fore and hind wings. The caterpillar is a semilooper having pale, yellowish pink colour. The life cycle from egg

to adult is completed in 22–35 days (egg period 3–5 days, larval period 13–20 days and pupal period 6–10 days).

Bombotelia jocosatrix Guen. (Lepidoptera: Noctuidae) is another leaf eating caterpillar recorded as a cashew pest from Andhra Pradesh. Early instar caterpillars feed on the leaf margins by making holes all along. Fully grown larvae feed on the entire leaf gregariously leaving behind the midrib only. The total life cycle from egg to adult is completed in 30.6 days (egg period 3.8 days, larval period 14.9 days and pupal period 11.9 days) (Rao *et al.*, 1978). Distinct sexual dimorphism was noticeable in the moths. Males are dark purple brown and females purple brown. Hind wings are white with purple brown margins with a small round spot in the centre in both the sexes. Mango is another host of this pest (Fletcher, 1914; Ayyar, 1940).

Stray cases of incidence of the leaf roller *Sylepta auranticollis* F., a Eucosmid caterpillar *Argyroploce tonsonia* F., and the Tassar silk moth *Antherea paphia* B. have also been noticed on cashew (Abraham, 1958).

Rao (1978) recorded *Spodoptera litura* F. as a pest of cashew foliage. Tobacco is another important host of this pest. When plant protection measures were taken up for the control of *S. litura* in tobacco nurseries, the caterpillars were found to migrate to cashew plantations and to cause considerable damage to cashew foliage in October–November.

Shoot tip caterpillars

The tiny yellowish or greenish brown caterpillars of the moth *Hypatima (Chelaria) haliqramma* M. (Lepidoptera: Gelechiidae) damage the shoot tips. It occasionally bores through the tender shoot tip to a depth of about 20–25 mm causing stunting and drying up of growing shoot tips. Upto 26% damage has been recorded in severe cases of infestation (Abraham, 1959). Remamony (1965) recorded the caterpillars of *Anarsia epotias* Meyr. (Lepidoptera: Gelechiidae) causing considerable damage to tender shoots. As the caterpillar reaches the third or fourth instar, it bores into the terminal shoot tip and tunnels backwards feeding on the internal tissues and filling the tunnels with frass. Usually it bores to a depth of 20–30 mm. Gummosis will also be seen in such shoots. The infested shoot gradually dries up.

As the infestation of shoot tip caterpillars coincides with the emergence of new flushes, sprays done against tea mosquito and other foliage pests at the time of emergence of new shoots will control these pests as well.

Leaf and flower thrips

Of the three species of thrips recorded as foliage pests of cashew in India viz., *Selenothrips rubrocinctus* Giard *Rhipiphorothrips cruentatus* Hood and *Retithrips syriacus* M. (Thysanoptera: Thripidae), the former two cause very severe damage to young plantations particularly during summer months. Fennah (1962) observed that the populations of *S. rubrocinctus* Giard on cashew trees in Trinidad, West Indies also regularly increased during the dry season, from a low level in December and January to a peak in April or May and then rapidly declined during the wet season. S. *rubrocinctus* was found to feed on leaves that were subjected to water stress and to breed only on debilitated trees

(Boboye 1968), the evidence suggested that the adequacy of its supply of nutrients depends on the induction of suitable metabolic conditions within the leaf by water stress. This pest is widely distributed in West Indies, East Africa and India. In Kenya, the infestation takes place at the end of rainy season and culminates in September–November. In India also the pest is most active in the summer months, March to May rather than during the monsoon.

The adults and immature stages of thrips colonise on the lower surface of leaves. As a result of their rasping and sucking activity the leaves become pale brown and slightly crinkled with roughening of upper surface. Infestation by foliage thrips in severe proportions had been observed during the summer months in cashew plantations in Tamil-Nadu. Spraying 0.05% endosulfan or fenitrothion so as to give a thorough coverage to the lower surface of leaves will control the pests.

Rhynchothrips raoensis G. and another unidentified species of thrips have been reported by Abraham (1958) attacking cashew inflorescences. The rasping and feeding injury made by thrips results in scabs on floral branches, apples and nuts. Infestation on developing nuts results in the formation of corky layers on the affected parts; malformation of nuts and even immature fruit-drop. The third round of spray against tea mosquito at the time of fruit set will control flower thrips as well.

Leaf beetles and weevils

Monolepta longitarsus Jac. (Coleoptera: Chrysomelidae) appears in large numbers during the South West monsoon period (June-August) and causes damage to the tender leaves and portions of stem. Young plantations and nursery seedlings are more severely affected by this pest. *Hyperaxis albostriata Mots., Hoplosoma abdominalis* Jac., *Basilepta falvicorne* Jac., and *Pagria constatipennis* Jac. (Chrysomelidae), *Arodepus marginatus* Pasc. (Attelabidae) and *Oxycetonia versicolor* Fab. (Cetonidae) have been observed to congregate on new shoots and feed on them.

The leaf twisting weevil *Apoderus tranquebaricus* F. (Coleoptera: Curculionidae) which is a pest on mango, was observed on cashew also at the time of emergence of new flushes (Abraham, 1958). The weevil folds the leaves along the midrib, deposits its oval orange coloured eggs on leaf tips and twists the leaf into a compact roll. The grub after hatching feeds on the rolled up leaf tissues.

Three other species of weevils observed feeding on tender foliage of cashew are *Myllocerus discolor* B., *M. viridanus* F., and *Amblyrhinus poricollis* B. Of these *M. discolor* was observed to cause heavy damage to tender leaves, particularly in nursery seedlings and young plantations.

Spotted locust and bag worms

The spotted locusts, *Aularches miliaris* Linn. (Orthoptera: Acrididae) have been observed to cause severe damage by feeding on the foliage of cashew trees (Pillai *et al.*, 1976). This is a polyphagous insect infesting teak, coconut, arecanut, coffee and erythrina. Its incidence in an epidemic scale in June 1975 in the Malappuram district of Kerala State caused severe damage to cashew, coconut, arecanut and other crops. An

unidentified species of bag worm (Lepidoptera: Psychidae) was observed feeding on cashew foliage in the cashew plantations of the Forest Department, Goa (Pillai *et al.*, 1976).

Mealy bugs and scales

Incidence of mealy bug *Planococcus lilacinus* (Ckll.) and wax scale *Ceroplastes floridensis* C. on tender shoots, mild incidence of the scale *Diaspis* sp. on leaves and stray incidence of the giant scale *Monophlebus sp.* on tender shoots were reported by Abraham (1958) and Basheer and Jayaraj (1964). *Pseudaonidia trilobitiformis* Green is distributed in the regions of East Africa (Kenya and Tanzania) and the Seychelles Islands (Ohler, 1977). The sucking action of insects leads to foliar yellowing and defoliation.

Wide spread infestation of white flies *Aleurodicus cocois* Curtis (Aleyrodidae) has been reported from cashew plantations of North East Brazil (Ohler, 1977). As a result of the attack sooty mould may develop on the ventral side of leaves. In cases of severe infestation there is a sharp drop-off in production, and defoliation of the plant with consequent general withering and eventual death (Agnoloni and Giuliani, 1977).

Mites

Bano and Chandra (1973) recorded *Oligonychus mangiferus* Rahman and Sapra (Acarina: Tetranychidae) from cashew. The young and adult mites were found congregating along the midrib and veins sucking the sap causing depressions. When the attack is severe, the leaves get desapped and turn brown. Infestations by mites have been observed in severe proportions in some cashew plantations in Karnataka, Andhra Pradesh and Orissa.

Oligonychus coffeae Neitner (Acarina: Tetranychidae) is a pest of cashew in Africa, (Rodrigues, 1967). This is a dark red mite that colonises on the upper surface of the leaves though it infests inflorescences as well. As a result of infestation the interveinal tissues appear bright red and later show large number of silvery blotches.

Pests on inflorescence

In addition to blossom webber and thrips, inflorescences are attacked by the hairy caterpillar *Euproctis scintillans* W. (Lepidoptera: Lymantriidae), the chafer beetle *Popillia complanata* Newm. (Coleoptera: Rutelidae), the caterpillar *Pingasa ruginaria* Gn. (Lepidoptera: Geometridae) (Sreeramulu *et al.*, 1975) the mealy bug *Ferrisia virgata* (Ckll.), the aphid *Toxoptera odinae* Vdg., and the flatids, *Flata* sp. and *Ketumala* sp. (Pillai *et al.*, 1976).

Apple and nut borers

Thylocoptila panrosema M. (Lepidoptera: Pyralidae) is a pinkish dark actively moving caterpillar which bores into tender apples and nuts. In years of severe infestation nearly 10% of the apples and nuts are affected. The apple borer *Nephopteryx* sp. also is responsible for heavy crop losses (Dharmaraju *et al.*, 1974). Dharmaraju *et al.*, (1976)

reported that damage by this pest amounts to 20–60% in certain cashew plantations in Bapatla and Chirala Taluks of Andhra Pradesh. The caterpillars attack the fruits at all stages and cause the shrivelling and premature fall of nuts. Only a single caterpillar is generally seen either in the apple or nut, but there are reports of up to five caterpillars occurring in apples and three in nuts. There are five larval instars lasting 15–33 days. The full grown larvae drop to the ground and pupate in earthern cocoons. The pupal period lasts 8–10 days. Ayyanna *et al.,* (1977) found that 0.15% carbaryl and malathion were the most effective insecticides against *M. moncusalis* and *Nephopteryx* sp., with endosulfan 0.05% and fenitrothion 0.15% being the next best.

Basu Choudhuri and Misra (1973) reported *Hyalospila leuconeurella* Ragonot (Lepidoptera: Pyralidae) and *Anarsia epotias* Meyrick (Lepidoptera: Gelechiidae) also as pests of cashew apples and nuts in South India. The control measures include identification of trees which bear apples and nuts during the off-season and control of the pests by mechanical destruction or spraying of infested inflorescences apples and nuts with a suitable insecticide. Phytosanitary measures during Pre-flowering season and foliar application of suitable insecticides during July-October will arrest the population build up of the pests.

Nut crinkler

Nair and Remamony (1964) reported the Coreid bug *Paradasynus* sp. *(rostratus* Dist?) (Heteroptera: Coreidae) sucking sap from tender nuts causing them to shrivel, and dry up. The adult bug lays eggs on leaf surface in groups of upto 52, equally spaced and arranged in regular rows of five or six. The incubation period was 8–11 days and the nymphal period comprising five instars was completed in 21–36 days with an average of 27 days. The eggs are parasitised in the field by *Hadrophanurus* sp. (Scelionidae) and *Anastatus* sp. (Eupelmidae). The third round of spraying done against tea mosquito at the time of fruit setting will control this pest also. The same Coreid bug has been recorded as a new nut crinkler pest of coconut also in Kerala.

Northwood and Kayumbo (1970) reported the theraptus bug *Pseudotheraptus wayi* Brown (Heteroptera: Coreidae) from Tanzania, as feeding on developing nuts and producing black sunken spots on the kernels. Usually there will not be any sign of damage on the shells. The percentage of affected kernels in some consignments may be as much as 8–10. This pest also infests coconut and cacao. Biological control of the pest using the predacious ant *Oecophylla longinoda* on coconut has been reported from Tanzania.

In view of the heavy economic losses caused by different insect pests it is imperative to adopt timely plant protection measures in cashew. Chemical control of various pests has been reported to be successful. However, it is rather impracticable to adopt control measures against individual pests except in cases of isolated outbreaks. Adoption of suitable plant protection measures to cover different pests at a particular time would be quite desirable and more economical. Researches on biological control of different pests are to be intensified and suitable measures to be taken for conservation of natural enemies of different pests. The future of pest control research in cashew lies in working out a strategy for integrated pest management covering all the major and minor pests.

APPENDIX 6.1.

Pests of Cashew

Name of pest	*Reference*
INSECTS	
Achaea catocaloides Gn.	Beccari and Gerini (1968)
Achaea ezea Cram.	Beccari and Gerini (1968)
Achaea faber Holl.	Beccari and Gerini (1968)
Achaea lienardi Bod.	Beccari and Gerini (1968)
Acrocercops syngramma Meyrick	Ayyar (1932, 1940, 1941 and 1942), Abraham (1958), Basu Choudhuri (1962), Browne (1968), Agnoloni and Giuliani (1977)
Aethalion reticulatum	Parente and Ribeiro (1970)
Aethemenes (Nezara) *chloris* Westw.	Beccari and Gerini (1968)
Ahasverus advena Watl.	Pinheiro (1968)
Aleurodicus cocos Curtis	Arruda (1970), Parente and Ribeiro (1970), Dunham and Andrade (1971), Agnoloni and Giuliani (1977), Ohler (1977)
Aleurotrichus flocósus	Parente and Ribeiro (1970)
Alphitobius diaperinus Panz	Pinheiro (1968)
Alphitobius laevigatus F.	Pinheiro (1968)
Amblyrhinus poricollis. Schoenherr	Browne (1968)
Analeptes trifasciata Fab.	Jones (1961), Tuley and Iwenjora (1963), Browne (1968), Agnoloni and Giuliani (1977)
Anarsia epotias Meyrick	Remamony (1965), Browne (1968) Basu Choudhuri and Misra (1973)
Anastrepha mombinpraeoptans Ein.	Beccari and Gerini (1968)
Anastrepha sp.	Araque (1968)
Anoplocnemis curvipes F.	Lefebvre *et. al.*, (1973)
Antheraea paphia L.	Abraham (1958), Browne (1968)
Antistarcha binocularis Meyrick	Peixoto (1960), Calzavara (1970), Parente and Ribeiro (1970), Agnoloni and Giuliani (1977).
Aoniella orientalis Newstead (= *Aspidiotus cocotiphagus* Marlatt)	Browne (1968)
Apate congener Gerst.	Pinheiro (1968)
Apate sp.	Beccari and Gerini (1968),Agnoloni and Giuliani (1977)
Apate terebrans Pallas	Peixoto (1960), Browne (1968), Pinheiro (1968), Agnoloni and Giuliani (1977)
Apion amplum F.	Ayyar (1932, 1940, 1941 and 1942), Anon. (1957), Abraham (1958), Anon. (1959), Wheatly (1961), Beccari and Gerini (1968), Pinheiro (1968)

Apoderus tranquebaricus Fabricius	Abraham (1958), Browne (1968)
Apologlostatus acaciae Schedl.	Beccari and Gerini (1968)
Apterygida albipennis Charp.	Pinheiro (1968)
Argyroploce tonsonia M.	Abraham (1958)
Arodepus marginatus Pasc.	Pillai *et al.* (1976)
Aspidiotus destructor Signoret	Peixoto (1960), Beccari and Gerini (1968)
Aulacaspis cinnamomi Newstead	Beccari and Gerini (1968)
(= Aulacaspis tubercularis Newstead)	
Aularches miliaris Linn.	Pillai *et al.* (1976)
Bag worm	Pillai *et al.* (1976)
Basilepta flavicorne Jac.	Pillai *et al.* (1976)
Batocera rufomaculata De G.	Pillai *et al.* (1976)
Belionota prasina Thumb.	Pillai *et. al.* (1976)
Bombotelia jocosatrix Guen.	Arjuna Rao *et al.* (1978)
Bostrychoplites sp.	Beccari and Gerini (1968)
Cadra cautella Wlk.	Pinheiro (1968)
Camponotus sp. Mayr.	Abraham (1958)
Carpophilus dimidiatus (F).	Pinheiro (1958)
Carpophilus sp.	Pinheiro (1968)
Catacanthus sp.	Davis (1949)
Ceroplastes floridensis Comstock	Ayyar (1932, 1940, 1941 and 1942), Abraham (1958 and 1959), Basheer and Jayaraj (1964), Browne (1968)
Ceryx imaon Cramer	Sathiamma (1978)
Charaxes numenes Hew.	Beccari and Gerini (1968)
Chrysobothris curta Kerr.	Pinheiro (1968)
Chrysomphalus ficus Ashmead	Browne (1968)
(= Aspidiotis ficus = Chrysomphalus aonidium L.*)*	
Coccus hesperidum L,	Wheatly (1961)
Coptops aedificator F.	Beccari and Gerini (1968), Pillai *et al.*, (1976)
Cricula trifenestrata Helfer	Ayyar (1932, 1940, 1941 and 1942), Abraham (1958), Morton (1961), Browne (1968)
Crimissa sp. Stal.	Parente and Ribeiro (1970), Johnson (1973)
Cryptolestes ferrugineus Steph.	Pinheiro (1968)
Cryptolestes pusillus Schonh.	Pinheiro (1968)
Ctenomeristis ebriola Meyrick	Thatchenko (1949), (1954–61), Browne (1968)
Diacrisia obliqua Walker	Pillai *et al.* (1976)
Diaspis sp.	Abraham (1958), Basheer and Jayaraj (1964)
Disphinctus humeralis Walker	Beccari and Gerini (1968), Browne (1968)
(= Pachypeltis humerale Walker)	
Disphinctus politus Walker	Beccari and Gerini (1968)
Dysdercus superstitiosus	Lefebvre (1973)
Eccoptopterus spinosus Oliv.	Beccari and Gerini (1968)

Egropa malayensis Dist.	Beccari and Gerini (1968)
Estigmene lactinea C.	Sreeramulu *et al.*, (1975)
Euproctis scintillans Walker (=*Porthesia scintillans*)	Abraham (1958), Browne (1968),
Euthalia garuda Moore	Browne (1968)
Ferrisia virgata Cockerell	Abraham (1958 and 1959), Morton (1961), Beccari and Gerini (1968), Browne (1968), Bohlen (1973), Pillai *et al.*, (1976)
Flata sp.	Pillai *et al.*, (1976)
Gnathocerus maxillosus F	Pinheiro (1969)
Helopeltis anacardii Miller	Morton (1961), Wheatly (1961), Beccari and Gerini (1968), Evaristo and Pais (1970), Northwood and Kayumbo (1970), Bohlen (1973), Nambiar *et al.*, (1973), Hill (1975), Agnoloni and Giuliani (1977).
Helopeltis antonii Signoret	Rao (1915), Ayyar (1932, 1940, 1941 and 1942), Puttarudriah and Appanna (1955), Abraham (1958), Morton (1961), Browne (1968), Damodaran and Nair (1969), Nambiar *et al.*, (1973), Nambiar (1974), Pillai and Abraham (1974), Pillai (1975), Pillai and Abraham (1975), Pillai *et al.*, (1976), Agnoloni and Giuliani (1977), Sathiamma (1977)
Helopeltis schoutedeni Reuter (=*Helopeltis bergrothi* Reuter)	Anon. (1957), Mutter and Bigger (1962), Beccari and Gerini (1968), Evaristo and Pais (1970), Northwood and Kayumbo (1970), Bohlen (1973), Nambiar *et al.*, (1973) Agnoloni and Giuliani (1977)
Helopeltis spp.	Agnoloni and Giuliani (1977), Ohler (1977)
Heterobostrychus brunneus Murr.	Pinheiro (1968)
Hilda patruelis Stal.	Wheatly (1961), Beccari and Gerini (1968), Bohlen (1973)
Hoplosoma abdominalis Jac.	Pillai *et, al.* (1976)
Hyalospila leuconeurella Ragonot	Browne (1968),
Hypatima haligramma Meyrick (=*Chelaria haligramma*)	Basu Choudhuri and Misra (1973)
Hyperaxis albostriata Mots.	Abraham (1958 and 1959), Basheer and Jayaraj (1964), Browne (1968)
Idarbela tetraonis Moore	Pillai *et al.*, (1976)
	Abraham (1958), Browne (1968), Pillai *et al.*, (1976)
Kissophagus confusus Egg.	Beccari and Gerini (1968)
Lamida moncusalis Walker (=*Macalla moncusalis*)	Abraham (1958), Basheer and Jayaraj (1964), Browne (1968), Ganeswara Rao *et al.*, (1973), Krishna Murthy *et al.*, (1974), Ayyanna *et al.*, (1977)

Lampetis fastuosa F.	Pillai *et al.,* (1976)
Lasioderma serricorne F.	Pinheiro (1968)
Latoia (Parasa) lepida Cram.	Abraham (1958), Basheer and Jayaraj (1964), Pillai *et al.,* (1976)
Lecanium latioperculatum Green	Ayyar (1932, 1940, 1941 and 1942), Browne (1968)
Lepidosaphes sp.	Wheatly (1961)
Leptocentrus sp.	Sathiamma (1978)
Liposcelis sp.	Pinheiro (1968)
Lygus palus Auct.	Beccari and Gerini (1968)
Lymantria obfuscata Walker	Misra and Basu Choudhuri (1974)
Lypesthes sp.	Sathiamma (1978)
Macrodactylus pumillo Burm.	Abrahao and Orlando (1956), Mariconi (1963), Parente and Ribeiro (1970)
Marshallus sp.	Agnoloni and Giuliani (1977)
Mecocorynus loripes Ches.	Mutter and Bigger (1962), Pinheiro (1958) Northwood and Kayumbo(1970), Hill (1975), Agnoloni and Guiliani (1977), Ohler (1977)
Megalopyge lanata	Parente and Ribeiro (1970)
Metanastria hyrtaca Cram.	Abraham (1958), Browne (1968), Nair *et al.,* (1974), Arjuna Rao *et al.*(1976)
Mimips bidentatus Schedl.	Beccari and Gerini (1968)
Monolepta longitarsus Jacoby	Abraham (1958 and 1959,) Basheer and Jayaraj (1964), Browne (1968)
Monophlebus sp.	Abraham (1958), Basheer and Jayaraj (1964)
Myllocerus discolor Boheman	Abraham (1958), Basheer and Jayaraj (1964), Browne (1968)
Myllocerus viridanus Fabricius	Abraham (1958), Basheer and Jayaraj (1964), Browne (1968)
Necrobia rufipes (DeG.)	Abraham (1958), Pillai (1959), Pinheiro (1968)
Nephopteryx sp.	Abraham (1958), Dharmaraju *et al.,* (1974 and 1976), Ayyanna *et al.,* (1977)
Nezara viridula L.	Le Pelley (1959), Browne (1968)
Nudaurelia dione Fabricius	Browne (1968), Northwood and Kayumbo (1970)
Oecophylla smaragdina Fabricius	Basheer and Jayaraj (1964), Browne (1968)
Oenospila flavifuscata Walker	Abraham (1958), Browne (1968)
Oereodes sparsus Bah.	Sathiamma (1978)
Olethreutes tonsoria Meyrick *(=Agyroploca tonsoria)*	Browne (1968)
Orthaga exvinacea Hamps.	Ayyanna *et. al.,* (1977)
Oryzaephilus mercator (Fauv.)	Tuley and Iwenjora (1963), Pinheiro (1968)
Oryzaephilus surinamensis (L.)	Abraham (1958), Pillai (1959), Pinheiro (1968)

Othreis divitiosa Walker	Beccari and Gerini (1968)
Othreis fullonia Clerck	Beccari and Gerini (1968), Browne (1968)
Othreis materna	Beccari and Gerini (1968)
Oxycetonia versicolor Fab.	Pillai *et al.*, (1976)
Pachypeltis mesarum Kirkaldy	Remamony and Abraham (1977)
Pachypeltis sp.	Sathiamma (1978)
Pagria constatipennis Jac.	Pillai *et al.*, (1976)
Palorus subdepressus (Doll.)	Tuley and Iwenjora (1963), Pinheiro (1968)
Paradasynus sp. *(rostratus* Dist.?)	Nair and Remamony (1964)
Paranaleptes reticulata Thomson	Gardener (1957), Jones (1961), Wheatly (1961), Tuley and Iwenjora (1963), Browne (1968), Hill (1975) Agnoloni and Giuliani (1977).
Parasa lepida Cramer	Abraham (1958), Browne (1968), Basheer and Jayaraj (1964), Pillai *et al.* (1976)
Phlaeothrips anacardii Newm.	Morton (1961)
Phycita leuconeurella Rag.	Thatchenko (1949), Beccari and Gerini (1968)
Phyllodromia bivittata Serv.	Pinheiro (1968)
Piezothetus flavipes Reut.	Pinheiro (1968)
Pingasa ruginaria Gn.	Sreeramulu *et al.*, (1975), Pillai *et al.*, (1976).
Planococcus citri Risso	Beccari and Gerini (1968), Browne (1968)
(= Pseudococcus citri Risso)	
Planococcus lilacinus Cockerell	Abraham (1958), Basheer and Jayaraj (1964),
(= Pseudococcus lilacinus)	Browne (1968)
Planococcoides njalensis Laing	Browne (1968)
(= Pseudococcus njalensis Laing)	
Plocaederus consocius Pascoe	Abraham (1958), Basheer and Jayaraj (1964), Browne (1968)
Plocaederus ferrugineus L.	Ayyar (1932, 1940, 1941 and 1942), Abraham (1958), Basheer and Jayaraj (1964), Beccari and Gerini (1968), Browne (1968), Basu Choudhuri (1973), Pillai *et al.*, (1976).
Plocaederus obesus Gahan	Pillai *et al.*, (1976)
Plodia interpunctella (Hb.)	Abraham (1958)
Popillia complanata Newm.	Sreeramulu *et al.*, (1975), Pillai *et al.*, (1976).
Polygraphus natalensis Egg.	Beccari and Gerini (1968)
Prionoma atratum Gmelim	Basheer and Jayaraj (1964), Beccari and Gerini (1968), Browne (1968)
Pseudaonidia trilobitiformis Green	Peixoto (1960), Wheatly (1961),
(= Aspidiotus trilobitiformis)	Browne (1968), Bohlen (1973), Agnoloni and Giuliani (1977), Ohler (1977).

Pseudotheraptus wayi Brown	Davies (1960), Wheatly (1961), Beccari and Gerini (1968), Northwood and Kayumbo (1970), Bohlen (1973), Agnoloni and Giuliani (1977)
Pulvinaria sp.	Beccari and Gerini (1968)
Retithrips aegiptiacus Marc. *(= Rethithrips syriacus)*	Peixoto (1960)
Rhaphidopsis melalanca Gerst.	Pinheiro (1968)
Rhipiphorothrips cruentatus Hood.	Abraham (1958), Browne (1968)
Rhynchothrips raoensis Ramakrishna	Ayyar (1932, 1940, 1941 and 1942)
	Abraham (1958), Browne (1968)
Saisettia nigra Nietner *(= Lecanium nigrum)*	Browne (1968)
Salberghella spp.	Lefebvre *et. al.,* (1973)
Sciothrips sp.	Wheatly (1961)
Selenothrips rubrocinctus Gr.	Ayyar (1932, 1940, 1941 and 1942), Abraham (1958 and 1959), Bigger (1960), Wheatly (1961), Fennah (1962), Mutter and Bigger (1962), Araque (1968), Browne (1968), Northwood and Kayumbo (1970), Lefebvre (1973), Agnoloni and Guiliani (1977)
Sitophilus Zea-mays Motsch	Pinheiro (1968)
Solenopsis sp.	Pinheiro (1968)
Spodoptera litura F.	Arjuna Rao (1978)
Stathmopoda sp. near *praealbata* Meyr.	Pillai *et al.,* (1976)
Stephanoderes macrolobii Egg.	Beccari and Gerini (1968), Agnoloni and Giuliani (1977)
Sylepta balteata Fabricius *(= Sylepta auranticalis)*	Abraham (1958), Browne (1968)
Tachardia artocarpi Auct.	Beccari and Gerini (1968)
Termites	Bohlen (1973)
Tenebroides mauritanicus L.	Abraham (1958), Pinheiro (1968)
Thalassodes quadraris Guen.	Beccari and Gerini (1968), Arjuna Rao *et al.,* (1977).
Thylocoptila panrosema Meyrick	Basheer and Jayaraj (1964), Browne (1968), Pillai *et al.,* (1976)
Toxoptera odinae Van der Goot *(= Aphis odinae)*	Abraham (1958), Basheer and Jayaraj (1964) Browne (1968), Pillai *et al.,* (1976)
Trachyostus aterrimus Schaufuss	Beccari and Gerini (1968)
Tribolium castaneum (Hbst.)	Abraham (1958), Pillai (1959), Pinheiro (1968)
Tupalis fasciatus	Davies (1950), Wheatly (1961)
Xylopsocus sellatus Fah.	Beccari and Gerini (1968)
Xyleborus andrewesi Bland.	Beccari and Gerini (1968)
Xyleborus maneus Blandf.	Beccari and Gerini (1968)

Xyleborus perforans Woll.	Beccari and Gerini (1968)
Xylothrips flavipes Ill.	Pillai *et al.*, (1976)
Xystrocera globosa Ol.	Pillai *et al.*, (1976)

MITES

Aceria sp.	Araque (1968)
Aleuroglyphus ovatus Trop.	Pillai (1959), Pinheiro (1968)
Brevipalpus californicus (Banks)	
Brevipalpus phoenicis (Geijskes)	Rodrigues (1970)
Calacarus citrifolii (Keifer)	Rodrigues (1970)
Caloglyphus sp.	Pillai (1959), Pinheiro (1968)
Cheyletus sp.	Pillai (1959), Pinheiro (1968)
Eotetranychus falcatus Meyer and Rodrigues	Rodrigues (1967), Northwood and Kayumbo (1970)
Lasioseius sp.	Pinheiro (1968)
Leiodinychus sp.	Pinheiro (1968)
Melichares sp.	Pinheiro (1968)
Melichares tarsalis	Pinheiro (1968)
Oligonychus coffeae (Nietner)	Wheatly (1961), Rodrigues (1970), Agnoloni and Guiliani (1977)
Oligonychus mangiferus Rahman and Sapra	Bano and Nagesh Chandra (1973)
Pronematus sp.	Rodrigues (1970)
Suidasia nesbitti Hughes	Pinheiro (1968)
Suidasia sp.	Pinheiro (1968)
Tetranychus sp.	Rodrigues (1970)
Tydeus munsteri Meyer Ryke	Rodrigues (1970)
Tydeus sp.	Rodrigues (1970)
Tydeus spatthus	Rodrigues (1970)
Tyrophagus castellanii	Pillai (1959), Pinheiro (1968)
Tyrophagus putrescentiae Sch.	Pinheiro (1968)
Tyrophagus sp.	Pinheiro (1968)

CHAPTER 7

DISEASES

Cashew is subject to the attack by a multitude of important pests and diseases, limiting the production considerably. However, compared to the number of pests attacking cashew and the intensity of damage they inflict on the crop, the magnitude of the disease problem is rather very low. Though more than four dozens of fungi have been reported from cashew (Appendix 7.1) those of economic importance are only a few. Because of this fact, the research thrust on diseases also is very meagre. Rao (1969), Nambiar (1978) and Agnoloni and Giuliani (1977) gave brief accounts of important diseases of cashew. The diseases of cashew and their control measures are described in this chapter.

Inflorescence blight

As the very name indicates, the malady is characterised by the drying of floral branches. Minute water-soaked lesions are discernible in the early stages on the main rachis and/or secondary rachii. Gummy exudations can be seen at the lesion site. The lesions turn pinkish brown in a day or so, enlarge in size and turn scabby within 2–3 days. The adjoining lesions coalesce to form bigger lesions. As a result of this, the affected inflorescences dry up and present a scorched appearance. The incidence of the disease becomes much aggravated when cloudy weather prevails. Studies carried out at Cashew Research Station, Ullal, India showed that this malady was caused by fungi like *Gloeosporium mangiferae and Phomopsis anacardii* in association with tea mosquito, *Helopeltis antonii* Sign. and hence a combination spray of a fungicide (Cuman 100g in 100 lit or Blitox 250g in 100 lit) and an insecticide (Dimecron 30 ml in 100 lit) was recommended earlier for the control of this blight (Anon, 1960 and Anon, 1965, 1966, and 1969). Damodaran and Nair (1969) reported the control of the disease with D D T 0.2% spray, but did not specify the exact role of the fungus and insect in the causation of the malady. However, recent investigations (Nambiar *et al.*, 1973) revealed that the disease was primarily caused by tea mosquito infestation and the fungi associated with it were only secondary saprophytic colonizers (Table 7.1). The fungi could be isolated only from old scabby lesions and not from small fresh lesions indicating the above fact. The finding is important in that the fungicide can now be eliminated from the spray schedule against this malady. (For details see chapter on pests).

A floral shoot die-back disease was reported from Nigeria by Olunloyo and Esuruoso (1975). The disease was caused by *Lasiodiplodia theobromae* (=*Botryodiplodia theobromae*). The fungus was isolated from cashew nuts in Tanzania also (Riley, 1960). Withering of petals and other floral parts followed by a progressive die-back of the rachis are the symptoms of this malady. It usually starts from the apex

TABLE 7.1. **Incidence of inflorescence blight of cashew with tea mosquito and fungi***

Treatment	*Total no. of inflorescences treated*	*Total no, of inflorescences affected*
Caging the inflorescence with *H. antonii* alone	20	20
Caging the inflorescence with *H. antonii* after inoculating with fungus		
(i) *G. mangiferae*	20	20
(ii) a non-sporulating fungus	20	20
Inoculating with fungus alone		
(i) *G. mangiferae*	20	0
(ii) a non-sporulating fungus	20	0
Inoculation of injured inflorescences with fungus		
(i) *G. mangiferae*	20	0
(ii) a non-sporulating fungus	20	0
Caging fungicide–treated inflorescence with *H. antonii*	10	10
Caging insecticide–treated inflorescence with *H. antonii*	20	0
Control : (i) Inflorescence caged	20	0
(ii) Injured inflorescence caged	20	0
(iii) Inflorescence left open	20	18

* *Source*: Nambiar *et. al.*, 1973.

developing downwards to the main peduncle which looses its normal green colour. As a result of the die-back the flowers are lost and no fruit set takes place. The immature nuts and apples when attacked become black and remain attached to the moribund floral shoots. The discolouration of the pith is traceable from the peduncle to the twigs when cut longitudinally. Insect damage is supposed to predispose the peduncles to infection by the pathogen. This is supported by the frequent isolation of the fungus from the tissues of dead flowers. The fungus enters the host slowly from the apex of the peduncle to the pith and within six months produce die-back symptoms.

Die-back or pink disease

The disease caused by *Corticium salmonicolor (=Pellicularia salmonicolor)* is prevalent during the South West Monsoon period (Anon, 1960; Rao, 1969; Estibeiro, 1970). The affected branches show white or pinkish growth on the bark. The fungus penetrates into the deeper tissues and causes gradual death of the shoots from apex downwards and hence the name die-back. Towards the cessation of monsoon, a film of silky thread of the fungus is seen on the branches. The mycelium is silvery white in the beginning but changes to a general pink at later stages. The asexual spores are hyaline individually, but pink in mass, and readily germinate in water and form the infective propagules. In advanced stages the bark splits and peels off. In a tree either one branch or many branches will be affected. On the affected branches, the leaves turn yellow and fall off giving a barren appearance to a portion of the tree (Fig.7.1). Control measures include pruning the affected branches, well below the site of infection and destroying them, protecting the cut surface by application of Bordeaux paste and giving prophylactic sprays with Bordeaux mixture (1%) twice, one in May-June before the onset of South-West monsoon and the second in October. Phytosanitary measures are important lest the affected branches serve as a source of inoculum for further spread of the disease. If left unpruned, these branches will also be the site of infestation and multiplication of bark beetles., etc.

Damping-off of seedlings

The disease occurs in nurseries where drainage conditions are poor. Kumararaj and Bhide (1962) found that damping–off caused severe loss of nursery seedlings in Vengurla in Maharashtra. Different fungi have been reported from different parts of the country as causative agents of the disease. Thus *Fusarium* sp., *Pythium* sp., *Phytophthora palmivora* and *Cylindrocladium scoparium* have been reported as pathogens from Kerala, Karnataka, Tamil Nadu, Andhra Pradesh and Maharashtra (Anon, 1960; Kumararaj and Bhide, 1962; Susamma Philip, 1973). *Sclerotium rolfsii* also has been implicated with the disease (Agnoloni and Giuliani, 1977). The fungi attack either the root or collar region or both of tender seedlings. In the case of *P. palmivora,* the affected seedlings become pale, show water soaked girdles of darkened tissues around the stems and the seedlings later droop ultimately leading to their death. In severe cases, leaves also exhibit water soaked lesions. The lesions enlarge and coalesce involving some times the entire lamina.

Susamma Philip (1973) reported infection of four month-old seedlings by *Cylindrocladium scoparium* causing wilting and withering of seedlings and rotting of

underground parts. The disease incidence was severe during rainy season. The fungus on inoculation produced identical symptoms in 14–25 days. The conidiophores of the fungus are erect 400–500μ long, 6–7 μ wide and dichotomously branched at the apex. Conidia are borne on phialides, cylindrical, uni–septate, 50–60 x 5μ and show polar germination. Control measures suggested are provision of adequate drainage conditions in the nursery beds or bags and drenching the beds/bags with ceresan wet 0.1% or Bordeaux mixture 1%.

Olunloyo (1976) observed a severe root rot of seedlings raised in polythene bags, the pathogen associated being *Pythium ultimum* and other fungi. He recommended incorporation of dexon in the soil at the rate of 113.6 kg/ha for controlling the disease.

Anthracnose disease

The disease is called "soorai" in Tamil Nadu and has appeared on epidemic form in Trichy in 1965 (Singh *et al.,* 1967; Anon, 1967). In Brazil, anthracnose disease is known to cause severe economic loss to the crop (Agnoloni and Giuliani, 1977). It was found to affect tender leaves, twigs, inflorescences, nuts and apples. Reddish brown, shiny, water-soaked lesions followed by resin exudation on the affected parts are the earliest symptoms seen. The lesions soon enlarge in size, killing the affected shoots. Affected tender leaves become crinkled and nuts and apples shrivelled. The inflorescences turn black as a result of attack. Successive attacks of terminal shoots for a couple of years may result in eventual death of the affected plants. Singh *et al.,* (1967) reported that *Colletotrichum gloeosporioides (= Gloeosporium mangiferae)* was the causative fungus, and that the fungus perennated on the dead tissues. The fungus enters the fruit through the floral stigma in the very early stage itself. The attacked nuts exhibit small black spots and apples become mummified. Rainfall seems to aid in spreading the disease. The disease is severe when rainfall coincides with the flowering season. Removal of affected parts of the plant, spraying the plants with 3:3:50 Bordeaux mixture (as has been recommended for control of anthracnose of mango caused by *C. gloeosporioides)* and provision of wind breaks by growing tall trees like casuarina, eucalyptus etc. to arrest the spread of the disease through-wind-blown spores, have been suggested for controlling the disease (Singh *et al.,* 1967). In Brazil, control of anthracnose was obtained by spraying Dithane M–45, Orthodifolatan 4F, Cercobin etc. (Lima et al., 1975, Menzes, Karam and Moura, 1975, and Menezes, Karam, Lima and Parente, 1975) Bastos and Figueiredo (1967) found that partially purified cultures of *Bacillus subtilis* inhibited the growth of *C. gloeosporioides* in culture.

In Cuddalore and Trichy areas of Tamil Nadu *Fusarium* sp. was isolated from dark brown shiny lesions (Anon., 1972). Perithecia of *Melanospora* sp. were found on affected parts when kept under moist conditions. However, the pathogenicity of the fungus has not been clearly established.

In additon to the above major diseases, the following diseases of less serious nature also were reported on cashew.

Fig. 7.1. Defoliation of a tree affected by 'die-back'

Fig. 7. 2. GUMMOSIS AFFECTED CASHEW TREE

Shoot–rot and leaf fall

Thankamma (1974) who reported the disease first in Kerala identified the causal organism as *Phytophthora nicotianae* var. *nicotianae.* The disease incidence was at its peak in July. During the South West monsoon period, black linear lesions develop on the stem along with gum exudations. The lesions enlarge in size resulting in collapse of the affected shoots and shrivelling of tender leaves. In the mature leaves the lesions are seen first on the midrib which later spread to the main lateral veins and leaf blade. Leaf and stem infection results in extensive defoliation. The fungus produces chlamydospores (35—37 μ) and sporangia (43.70—62.78 μ). Oospores were not observed in single culture, but formed when paired with *P. meadii.* The oospores measured 42 μ.

Decline in cashewnut

The disease was reported from Calicut (Ramakrishnan, 1955) causing defoliation and drying of twigs in the dry season. In 2–3 years the affected trees succumb to the disease. Fibrous roots of the affected trees were found to be infected by *Pythium spinosum.* Inoculation trials showed that the infection took place in rainy season and the symptoms appeared only later during the dry season. Application of cheshunt compound in the soil at the base was recommended to control the disease.

Leaf spots

Many types of leaf spots have been reported on cashew (Batista, 1957; Anon., 1960; Guba, 1961; Early and Punithalingam, 1972): grey blight *(Pestalotia microspora, P. dichaeta)* red leaf spot *(Phyllosticta* sp.), brown leaf spot *(Colletotrichum gloeosporioides)* ferruginous spots *(Phomatospora anacardicola)* leaf spot caused by *Phomopsis anacardii,* and red rust caused by an alga *Cephaleuros mycoides.* Spraying of 1% Bordeaux mixture, copper oxide 0.3% or Benlate 0.3% was recommended to control these diseases (Anon., 1960, Matta and Lellis, 1973). Olunloyo (1975) reported a leaf blight caused by *Pestalotia paeoniae* in Nigeria, while Polanaco (1973) observed in Venezuela *C. gloeosporioides (Glomerella cingulata)* affecting young leaves and *P. conglomerata* affecting older leaves. Batista (1957) studying foliage lesions on cashew caused by *Phomatospora anacardicola* reported that the asci measured 35–50 $\mu \times$ 15–16 μ. A vein and leaf blight caused by *Colletotrichum* sp. was reported recently from Maharashtra (Anon., 1973). Aquino and Melo (1974) and Castro *et al.,* (1977) reported *Diplodium anacardiacearum* from lower surface of cashew leaves causing small black disk shaped dots. *Phyllosticta anacardicola* and *Cercospora anacardii* were recorded from cashew leaves (Batista and Vital, 1952; Golato, 1970a). Against *Cercospora* leaf spot, Golato (1970b) recommended treatment with Zineb 0.2%. In some of the cashew growing areas, leaves of a few cashew trees show yellow spots. Sometimes the spots will be innumerous. The etiology of this disease is not exactly known.

Sooty mould

Leaves are often covered by dense sooty masses of the fungus, *Capnodium* sp. on both the surfaces, thus hindering the normal photosynthetic activity (Anon., 1960; Arailde and Mattos, 1971). This can be controlled by spraying fish oil rosin soap 1.5 kg.

in 100 lit water followed by 2% starch solution. The spray will control the associated insects and enable the sooty mould to fall off in flakes from the leaves when dried.

Powdery mildew

Phadnis and Elijah (1968) reported that cashew blossoms were affected by the fungus *Oidium* sp. in Maharashtra during cloudy days. Fruit set was found to be affected to a considerable extent. Powdery mildew was often found to occur along with anthracnose (Aquino and Camelo, 1971). Julio da Ponte (1971) described the fungus as *O. anacardii* Noach, and found that leaves, shoots and inflorescences were infected. In severely affected trees, the leaves become shrivelled and dry. Dusting of sulphur was recommended as a control measure. A hyperparasite *Cicinnobolus cesatii* was recorded from the lesions (Aquino and Camelo, 1971).

Leaf rot disease

This is a minor disease occurring in sporadic cases. The pathogen, *Cylindrocladium quinquiseptatum* causes leaf rot during the monsoon season resulting in defoliation.

Gummosis

The disease is characterised by exudation of a brownish liquid which later turns black in colour. Main stem and branches are affected and longitudinal cracks can be seen on the affected branches from which gum exudes (Fig. 7.2). This was observed in Kerala and Tamil Nadu Different fungi have been implicated with the disease. Fungi like *Pellicularia salmonicolor, Diplodia natalensis* (Medeiros, 1951) and *Ceratocystis* sp. have been isolated from affected parts in different places.

Diseases of apples and nuts

Fungi like *G. mangiferae, Aspergillus niger,* and *Rhizopus* sp. have been found to affect the cashew apple resulting in their decay (Anon., 1960). While immature and mature nuts were infected by *Cladosporium* sp. (Rangaswami *et al.,* 1970) and *Nematospora coryli* Peg. and *N. gossypii* Ash and Nowell (Golato, 1970a), *Aspergillus niger, A. flavus, A. tamarii, Rhizopus nigricans, Fusarium* sp. and *Gliocladium* sp. infected kernels causing dry rot (Esuruoso, 1974). Olunloyo (1978) reported a dry rot of immature cashewnuts in the plantations in Nigeria, resulting in reduced nut production per inflorescence. Fungi like *A. tamarii, Penicillium citrinum* and *L. theobromae* were found associated with the disease. Olunloyo (1978) found that the release of sugary exudation from immature nuts served as a predisposing factor to invasion by the above fungi. It was also observed that insect *Atopmyrmex* sp. which feed on the sugary exudate, help in disseminating the microorganisms. Infection of kernels by *A. niger* and *Rhizopus* sp. resulted in 5% damage (Anon., 1960). The fungi *Nematospora sp.* penetrate into the kernel and cause sunken dark spots which lower the market value of nuts (Agnoloni and Giuliani, 1977). Since injuries made by insects predispose the nuts to such infection, insecticide treatment as well as avoiding mechanical injuries while harvesting and drying were suggested by these authors to control the fungi.

Storage diseases may be due to imperfect drying or poor storage. Krishnaswamy *et al.,* (1973) reported contamination of cashew kernels with *Escherichia coli, Salmonella* sp. and *Clostridium* sp. in Kerala and Tamil Nadu. The extent and type of contamination depend on the level of sanitation in the processing units. Raw nuts were much more contaminated than the processed ones. Okwelogu and Mackay (1969) found that cashew-nuts are infected by *Aspergillus* sp. *Fusarium* sp., *Paecilomyces* sp., *Penicillium* sp. and *Rhizopus* sp. at 27°C when relative humidity is above 75%.

A "sudden death" disease was first recorded in Tanzania and is supposed to be caused by *Valsa eugeniae* Nutman and Roberts (Wallace and Wallace, 1955; Westergaard and Kayumbo, 1970). The other possible causative agents suggested are bacteria, virus, mineral deficiency, fungi like *Botryodiplodia theobromae* etc. The affected trees show foliar yellowing, defoliation and quick death. No definite control measures are known

In Maharashtra, Sathe and Srinivasulu (1971) recorded *Diatrypella indica* from dried stems of cashew.

In addition to fungi, diseases due to bacteria and nutritional deficiencies are also known to affect cashew. In Brazil, Robbs (1954) recorded a bacterium, *Pseudomonas mangiferae* occurring in cashew. Lefebvre (1973) reported a little leaf disease in cashew characterised by small, narrow, rolled leathery leaves which in extreme cases become needle like. He attributed this to Zinc deficiency and found that application of Zn to the soil or by foliar spray alleviated the symptoms. Adams *et al.,* (1971) opined that leaf necrosis observed in the Kenya coast was probably due to iron deficiency as they found that in pot culture studies application of iron chelates eliminated the necrosis. Symptoms due to deficiencies of N, P, K, Ca, Mg and S in young cashew plants grown in nutrient solutions were described by Avilan and Brasil Sob (1976).

APPENDIX 7.1. **Fungi, alga and bacteria recorded on cashew**

Name of the fungi/alga/bacteria	Reference
FUNGI	
Aspergillus flavus LK. ex. Fr.	Esuruoso, 1974
A. niger van Tieghem	Esuruoso, 1974
A. tamarii Kita.	Esuruoso, 1974 Olunloyo, 1978
Asterina carbonacea Cooke	Polanco, 1973
Botryodiplodia theobromae Pat.	Olunloyo, 1975
(Lasiodiplodia	Wallace and Wallace, 1955
theorbomae (Pat.) Gr. & M.)	Olunloyo and Esuruoso 1955
Capnodium sp.	Anon., 1960
Ceratocystis sp.	Author's observation (Unpublished)
Cercospora anacardii	Golato, 1970

Cicinnobolus cesatii de Bary	Aquino and Camelo, 1971
Cladosporium sp.	Rangswamy *et al.*, 1970
Colletotrichum gloeosporioides Penzig.	Singh *et al.*: 1967 Santos, 1968 Cordoba, 1967 Morton, 1961 Anon., 1960
Corticium salmonicolor B. & Br.	Browne, 1968, Morton, 1961
(Pellicularia salmonicolor (B. & Br.) Dastur)	Sarma *et al.*, (Personal communication)
Cylindrocladium quinquiseptatum Boed. & Reit.	Susamma Philip, 1973
C. scoparium Morg.	Wallace and Wallace, 1955
Cytonema sp. (*Valsa eugeniae* Nutman and Roberts)	Westergaard and Kayumbo, 1970.
Dendrodochium paraense	Ludowijk, 1927
Diatrypella indica Sath. & Srini.	Sathe & Srinivasulu, 1971
Diplodia natalensis Evans.	Medeiros, 1951
Diplodium anacardiacearum Bat. & Covalcante	Aquino and Melo, 1974
Fusarium sp.	Castro *et al.*, 1977; Anon., 1972 Ludowijk, 1927.
F. udum (Berk.) Woll.	Anon., 1972
(Gibberella bacata)	Browne, 1968
Ganoderma lucidum (Leys.) Karst	Okwelogu and Mackay, 1969
Gibberella bacata	Bohlen, 1973
(Fusarium udum (Berk.) Woll.)	Browne, 1968
Gliocladium sp.	Okwelogu and Mackay, 1969
Gloeosporium mangiferae P. Henn.	Esuruoso, 1974
Glomerella cingulata (St.) Sp. & Schr.	Anon., 1960
Lasiodiplodia theobromae (Pat.) Gr. & M.	Polanco, 1973 Olunloyo and Esuruoso, 1975 Olunloyo, 1978
Melanospora sp.	Anon., 1972
Meliola anacardiacearum (St.) Hans.	Ohler, 1977
Nematospora coryli Peg.	Golato, 1970
N. gossypii Ash & Now.	Golato, 1970
Oidium anacardii Noach	Aquino and Camelo, 1971 Julio da Ponte, 1971 Calzavara, 1970 Phadnis and Elijah, 1968
Oidium sp.	Okwelogu and Mackay, 1969
Paecilomyces sp.	Anon., 1960, Browne, 1868, Morton, 1964
Pellicularia salmonicolor (B. & Br.) Dastur	

Penicillium sp.	Okwelogu and Mackay, 1969
P. citrinum Sopp.	Olunloyo, 1978
Pestalotia conglomerata	Polanco, 1973
P. dichaeta Speg.	Anon., 1960
P. microspora Speg.	Guba, 1961
P. paeoniae	Olunloyo, 1975
Phomatospora anacardicola Bat.	Batista, 1957
Phomopsis anacardii Earl.	Anon., 1960 Early,
& Punith.	and Punithalingam, 1962.
Phyllosticta anacardicola	Batista and Vital, 1952
Phyllosticta sp.	Anon, 1960
Phytophthora nicotianae var.	
nicotianae Van. Breda de Hann	Thankamma, 1974
P. palmivora Butl.,	Kumararaj and Bhide, 1972
Pythium spinosum Sawada	Ramakrishnan, 1955
P. ultimum Trow.	Olunloyo, 1976
Rhizopus nigricans Ehrenb.	Esuruoso, 1974
Rhizopus sp.	Anon., 1960
Sclerotium rolfsii Sacc.	Browne, 1968
	Polanco, 1973
Valsa eugeniae Nutman and Roberts	Wallace and Wallace, 1955
	Westergaard and Kayumbo, 1970

ALGA

Cephaleuros mycoides Karst.	
(=C. virescens Kze.*)*	Anon, 1960; Golato, 1970
(=C. parasiticus)	Ludowijk, 1927.

BACTERIA

Clostridium sp.	Krishnaswamy *et. al.,* 1973
Escherichia coli (Migula) Cast.	
and Chalm.	Krishnaswamy *et al.,* 1973
Pseudomonas mangifera	Robbs, 1954
Salmonella sp.	Krishnaswamy *et. al.,* 1973

CHAPTER 8

HARVESTING AND PROCESSING

The hard kidney shaped nut of *A. occidentale* is the raw material for the cashewnut processing industry. However, in Goa the major cashew based industry is distilling alcoholic beverage called 'fenni' from cashew apple (see Chapter 9). The nut consists of a tough fibrous shell (pericarp) a thin brown filmy skin (husk/testa) and a white nut (kernel), which is edible and popularly known as cashewnut of the trade. The shell has a honeycombed structure and its cells contain a natural secretion of corrosive fluid known as cashewnut shell liquid (CNSL).

Harvesting

The crop is gathered from the ground after the apple is allowed to drop down naturally, with the attached nut. The fruits are collected everyday and the nuts are separated. Allowing the fruit to fall by itself ensures a fully matured nut. However, if it is left ungathered for sometime, the quality of the nut may get affected. The nuts gathered are sun dried for 2–3 days before storing. The main crop usually is harvested in April–May in India, but a few trees yield light crop during October–November.

In India, the cashew plantations are concentrated in Kerala, Karnataka, Tamil Nadu, Andhra Pradesh, Maharashtra, Goa and Orissa (the area and production figures are given in Chapter 2). There are about 250 medium sized cashew processing factories in India employing more than one lakh workers (Natarajan, 1977). Each factory processes 500 tonnes per annum.

Processing

Processing of cashewnuts can be defined as the recovery of edible meat portion–the kernel from raw nuts, by manual/mechanical means. In India, the processing is mostly manual (Russel, 1969 and Shivanna and Govindarajan, 1973). It consists of moisture conditioning roasting, shelling, drying, peeling, grading, and packaging.

Roasting

Roasting is designed to make the shell brittle. This is achieved effectively by a moisture absorption step preceding the roasting. The raw nuts are sprinkled with water and allowed to remain in moist condition for 24 to 48 hrs. This step is known as conditioning. The optimum moisture level at the end of conditioning is reported to be 15–25%. Two important points to be taken care of during conditioning are (i) the water should not seep through the brown testa and (ii) the water should be free from iron contaminations. Iron contamination in the water can interact with polyphenolic materials of testa and the resultant bluish–black complex may give patches on the white kernel.

The earliest process was the pan roasting wherein the nuts are heated on a metal pan over an open fire. Due to the heat and slight charring the shells become brittle. The pan roasting is not followed in organized sectors of the industries. The two important methods of processing now adopted are (i) Drum roasting and (ii) Oil bath roasting.

Drum roasting

The nuts are fed into a rotating red-hot drum, which ignites the shell portion of the nut and the ignition starts. The drum maintains its temperature because of the burning of the oil oozing out of the nuts. The drum is kept in rotation by hand for about 2–4 minutes. The roasted nuts which are still burning are covered with wood ash to absorb the oil on the surface. The rate of shelling and the outturn of whole kernels are very high in this method. However, the main disadvantage is the loss of CNSL which has a very good export potential. In addition there will be considerable heat and acrid fumes in the vicinity of this operation.

Oil bath roasting

The conditioned raw nuts are passed for 1–3 minutes through a bath of heated cashewnut shell oil maintained at a temperature of 190–200°C by means of screw or belt convoyer. The vessel is embedded in brick work and heated by a furnace which uses spent shells as fuel. During the roasting, the shell gets heated and cell walls get separated releasing oil into bath. As the level rises, the oil is recovered by continuous overflow arrangement. The roasted nuts are then conveyed into a centrifuge. The residual oil adhering to the surface of the nuts is removed by centrifuging. The roasted nuts are mixed with wood ash and sent for shelling. This method is fairly automatic, and the technique followed in different factories varies to some extent with regard to temperature and time of roasting.

In addition to the above two methods, in some places where hand and leg shelling machines are used, only a mild (either oil bath or drum) roasting is carried out. During the mild roasting only a small quantity of oil is recovered. The ideals to give a heat treatment without bothering about the recovery of CNSL. Drum roasting is usually carried out at about 100–120°C. No CNSL is lost due to ignition. The choice of mild oil bath or mild drum roasting depends on the built–in facility of a particular factory.

In Panruti (Tamil Nadu) the conventional roasting is completely avoided. The raw nuts are exposed to the intense sun that is prevalent in the region. The well dried nuts are hand shelled. In this method complete CNSL remains in the shell until shelling is complete. CNSL is later recovered by heating the shells in special tall mud pots referred to as kilns with holes at the bottom.

Shelling

The nuts after roasting are shelled manually except in some units where hand–and leg operated shelling machines are used (Fig. 8.1.). The manual shelling is an operation which requires some amount of dexterity. The nuts are knocked 2–3 times on each of the long edge by wooden mallets or light hammers taking care to see that the whole kernels are released without damage or breakage as far as possible (Fig. 8.2). The workers

in the shelling units in casew factories have acquired the skill through practice and the out–turn is more than 90% of the whole kernels in most of the factories, Individual workers' output is about 7–10 kg per 8 hr working day. As the shell oil is highly corrosive the workers smear ash or clay on their hands to prevent contact of the oil with the skin.

Fig. 8. 1. HAND AND LEG SHELLING

Fig. 8. 2. HAND SHELLING

The mechanical shelling gadget consists of two blades, between which a raw nut is inserted. The gap is adjustable and, therefore, it will be advantageous if the raw nuts are pre-graded on the basis of size. By means of a lever operated by leg, the blades are brought together which will cut into the shell without damaging the kernel inside. When the lever is operated, the halves of the concave blades are opened which in turn opens

e shell. The kernel is scooped out by means of a sharp needle. The output per worker er 8 hr shift in this method of shelling is estimated to be 15–18 kg of kernel.

Drying

After the kernels are removed from the shells they have to be dried to reduce moisture and loosen the adhering testa. Most commonly used one is Broma Drier (Lakshminarayana *et al.,* 1965; Russel, 1969). The chambers of the drier are indirectly heated by flue gases from a furnace at the bottom. Cashew shells are burnt as a source of heat. There are 4 to 6 chambers and in each chamber six-wire-mesh trays of 90 x 45 cm and 10–15 cm depth are loaded. Air vents are provided at the top and sides for the moisture to escape.

Each tray can hold 10 kg of material to a depth of 5–7.5cm. Temperature ranging from 70–100°C of the upper trays to 40–70°C in the lower trays will be prevailing (Mathew, *et al.,* 1972). In order to get uniform drying, the position of trays is changed at intervals of 10–30 min. The normal duration of heating is 6–12 hr. During this step despite precautions excessive scorching is likely to occur. To minimise the losses, a through-flow drier has been designed and fabricated at CFTRI Mysore with a capacity of 250 kg in a 4 hr shift to work at a temperature of 80°C (Fig.8.3). The scorching of cashew kernels is totally avoided and the drying time is reducedto 4 hrs. The moisture content of the dried samples will be in the range of 2 to 4.5%.

Peeling

Peeling is the operation of removal of the testa from the kernels. The skin would be loosened from the kernels by the drying which enables easy peeling off. Peeling is done by hand (Fig.8.4). In a small percentage of kernels, pieces of testa may still be adhering and these are removed with the help of sharp bamboo sticks/other devices. The testa which had been hitherto wasted has been found to be an excellent source of tannin.

Grading

The next stage in the processing is the grading of kernels on the basis of specifications for exportable grades. There are 25 exportable grades of cashew kernels (description of these grades is given in chapter 10). The kernels are sorted into Wholes, Splits and Brokens primarily on the basis of visual characteristics. The wholes are again size-graded on the basis of the number of kernels per 1 lb. The entire grading operation is done manually. However for size-grading mechanical operation is also practiced.

Packing

Final operation is packing in 10 kg capacity tins which are subsequently evacuated and filled with carbon dioxide. In some parts to overcome the possible over-drying a rehumidification step is introduced before packing. The practice of filling with an inert gas is mainly to combat infestation during transit. It may be pointed out that with high quality nut, free from infestation, storing with or without carbon dioxide makes very

little difference particularly with reference to rancidity (Shivasankar *et al.*, 1975). The importance of inert gas appears to be more for circumventing a possible insect attack from an occasional insect egg entering the tin while packing.

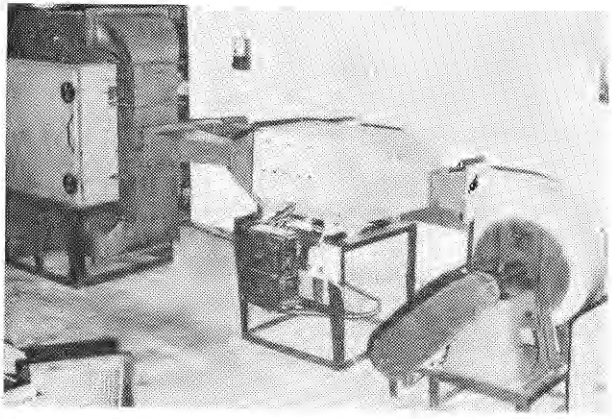


Fig. 8. 3. THROUGH-FLOW DRIER FOR DRYING CASHEW KERNELS

Fig. 8. 4. PEELING

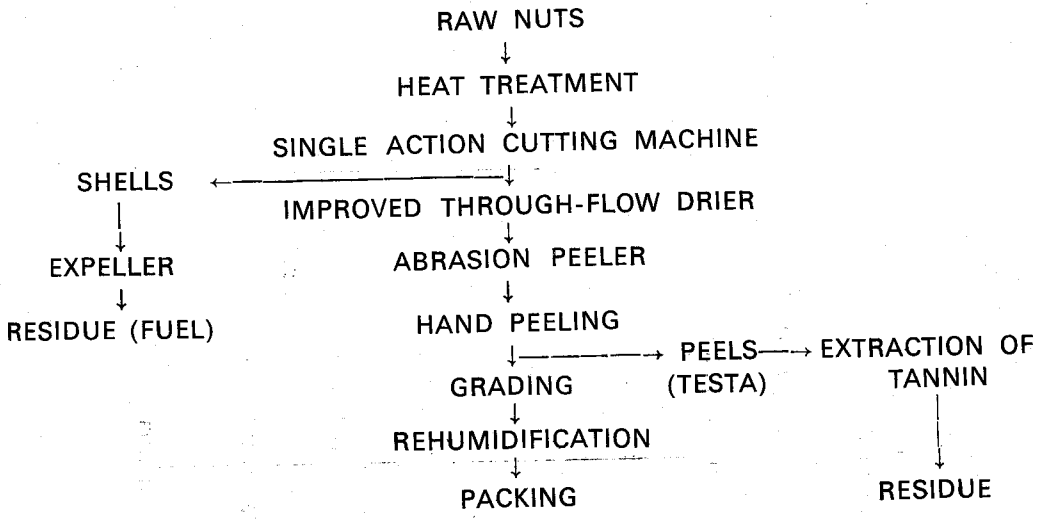
Nitrogen can also do the same function. However, carbon dioxide being a heavier gas is more convenient for handling. Contention that absorption of carbon dioxide makes the kernel more tasty does not have much truth. In any case the processed kernels are rarely consumed without a subsequent heat processing in the form of roasting frying and/or baking.

Relative merits of processing procedures followed in different parts of India

The Figure 8.5. represents the main differences in the processing steps in three different states of India.

It can be seen that the processing after shelling is almost similar except for adoption of rehumidification in some factories in Mangalore (Karnataka). Shelling, in general, is entirely by hand. Mangalore units employ the most modern techniques prevalent in India. Here the shelling gadget used gives improved output per worker without affecting the, yield of whole kernels. Another notable feature is the use of mild roasting and efficient extraction of CNSL by means of motor driven expellers. The technology employed in Panruti (TN) is comparatively less developed but interesting feature being removal of CNSL by Kilns after shelling operation.

An improved processing technology with more mechanisation is given below.



The mild roasting done in Mangalore and sun-drying done in Panruti prior to shelling indicate the possibility of simplifying roasting. The present shelling gadget can be improved to operate with only leg in one direction in two stages so that the hands are free for handling the product. Similarly it is possible to introduce an abrasive peeler to do initial 75% peeling. By using the improved through-flow-drier unwanted scorching can be reduced. It would be also advantageous to extract CNSL in an expeller after the shells are completely removed from kernel. As the peels are a good source of tannin, this aspect can also be exploited in future processing set ups.

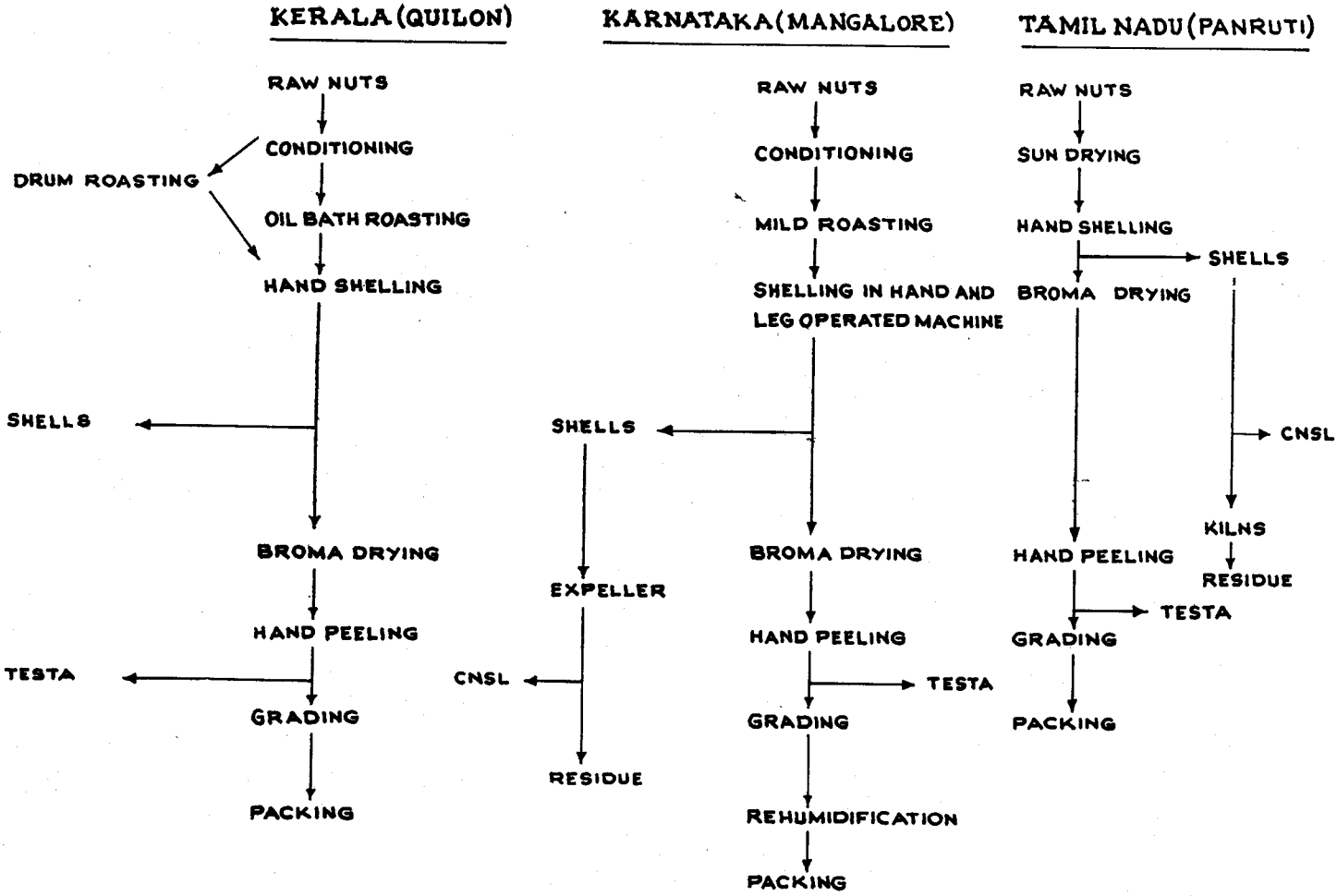


Fig. 8. 5. PROCESSING METHODS

Mechanical processing plants

In recent years with the help of European machinery manufacturers mechanical processing has been introduced in Africa. Two well known technologies are provided by (i) Sturtevant Engineering Co., London (who have designed their plant on TPI know-how) and (ii) Oltremere SPA Industria Prodotii Alimentazie Derivati, Bologna, Italy (Casadio, 1971; Bown, 1972).

TPI process employs a centrifugal automatic cracking device. According to the reports the yield of wholes after decortication is between 75–80% which corresponds to around 55% wholes at the packing stage. The process also uses an oil bath roasting at all temperature around 170–190°C followed by passing through the cracker, where the nuts after centrifugally accelerated are allowed to hit a series of target plates. On an average this process is repeated about 6 times. After the shelling, the kernels are dried in a continuous-drier heated by cashew shells to 85°C for one hour. The kernels are then led to a mechanical heater at the end of which about 75–80% of the peeling is completed. The rest of the peeling is done by hand.

The Oltremere plant uses a cutting machine for the decortication which gives about 65–70% wholes. The proposed capacity of the mechanical plants in different countries is given in Table 8.1 (Wilson, 1975).

It must be pointed out that the manual operation in India gives a considerably higher yield of Wholes (90–95%) when compared to these mechanical processing units. However, it is possible that the machines may be further improved to give the industry in India a greater competition.

TABLE 8.1. **Total capacity of mechanical processing plants in the world**

Country	*Sturtevant plants Capacity in tons/year*			*Oltremere plants Capacity in tons/year*		
	Installed upto 1973	*Orders for 1974*	*Total*	*Installed upto 1973*	*Orders for 1974*	*Total*
Mozambique	11,500	45,000	56,500	45,000	15,000	,60,000
Nigeria	..	2,000	2,000	..	..	..
Tanzania	..	1,000	1,000	12,000	12,000	24,000
China	..	1,000	1,000	..	..	..
Brazil	..	5,000	5,000	..	..	..
Kenya	..	..	..	..	15,000	15,000
Dahomey	..	..	..	57,000	43,000	100,000
			65,500			199,000

Source: TPI G. 91 1975

CHAPTER 9

CASHEW PRODUCTS

Every part of cashew is useful to man. Its edible and nutritious kernel contains fat, protein, carbohydrate, minerals and vitamins. Cashewnut shell liquid is an important raw material in paint, chemical and wood industry. Cashew apple, practically wasted at present is highly nutritious. It could be utilised for the production of alcoholic beverages, juice, syrup, jam, etc. Besides this, cashew tree is a valuable source of raw materials for pulp industry and is the major source of fuel in Kerala. In this chapter the main products and byproducts derived from cashew tree are discussed.

Nuts

Cashew is the most versatile of all nuts and is the most popular nut used by the confectionery industry. In USA alone 87% of the cashewnuts are used in nut salting. Whole kernels and pieces are being used in formulating confections, cakes, and cookeries, The nuts are exalbuminous and rich in protein, calcium, phosphorus, unsaturated fats. vitamins (B_1, B_2, D,E and PP), low in carbohydrates and saturated fats (Table 9.1). Hence they are of high nutritive value. As the nut fats are complete, very active and easily digestible, the nuts can be used by both old and infants alike.

TABLE 9.1. **Composition of cashew kernel**

Constituents	*Percentage* *	*Constituents Aminoacids*	*Percentage**
Moisture	5.9	Arginine	10.3
Protein	21.0	Cystine	1.3
Fat	47.0	Histidine	1.8
Carbohydrate	22.0	Lysine	3.3
P	0.45	Methionine	1.3
Ca	0.55	Phenylalanine	4.4
Fe	5.0 mg/100 g	Threonine	2.8
		Tyrosine	3.2
		Valine	4.5

Cashew proteins are complete with all essential and nonessential amino acids and can be considered equal to peanut and soybean for proteins and to meat, milk or egg for proteic substances. The kernels supply about 6000 calories energy per kg as against 3600 by cereals, 1800 by meat and 650 by fresh fruit.

A globulin called " anacardein " of the following composition is isolated from cashew nuts: Carbon 50.41%, Hydrogen 7.32%, Nitrogen 19.30%,Sulphur 0.78% and Oxygen 22.19%. The nitrogen is distributed as: Humin N 1.40%, amide N 11.91%, dicarboxylic acid N 18.79%, organic N 21.57%, Histidine N 4.78%, Lysine N 1.54%' monocarboxylic acid N 29.50%, nonamino N 10.09%.

The testa contributes to 3.5% of kernel weight and has the following composition: moisture 11.55%, mineral substances 1.60%, cellulose 11.59%, carbohydrates and sugars 37.44%, ether soluble substances 30.84% (Woodroof, 1967). The testa contains polyphenols like (+) catechin, (—) epicatechin etc. (Subramanyan and Nair, 1969).

The kernel peel having some adhering kernel particles serves as an excellent poultry feed as they are having the following nutritive composition: Moisture 8%, Protein 7.6%, fat 12.3%, carbohydrate 59.2%, and ash 1.8% (Mahendru, 1975). The residue from peeled kernels after extracting kernel oil, also called caribbean oil (40%) is used to produce cashew kernel butter which is almost similar to peanut butter. The kernel oil contains: Oleic Acid 73.77%, Linoleic Acid 7.67%, Palmitic Acid 6.4%, Stearic Acid 11.24%, Lignoceric Acid 0.5%, unsaponifiable matter 0.42%. The oil contains 18.2% saturated acids and 81.8% unsaturated acids. The oil is light, sweet, light yellow, odourless and as nutritive as olive oil, soybean oil or wheat oil.

Salad oil extracted from kernel is expensive and so not marketed to any degree. The properties are: sp. gravity at 78.8°F-0.9105, refractive index at 86°F-1.4665 Iodine No.-85.2, acid No.-1.45 (Woodroof, 1967).

The nuts are mostly salted. For salting, the nuts pass through several processes like roasting at 120–175°C followed by cooling to 65°C, application of oil dressing with an antioxidant, application of salt with an antioixdant, cooling to 43°C, application of shine oil, allowing to set and packaging under vacuum.

The pericarp of the nut consists of coriaceous epicarp, spongy mesocarp and stony endocarp. The kernel covered with testa is contained in a shell about 3 mm in thickness. The mesocarp consists of a honey comb net work of cells containing a viscous liquid called cashewnut shell liquid. The shell has the following composition: moisture 13.17%, ashes 6.74%, cellulose and lignin 17.35% azotic substances 4.06% sugars 20.85%, and ether soluble substances 35.10%.

Apple

On the basis of production of nuts in India, it is estimated that about 8,40,000 tonnes of cashew apple fruits are available, out of which Kerala alone accounts for about 6,00,000 tonnes. At present most of these apples are wasted and practically not utilised industrially in any of the cashew growing tracts in India except Goa.

The fruit is very juicy and the expressed juice has a brix of 12–14° containing 10.15–12.5% sugars (mostly reducing) and about 0.35% acid (as malic). It is known for its rich vitamin C content, upto five times that of citrus fruit (Table 9.2).

TABLE 9.2. **Chemical composition of cashew apple**

Constituents	*Percentage*
Moisture ..	87.8
Proteins ..	0.2
Fat ..	0.1
Carbohydrate ..	11.6
Calcium ..	0.01
P ..	0.01
Fe ..	0.2 mg/100g
Vitamin C ..	261.5 mg/100g
Minerals ..	0.2
B carotine ..	0.09

The apple is eaten as such by sucking the juice and discarding the residual fibrous mass. Sugar or salt is added sometimes for reducing the astringency.

The astringent, acid, and acrid taste is due to about 0.35% tannins and other substances present in the apple (Jain *et al.*, 1954). Sastri *et al.*, (1962) found that tannin decreased with progressive increase in ascorbic acid as the fruit ripened.

Removal of astringent and acrid principles

According to Jain *et al.*, (1954) steaming the cashew fruit was the most efficient in removing the astringent and acrid principles. Pressure of steam and time of exposure vary from 2–6 kg and 5–15 minutes respectively, according to the quality of the fruit and the product to be made. The fruits have to be thoroughly washed in water before further processing. Treatment of the fruit for 4–5 minutes in boiling solution of common salt(2%), or H_2SO_4 (0·2 N) followed in each case by washing in water gave results comparing closely with those for the steam treated fruit. The residual traces of undesirable constituents can be successfully removed by treatment of the juice with very small concentrations of casein, gelatin, pectin or lime juice followed in each case by straining or centrifuging.

The juice from the fresh fruit can also be treated with gelatin (0.25–0.4%) and pectin (about 0.35%) depending upon the undesirable constituents in the fruit, Lime juice (25%) imparted a strong flavour of its own, besides raising the acidity. The flocculent

precipitate formed in addition to the above materials can be removed by straining or centrifuging.

Cashew apple beverages

Clarified cashew apple juice

The cashew apple is highly perishable and requires prompt handling. Only good and sound fruits should be used for juice extraction. The cashew juice can be extracted from cut fruits in a screw type juice extractor or by pressing in a basket press or preferably by a combination of the two operations. The astringent and acrid principles are removed. After filtration, the brix of the juice is raised to 15° and acidity to 0.4% by addition of sugar and citric acid. The juice is then boiled for a minute and preserved by overflow pasteurization at 85–90°C for 30 minutes in 12 oz glass bottles or 1 lb squat cans.

Cloudy juice

The cashew apples steamed at 2–4 kg pressure for 5–10 minutes or boiled for 4–5 minutes in sulphuric acid (0.2 N) or common salt followed by cooling and washing in water are used for juice extraction. The juice expressed are then treated with 0.045% gelatin, 0.1% casein or 0.05% lime juice. The precipitate is separated and juice formulated and preserved like the clear juice.

Jain *et al.,* (1954) reported that clarified and cloudy juices gave good blends with lime, pineapple, orange, grape and apple juice which further yielded good carbonated beverages. They also reported the possibility of spiced cashew apple juice.

Preservation and storage of cashew apple juice and its blends have been studied by Sastri *et al.,* (1963). Extraction of cashew apple juice with a screw type juice extractor yielded more juice (66%) than a basket press (38%). The latter, however, required less gelatin to remove the astringent principles.

The loss of ascorbic acid in cashew apple juice or its blend at the end of 32 weeks storage was found to be 49–66% at 37°C and 29–54% at room temperature. The colour of cashew apple juice was highly sensitive to heat. Browning during storage was comparatively less in canned than in bottled juice. After 32 weeks storage at 37°C the juice and its blends with 50% pineapple juice or with 1.5% lime juice were quite acceptable from taste and flavour stand point.

Studies were also carried out at CFTRI Experiment Station, Trichur on different methods of extraction of juice from cashew apple, clarification of cashew apple juice cashew apple juice blends etc. (Satyavathi *et al.,* 1963). The clarified cashew apple juice with 10% lime juice and adjusted to 20°B gave a good palatable product. The clarified cashew apple juice adjusted to 15°B and 0.35% acidity blended with ginger extract was also quite good. Blends with equal parts of pineapple juice or with 25% of mango pulp were also found acceptable.

Cashew apple syrup

The juice from cashew apple steamed at 2–4 kg steam pressure for 5 to 10 minutes can be treated with 6 to 7% of its quantity of lime juice, accompanied by stirring, allowed

to settle for about 15 minutes and strained through thick cloth. Appropriate quantity of sugar to raise the brix to 35° can be added and the mixture brought to a quick boil. After holding for a minute at boiling temperature the syrup can be cooled quickly and bottled after preservation with 350 ppm SO_2 (Jain *et al.,* 1952). The syrup can be used after dilution and can also form a base for carbonated beverage.

The following are some of the drinks from apple juice:

Cashola: This is a ready-to-serve carbonated beverage obtained from clarified cashew juice (Anon., 1970). The acidity of juice is raised to 0.4% and its brix to 29°C. The carbonated beverage from this base is prepared by dilution with three volumes of water.

Cajuda: This is the most popular cashew drink in South Brazil (Johnson, 1977). Apple juice is bottled as such without any adhesives. It is mixed either with water or combined with milk and sugar in a drink called *Cajuada. Cajuina,* a less common drink is prepared by pasteurising the juice. Followed by filtering to obtain a clear, light nonalcoholic drink. *'Cajuvita'* is a vitamin-enriched juice while *'caju aperativo'* is the juice mixed with sugarcane brandy.

Cashew apple juice concentrate

Jain *et al.,* (1954) reported that on concentration at 50–55°C under vacuum, both the clear and cloudy juices yielded good quality concentrates for use in the preparation of aerated drinks. A concentration of 30–35° brix could be reached in case of cloudy juice and 65–70° brix in case of the clarified juice.

Physical and chemical changes during concentration of cashew apple juice in an open pan and a forced circulation evaporator and also in a thin-film evaporator were studied by Pruthi *et al.,* (1963). Two stage vacuum concentration of the detanned cashew apple juice with the addition of 100 ppm sulphur dioxide at the two fold concentration stage, yielded a concentrate that kept well for 16 weeks at room temperature.

The possibility of preparing a golden syrup from cashew apple juice by adopting clarification process as practiced in the refining of sugar was studied at CFTRI Experiment Station, Trichur (Satyavathi, *et al.,* 1963). The cashew apple juice was clarified by adjusting the pH to 7.4 using calcium oxide and heating to 195°F when all the suspended matter and other substances settled down. The clear juice was siphoned off, pH adjusted to 6.0 using phosphoric or citric acid and concentrated under vacuum in a forced circulation evaporator. The concentrated syrup had a bland taste and contained 400–500mg ascorbic acid. The golden syrup prepared from cashew apple juice compard well with commercial golden syrup and was richer in nutrients. However, the colour of the concentrate was rather brown with good clarity. But on dilution to 15°B the colour was quite good. The concentrate gave good blends with ginger and lime.

The clarified juice by gelatin treatment concentrated in a forced circulation evaporator after addition of sulphur dioxide had 600–800 mg of ascorbic acid and blended well with ginger extract (Satyavathi *et al.,* 1963).

Cashew apple vinegar

Satyavathi *et al.,* (1963) studied the possibility of preparing vinegar from cashew apple juice. The brix of the cashew apple juice was raised to 12°, the juice was pasteurized, cooled and inoculated with a pure strain of yeast, *Saccharomyces cervisiae* or brewer's yeast for alcoholic fermentation. Addition of 0.05% ammonium phosphate was found to help fermentation. Vinegar fermentation was done by " slow process " as well as by " quick process." In the " slow process " the alcoholic ferment was mixed with one-third the quantity of mother vinegar (unpasteurized vinegar) and left as such. In the quick process the vinegar was prepared by passing the alcoholic ferment mixed with mother vinegar through a column 1.3–1. 7m in height filled with corn cobs. The vinegar prepared was filtered and pasteurized. The cashew vinegar thus prepared had more than 5.3% acidity and compared well with commercial vinegar.

Cashew apple candy and jam

The preparation of cashew apple candy after curing the ripe and undamaged cashew apple in brine solution starting with 2% concentration and increasing it upto 10% (this takes 5–6 days) and steaming at 2–4 kg pressure for 10–15 minutes is reported, by Jain *et al.,* (1954). The actual candying process was then carried out as usual starting with a 30° brix syrup containing 0.05% citric acid.

Jain *et al.,* (1954) have also reported the preparation of cashew apple and mixed jams after treating the fruits in 2% common salt solution for 3 days followed by steaming at 4–6 kg pressure for 10–15 minutes. Sugar equal to the weight of the fresh fruit can be used and 0.3% citric acid added towards the end of the cooling process. Mixed fruit jams by mixing the cashew apple pulp with equal quantity of banana pulp or pineapple pulp can also be prepared.

Canning of cashew apple

Firm fruit suitable for canning is first peeled by treatment in 0.5% boiling sodium hydroxide solution for 3–4 minutes, followed by rinsing in water and a subsequent treatment for about 4 minutes in boiling 0.2 N solution of $H_2 SO_4$. The fruit after washing is steamed for about 4 minutes at 2 kg steam pressure followed by cooling under a spray of water. After draining, the fruit is cut into halves (lengthwise) and after trimming off the undesirable portions, canned in 40° brix syrup using an exhaust time of 4–5 minutes in boiling water or steam and a process time of half an hour in steam at 4 kg pressure (Jain *et al.,* 1954). A good quality salad pack is said to be obtained by mixing pineapple ring segments with cashew apples in equal proportions.

Canned curried vegetables from raw green fruit in combination with potatoes (1:1) or potatoes and tomatoes (2:1) with or without tamarind are also reported (Jain *et al.,* 1954).

Cashew apple chutney and pickles

Cashew apple chutney can be prepared from fruits treated in 2% brine as for jam followed by washing and steaming at 4 kg steam pressure for 5–7 minutes (Jain *et al.,* 1954).

Raw green fruit is steamed as recommended earlier, washed and kept in 10% brine for a week. It is then pickled in the usual way as half fruits after trimming off the undesirable end portions (Jain *et al.*, 1954).

It has been reported that cashew apple products as preserves, juice and wine are commercially produced and marketed in Brazil (Johnson, 1977). The production of cashew preserve was started as a cottage industry in the colonial period. The following five types of preserves are mainly made in Brazil: (i) stewed apples in syrup *(doce em calda)*, (ii) the typical sweet *(doce)* having a consistency of thick jam, (iii) cooled pulp formed into balls and coated with sugar *(caju cristalizado)* (iv) cooked and partially dried apples in syrup *(caju ameixa)* and (v) jelly. The apples are to be processed within hours of their receipt at the factory.

Bottled apples are sold in Ceara in Brazil to tourists (Johnson, 1977). While the peduncle is still small, the nuts are removed and the peduncle introduced into bottle and allowed to grow. When fully matured, the apples are separated from the main branch and the bottle is filled with sugarcane brandy.

At present a number of factories in Brazil manufacture preserves and juice. Juice production is commonly linked to the manufacture of preserves. Cashew juice concentrate and wine are also marketed.

The natives of Brazil, dry the peduncle and powder them into a meal which can be used as a bait for catching crustaceans (Johnson, 1977). In Mozambique, it is used as animal feed.

Alcoholic beverages

These are obtained by the fermentation of apple juice. In Goa, a sort of brandy called ' Fenni ' is made by fermenting apple juice (Naronha, 1973, 1975; Manekar, 1973a, 1973b, 1975; Thomas d'sa, 1971). Fenni is derived from the word *Fenno* in Konkini language (vernacular of Goa) meaning froth (Naronha, 1975). In Tanzania, a product called *Koniagi* akin to gin is made. Naronha (1973) reported that in Goa cashew apples were utilised exclusively for the preparation of liquor by distillation through old and crude methods. The Government has recently brought necessary legislation introducing distillation by modern techniques. Goa is the only place in India where cashew liquor has been distilled, for the last three centuries or more. More recently apples are used in Kerala for making cashew brandy. Efforts are in progress to start one more cashew apple distillery in North Kerala. In Brazil cashew wine prepared by fermentation of apples is declining in importance as the wine commands a price not too much above juice, yet requires more expenditure to produce (Johnson, 1977).

Good and sound cashew apples preferably by plucking from the trees should be used. The cashew apples should be washed under a shower and the tannin content reduced by mechanical or chemical process. Finally, the juice should be extracted by mechanical crusher and preserved under anaerobic conditions. The total yield of cashew apples in Goa will be approximately 35,000 tonnes which can give about 17,500 kilo lit of juice and about 2,187,500 lit of cashew fenni when distilled by modern techniques.

But actually the total collection will not be that much due to various factors like eating by wild animals and premature removal of nuts. Taking the brix of fresh cashew juice as 10.5°, after complete fermentation under anaerobic conditions, the alcohol would be 10.5 x 0.575 = 6.03. Since 8 litres of cashew apple juice are required to obtain one litre of fenni, the alcohol content will be 6.03 x 8 = 48.24%. The chemical composition of cashew fenni prepared by scientific distillation in Goa has been reported by Naronha (1973).

Manekar (1975) in his paper on ' Caju fenni ' described the method of preparation and other details regarding cashew fenni in Goa. According to him, in India cashew apples are wasted except in Goa where complete use of it is made in the manufacture of alcoholic beverages. The secret of making Caju fenni lies with Goan ingenuity. Backed by expertise and experience extending over several years, the Goan has mastered the art and know-how to manufacture good fenni. In the traditional method the juice of cashew apples is collected in vats which when allowed to stay, is acted upon by the bacteria present in the apple causing fermentation. The fermented juice is distilled in pot stills to give " Arrack " which on further distillation produces " Fenni " which is 25 U.P. (under proof). It is further matured in wooden barrels to give " Finenesse " to the product.

However on modern scientific lines, the cashew apple juice should be extracted from good fruits by mechanical means, the juice filtered, detanned, pasteurized and cooled. It should be inoculated with a strain of pure yeast and after fermentation and racking, the distillation should be done by modern techniques. Good quality dessert wine and brandy from cashew apple have been developed at CFTRI (Subba Rao, 1972). Distillation has been done using columnar stills for obtaining the brandy. Collection of cashew apples at a central place is beset with difficulties as it should be transported in the shortest possible time. Otherwise, other organisms will, multiply utilising the sugar.

Eventhough technical know-how for the preparation of different products from cashew apples are available, except for the manufacture of ' fenni ' in Goa mainly on a cottage scale, cashew apples are not commercially utilised in India. Collection of cashew apples is one of the problems. Since the cashew apples are highly perishable the fruits cannot be kept for more than a day. The apples must be processed within hours of their receipt at the factory. Fermentation sets in quickly. The flavour and taste of cashew apples are not liked by many. Due to the presence of astringent and acrid principles as mentioned earlier, the fruit as such cannot be used as in the case of other fruits. Removal of astringent and acrid principles by steaming or by gelatin precipitation involves one more step in processing and adds to the cost of the final product. Another reason may be that in the regions where cashew apples are available fruits with a better flavour and taste like pine apple, mango etc. are also available and the products from them have a better consumer appeal than those from cashew apple. Cashew apple is superior to other fruits in Vitamin C content (150–350 mg/100 g). But unless much publicity is given, the products from cashew apple cannot compete with other fruit products. In that case also blending of cashew apple juice after clarification with ginger, lime juice, pineapple or mango will be necessary for juice, concentrates or concentrate-based beverages. In case of distilled alcoholic products like fenni, and in fruit products as vinegar this taste factor is not that much of a problem.

Cashewnut shell liquid

The pericarp of the nut consists of a coriaceous epicarp, spongy mesocarp and stony endocarp. The kernel covered with testa membrane is contained in a shell 1/8 inch thick. The mesocarp consists of a honey comb net work of cells containing a viscous liquid called cashewnut shell liquid (CNSL) which provides a natural protection to the kernel against insects.

CNSL is valuable raw material for a number of polymer based industries like paints and varnishes, resins, industrial and decorative laminates, brake linings and rubber compounding resins (Kamath, 1956). CNSL is traditionally obtained as a byproduct during the isolation of the kernel. Though India is the major producer of CNSL, East African countries like Tanzania and Mozambique have also started producing this material in recent years. The average annual production of CNSL in India is of the order of 10,000–14,000 tonnes(Anon, 1977a)though the potential availability of this liquid is about 37,000 tonnes. Production of CNSL in India (1970–74) is given in Table 9.3. The world Patent Literature on CNSL and its utilization have been published (Anon, 1964, 1977, 1978). The survey indicated that CNSL and its derivatives are in good demand for paints, synthetic resins, laminated products, brake linings and clutch facings when the material is available at reasonable rates. Recently Murthy and Sivasamban (1978) reviewed the CNSL and its utilisation. The consumption of CNSL by various industries during 1971–78 is given in Table 9.4.

Extraction of CNSL

There are various processes for the extraction of CNSL from the raw nuts, *viz.* Hot oil bath, Expeller, Kiln, Solvent extraction processes. The most common method is the ' Hot oil ' process which was first introduced in India by M/s. Peirce Leslie and Company Limited in 1975.

i. Hot oil bath: The raw nuts are passed through a bath of hot CNSL itself by which the CNSL is extracted from the shells of the nuts. This method extracts only 50% of the liquid contained in the nuts. Although some improvements have been made in this process the method had basically remained the same and is extensively in use in Quilon and other areas in Kerala.

ii. Expellers: Shells from which part of the oil has already been extracted either by ' hot oil process ' or by roasting are used. In Mangalore area (Karnataka) some factories have introduced manually operated cutting machines in which the shells of the lightly roasted nuts are cut keeping the Kernel intact. The shells are subjected to expeller operation for extracting CNSL. About 90% of the liquid present in the shell can be extracted by this method.

iii. Kiln method: This method is extensively employed in Tamil Nadu and to some extent in Kerala. In this method the nuts are either shelled after sun-drying or after drum roasting. The liquid extracted by this method is crude and contaminated with shell pieces and other foreign matter.

iv. Solvent extraction: The solvent extraction process is the most efficient since it is possible to extract maximum quantity of CNSL from the shells by this method; but this process is expensive and needs considerable technical skill.

TABLE 9.3. **Production of CNSL in India**
(Quantity in metric tonnes)

Year	*Kerala*	*Karnataka*	*Tamil Nadu*	*Total*
1970	4,600	4,200	1,000	9,800
1971	4,200	3,800	900	8,900
1972	3,500	3,800	800	8,100
1973	3,500	3,900	700	8,100
1974 (estimate)	9,500	3,900	600	14,000

Source : "Cashewnut Shell Liquid - Prospects for Expansion of Internal Consumption and Exports" by Indian Institute of Foreign Trade, p. 13

TABLE 9.4. ***Consumption of CNSL by various industries***
(Quantity in metric tonnes)

Industrial uses	1974	1975	1976	1977	1978
Brake linings	1000	1100	1200	1350	1500
Paints and varnishes	900	1100	1300	1600	1900
Chemical resistant cement	60	75	95	120	130
Oil tempered hardboards	60	50	70	80	100
Foundry core oil	700	850	1050	1300	1600
Epoxy resins	Neg.	—Included in the estimate for cardanol			
Laminates			*–do–*		
Water proofing compound	16	20	20	30	32
Filter paper	..	150	150	150	150
CNSL based resins	20	50	50	50	50
Cardanol	850	1100	1340	1900	2280
Total :	3596	4495	5275	6580	7762

Source : "CNSL Prospects for Expansion of Internal Consumption and Exports" by the Indian Institute of Foreign Trade, p. 45

v. Other methods of extraction: A new method of extraction of CNSL developed in India is based on the extraction of the oil from shells by the action of ultra frequency microwaves. It is also reported that an Italian process for the mechanical shelling and peeling of cashewnut is being adopted for processing of cashewnuts in Tanzania and Mozambique.

Chemistry and composition of CNSL

As a result of extensive research work (Ruhemann and Skinner, 1887; Spiegel and Dobrin, 1896; Smith, 1931; Pillay, 1935; Gokhale *et al.,* 1940). It was found that cold extracted CNSL consists mainly of anacardic acid (6–alkyl salicylic acid) 90% and cardol (3–alkyl resorcinol) 10%. However during the commercial extraction the liquid undergoes heat treatment due to which it decarboxylates, the anacardic acid being converted to cardanol (3–alkyl phenol). Thus commercial CNSL contains cardanol and dihydric phenol (cardol) as major constituents and minor amounts of anacardic acid along with trace amounts of gallic acid, glucosides etc.

It has been shown (Gokhale *et al.,* 1940; Wasserman and Dawson, 1946; Sletzinger and Dawson, 1946; Izzo and Dawson, 1949; Paul and Yeddanapalli, 1954) tha the substituent chain present in anacardic acid, cardol and cardanol is not a homogenous diolefin, but is a mixture of olefins with different degrees of unsaturation. It was found by Murthy, *et al.,* (1968) using modern chromatographic techniques that cardanol (A.V. 20, I. V. (wijs)212–228, H. V. 180–200) had the saturated component 5.4%, monoolefin 48.5%, diolefin 16.8% and triolefin 29.3%. They also reported the presence of another component in CNSL and commercial cardanol in addition to the components of cardanol and cardol. Gedam *et al.,* (1972), using NMR technique showed the presence of 6–methyl cardol. They also showed the presence of higher proportions of diene and triene components in 6–methyl cardol and cardol than in cardanol. The average side chain unsaturation in the case of cardanol, 6–methyl cardol and cardol amounts to 1.5, 2.0 and 2.0 double bonds per mole respectively. Tyman (1976) showed that cold extracted CNSL contained $82 \pm 1.05\%$ anacardic acid, $13.8 \pm 0.17\%$ cardol,. $2.6 \pm 0.16\%$ 2–methyl cardol and $1.6 \pm 0.17\%$ cardanol, by the use of gas–liquid chromatographic methods. For commercial CNSL, the mean results were $83.0 \pm 0.51\%$ cardanol and $2.7 \pm 0.34\%$ 2–methyl cardol.

Properties of CNSL

The physical and chemical characteristics of typical samples of CNSL are as follows:

	Solvent extracted CNSL	*Commercial CNSL*
Specific gravity 30°C	0.9958–0.9998	0.92–0.98
Viscosity	170–230	150–160
Loss on heating %	8–12	2
Acid value	104–110	8–20
Iodine value (wijs) 1hr	220–230	220–270
Saponification value	106–118	18–30

The Indian Standards Institution has adopted a specification IS: 840–1972 for commercial CNSL.

Toxic nature of CNSL

CNSL is toxic to human skin on contact. The dermatitis produced in human beings by CNSL is due to the presence of urushiol, a homologue of catechol or similar material. However, the decarboxylated and refined CNSL is not toxic.

Industrial applications of CNSL

CNSL and its derivatives have been employed for various types of preparations for use as resins, polymers, bactericides, fungicides, and pesticides. CNSL owes its importance in the production of resins and polymers to its phenolic character, combined with the unsaturated side chain. Harvey and his collaborators carried out extensive work on the utilization of CNSL in the preparation of surface coatings and other products (Harvey and Caplan, 1940). M/s. Harvel Corporation patented a number of processes on the utilization of CNSL in USA, UK, and Japan during 1943–1963. Because of the unsaturation in the side chain of cardanol, CNSL undergoes polymerization and oxidation reaction producing a variety of products of industrial utility. CNSL polymerizes when heated in presence of some metals like copper, aluminium, lead or their oxides and forms good media for paints when further cooked with drying oils. Rubber like products and other useful materials have been obtained by copolymerizing CNSL with styrene after treatment with aldehydes. Jain and George (1972) reported a CNSL based sealant for sealing cracks and joints in buildings. The advantages of CNSL coatings are that they yield flexible and hard films with good adhesion to all common substrates and excellent water and chemical resistance. CNSL based varnishes possess superior insulation, insecticidal and anticorrosive properties.

Condensation products of CNSL with formaldehyde or other aldehydes

Condensation of phenol with formaldehyde to produce phenol-formaldehyde resins of the novolak or resole types is well known. Similar reactions also take place with CNSL but due to the presence of the long hydrocarbon chain, the condensation products are more flexible than the conventional phenolic resins. These resins can be used for surface coatings with or without oil modification when colour is not of much importance but high chemical resistance is desired. A number of useful products based on CNSL–aldehyde condensation products useful for different purposes like surface coatings, moulding powers, insulating varnishes were developed by the Harvel Corporation. Air drying varnishes are prepared by reacting CNSL with aldehydes, drying oils and vinyl monomers in the presence of catalysts and are used as media for primers, marine paints, and as insulating varnish. High grade varnishes prepared from polymerised CNSL aldehydes and oleoresinous varnish are used as media for enamels.

Work done in India

In India the utilisation of CNSL formed the subject of investigation by many workers (Siddique and Khan, 1942; Ajmani and Jatkar, 1944; Ranganathan and Tandon, 1946; Mathur and Aggarwal, 1953). Important contributions in this field came from Research and Design and Standard Organisation (RDSO), Indian Railways, Regional Research Laboratory (RRL), Hyderabad, National Chemical Laboratory (NCL), Poona.

Extensive work was carried out (Ramanujam and Ajmani 1958a and b; Ramanujam and Ramamurthy, 1958, 1959) on the preparation of a variety of coating compositions possessing insecticidal properties by adding DDT, Gammexane or dieldrin to CNSL or chlorinated CNSL after treatment with formaldehyde. Fire resisting and heat insulating paints based on sodium silicate and CNSL or chlorinated CNSL or their condensation products were developed. Emulsion of CNSL resins and polymerized CNSL were made by dispersing them in aqueous slurry of bentonite or tannin with or without formalin. Isogel dispersion resins obtained by converting CNSL into a non–tacky and semi–solid resin by treating it with aldehydes in suitable solvent media. Zinc rich paints were also developed based on CNSL. Fire retardant paints were obtained by pigmenting chlorinated CNSL medium with red mud, titanium dioxide, sodium silicate, antimony oxide, brass, mica powders, vermiculite and asbestos. Epoxy resins from CNSL were also prepared and used in protective coatings.

Research on the utilization of CNSL for more than a decade has helped in developing a number of surface coating materials based on CNSL and its derivatives. A process for upgrading the low grade CNSL (Murthy and Aggarwal, 1959) was developed. CNSL oleoresinous varnishes (Patel, *et al.,* 1968) were prepared by heating even low grade CNSL, drying oil and a suitable resin together. Air drying varnishes having excellent properties suitable as media for anticorrosive primers, ship bottom paints and impregnating and insulating varnishes were prepared by reacting CNSL with hexamine, drying oil and polymerizable monomer in presence of a catalyst. High grade varnish (Sivasamban *et al.,* 1961a, and b; and Aggarwal *et al.,* 1966), from CNSL having excellent water resistance was prepared by reacting polymerized CNSL with formaldehyde and then mixing it with a suitable proportion of oleoresinous varnish. Baking varnishes from CNSL were prepared by condensation of CNSL with fatty acid or with dicarboxylic acids and then reacting with glycerine at elevated temperature.

Production of cardanol

Cardanol is the major constituent of CNSL. The dark colour of CNSL prohibits its use in light coloured finishes. A method was developed to obtain pale coloured cardanol in 60–70% yield by distillation of CNSL under low pressures (Murthy *et al.,* 1961). About 30–35% residue is left over during the distillation. The cardanol obtained as above is available in two grades (Murthy and Sivasamban, 1978) (Table 9.5).

TABLE 9.5. **Characteristics of the two grades of cardanol**

	Grade I	*Grade II*
Empirical formula	$C_{21}H_{320}$	$C_{21}H_{320}$
Specific gravity 30°C	0.9272–0.9335	0.9272–0.9335
Viscocity (30°C) (CP)	47–52	47–52
Volatile loss	1%	2%
Ash content	Negligible	0.5%
Iodine value	212–228	212–228
Acid value	2	5
Hydroxyl value	180–200	180–200
Colour	Straw pale	Pale brown

Utilization of cardanol and distillation residue

Lacquers of different types suitable as coatings, insulating varnishes, furniture coatings, as media for quick drying enamels were prepared by Murthy and his colleagues (Murthy *et al.*, 1969; Ramanujam *et al.*, 1970). The CNSL distillation residue and its blends with alkyd were used in the preparation of air drying varnishes, cycle enamels and primers (Ramanujam, *et al.*, 1971 a and b). Cardanol based phenolic resins are more flexible with higher solubility in normal hydrocarbon solvents. The films of cardanol based resins are known for their superior electrical resistance. Vinyl resins (Kulkarni *et al.*, 1973; Isaiah, *et al.*,1968;Isaiah and Aggarwal,1969) based on cardanol have given films of excellent properties. Pale coloured adhesives have been obtained by reaction of cardanol–formaldehyde resin with epichlorohydrin (Murthy *et al.*, 1969).

Production of hydrogenated cardanol and its utilization

A process was developed (Hemalatha *et al.*, 1971; Madhusudhan *et al.*, 1973) for preparation of hydrogenated cardanol or 3–pentadecylphenol (3–PDP) which can be used in azopigments as coupling agent and in surfactants. Pure phenolic resins like Novolaks and Resoles are prepared from cardanol by reacting with formaldehyde. By condensation of these resins, epoxy resins are prepared using epichlorohydrin and sodium hydroxide. This is used for preparation of lacquers. Phenolic resins were prepared (Hemalatha and Aggarwal, 1969) from cardanol and 3–PDP either alone or in combination with other phenols by reaction with formaldehyde. Paints based on 3–PDP and in blends with alkyd resins gave excellent weathering performance (Sundara Ramiah, *et al.*, 1973). Different lacquers are prepared from cardanol by reacting it with hexamine at different temperatures. They are used as external decorative lacquer for biscuit tins, wooden furniture, etc.

Considerable work on the utilization of CNSL and its derivatives in surface coatings and other industries was carried out in Poona, India. Cardanol and 3–pentadecyl phenol were employed for the preparation of azodyes (Gulati and Subba Rao, 1966). CNSL has been used to prepare anion exchange resins by reaction with hexamine and formalin (Krishnaswamy, *et al.*, 1957; Dasare and Krishnaswamy, 1965).

Other useful derivatives from CNSL

Brake–lining is one of the important products in which large quantity of CNSL is employed. Brake–linings made from CNSL have excellent frictional and other desirable properties (Shivadasani, 1972). The foundry industry is another industry which utilizes considerable quantities of CNSL. It imparts good scratch hardiness to sand cores after baking and makes them resistant to water and weathering conditions (Verma,1969). In addition to the above mentioned products, CNSL and its derivatives are used in the preparation of antioxidants, lubricants, bactericides, fungicides, disinfectants, insecticides, pesticides, herbicides, drugs, etc. (Eichabum, 1946; Gulati and Rao, 1964; Guati *et al.*, 1964; Koteswara Rao, 1965, Koteswara Rao *et al.*, 1966); de Blic (1972) reported the use of CNSL resins for protecting the thatched roofs. Rice husk boards prepared from CNSL residue based resin as binder are useful for false roofing, as insulating panels and for accoustic purposes.

A number of derivatives of 3–pentadecyl phenol were synthesised and have been found to give good pesticidal and pharmacological properties. Processes for the preparation of L–(3–pentadecyl acryloxy)– propionic acids and their derivatives and for the preparation of L–(3–pentadecyl acryloxy)–isobutyric acids and their esters have been developed.

Products from bark, stem and leaves

Bark contains an acrid sap of thick brown resin which becomes black on exposure to air. This is used as an indelible ink in marking and printing lines and cottons. Woodroof (1967) reported its use as a varnish, as preservative for fish nets and as flux to solder metals. Since it contains plenty of tannin (4.9%), it is used for tanning also.

Stem yields amber coloured gum which is partly soluble in water, the main portion swelling into a jelly–like mass. This is used in book binding as cardol, one of the components, acts as a vesicant and has got insect repellant properties (Thatchenko 1949).

Wood of cashew is fairly hard and has a density of 500 kg/m^3 (Mahendru, 1975). In Latin America, it is referred to as "White mahogany". In addition to its popular use as firewood, for charcoal, as wheel hubs, yoke etc., the pulp from the wood is used to fabricate corrugated and hard board boxes. These boxes are collapsible, but are strong enough to compete with conventional packing wooden cases. The ash is rich in potassium and so used for applying as a manure to crop plants. Since cashew wood is able to withstand sea water it is used in building fishing boats and also in fabricating containers usually required for transhipment of poly–vinyl acetate emulsions. This helps to save a lot of non–woody materials employed at present. For arresting low concentrations of hydrogen sulphide, iron–oxide impregnated cashew woods can be used. The wood is used for making furniture, false ceilings, interior decorations etc., since they are less attacked by death watch beetle *(Xestobium rufovilosum).*

The leaves and branches are used by tribals as an antiseptic post–parturition bath additive (Mahendru, 1975). The use of young leaves and shoots as salads or for cooking with rice has been reported (Agnoloni and Giuliani, 1977). The leaves contain 1.7–1.9% minerals and 2.5–3.9% tannins with 55–65% moisture. They also contain cardol and anacardic acid.

Medicinal uses

There are many medicinal uses of the plant (Watt, 1889). The kernels possess aphrodisiac qualities. Apple is eaten as a remedy for scurvy. Cashew syrup is a good remedy for coughs and colds. Cashew apple juice is said to be effective in treating syphilis. Root infusion is an excellent purgative. Old cashew liquor in small doses cures stomach ache. Fenni has laxative properties. The cardol and anacardic acid possess powerful rubefacient and vesicant properties. The oil obtained from the shell by maceration in spirit is applied to cure cracks on the sole of the feet, common in villagers.

CHAPTER 10

MARKETING

Introduction

Cashew gained commercial importance when shipments of cashew kernels commenced from India during the first quarter of the present century and in 1925 a significant quantity of 50 tonnes of cashew kernels was exported from India. Since then the export trade has developed phenomenally so much so that during 1960 India met 95% of the world demand for cashew kernels by exporting 39,436 tonnes, with the U.S.A. as the biggest buyer followed by the U.S.S.R, U. K., Eastern Europe, Australia, Canada and West Germany. Cashew industry in India was mainly depending upon the imports of raw nuts from other cashew producing countries notably Tanzania, Mozambique and Kenya. The year-wise import of raw cashewnut into India, export of cashew kernels from India and their values and the percentage of indigenous production reflected in export trade for the period from 1947 to 1978 have been given in Table 10.1. It will be seen that the annual export of cashew kernels from India ranged from 50,000 to 66,000 tonnes in the past decade except for the year 1977–78, and that about two-third of the processed nuts were imported till the year 1973–74 and only one–third of the processed nuts came from the indigenous production which reflected in the export. From 1974–75 onwards the percentage component of the indigenous nuts which entered in the export trade has been increasing.

The export of cashew kernels from India has grown at the rate of 4.1% per annum during the period 1947–78. During the same period the world export of cashew kernels has grown at the rate of 6.6% per annum. The component of indigenous production in export trade has grown comparatively at a slow rate of 3% per annum. The elasticity of the cashew kernels exported from India with reference to the indigenous component in export trade has turned out to be 1.36 and the elasticity with reference to the total exports in the world is only 0.62. It is evident therefore that Indian export has been growing faster than the Indian production but lagging behind the world demand. The only solution to the growing problem facing the industry is to increase the indigenous production to the level of 5 lakh tonnes within a short period of 5 to 8 years.

Present pattern of marketing

Marketing of raw cashewnut in India has not yet been organised in a systematic, manner except in Kerala. A major portion of the produce is bought by itinerant merchants and the agents of the processing units who visit the growers' premises for the collection of the produce. A number of wholesale merchants and the processing factories open their collecting centres in important producing areas for buying nuts direct from the

TABLE 10.1. **Export of cashew kernels, import of raw nuts and indigenous production**

Sl. No.	Year	Export of cashew kernels		Raw nuts equivalent at 24% of recovery	Import of raw nut		Component of indigenous production	Percentage of indigenous production reflected in export
		Quantity	Value in Rs.(000)		Quantity in MT	Value in Rs. (000)		
1.	1946–47	15410	55610	64208	31545	12063	32663	50.87
2.	1947–48	16906	41330	70442	35150	11879	35292	50.10
3.	1948–49	18578	49250	77408	43512	15302	33896	43.79
4.	1949–50	19277	56080	80321	54205	21599	26116	32.51
5.	1950–51	26307	85510	101279	54819	28456	46460	45.87
6.	1951–52	21250	88900	88542	43030	32760	45512	51.40
7.	1952–53	28343	129774	118096	52509	46584	65587	55.54
8.	1953–54	27056	109906	112733	65227	42251	47506	42.15
9.	1954–55	34784	106968	144933	87185	42530	57748	39.84
10.	1955–56	31359	129246	130663	63154	48372	67509	51.67
11.	1956–57	31275	145345	130313	51416	42897	78897	60.54
12.	1957–58	36735	151568	153062	99440	69440	53981	35.27
13.	1958–59	41020	158525	170917	125400	76484	45517	26.63
14.	1959–60	38789	160514	161621	95950	72600	65671	40.63
15.	1960–61	43625	189130	181771	118321	26082	63450	34.91
16.	1961–62	41755	181705	173983	101876	67022	72107	41.44
17.	1962–63	48555	193613	202313	155331	91727	46982	23.22
18.	1963–64	50994	214147	212475	157458	109320	55017	25.89
19.	1964–65	55676	290615	231983	191523	164385	40460	17.44
20.	1965–66	51267	273996	213613	160636	150603	52977	24.80
21.	1966–67	50756	427535	211483	141021	212432	70462	33.32
22.	1967–68	51039	430291	212663	168218	250837	44445	20.90
23.	1968–69	63661	609291	265254	195528	313767	69726	26.29
24.	1969–70	60625	574217	252604	163426	275994	89178	35.30
25.	1970–71	50284	520568	209516	169359	294076	40157	19.17
26.	1971–72	60378	613321	251575	169985	279060	81590	32.43
27.	1972–73	66278	688214	276158	197938	318093	78220	28.32
28.	1973–74	52293	744322	217887	150249	287986	67638	31.04
29.	1974–75	65025	1181373	270937	160358	366043	110579	40.81
30.	1975–76	53640	961328	223500	137196	335578	86304	38.61
31.	1976–77	51565	1059860	214851	74131	180800	140720	65.5
32.	1977–78	39111	1476121	162962	60194	187199	102768	63

farmers. The petty dealers who buy the nuts from the growers also dispose of the nuts in these depots. Cashewnuts are brought for sale to the assembling markets largely by the itinerant merchants.

As there are a number of intermediaries operating in the field between the primary producer and the processing unit, the different costs and margins in the total spread between the producer and the processing unit are quite significant and the producer's share in the price paid by the processing unit is generally low.

Collection of raw nuts

The harvesting season is from February to the end of May or early June on the West Coast and one month later on the East Coast. Harvesting is done by the grower himself or by hired labour. There is no systematic collection of raw cashewnuts in most of the states except in Goa where the apples are also collected and utilised for the manufacture of cashew fenni. It is desirable in the interest of both the grower and cashew industry that nuts must be harvested only when the apples are fully ripe.

Grading procedures

One of the impediments to establish a suitable agency to undertake the collection and marketing of raw cashewnuts is the absence of any standard system of grading. While there is an elaborate system of grading in vogue in the case of cashew kernels (Table 10.2) raw cashewnuts are not graded either by the producer or by the trader. In the absence of a well defined grading system for raw nuts, the producers do not get prices commensurate with the quality of their produce.

The Directorate of Marketing and Inspection in the Ministry of Agriculture had framed grade standards for raw cashewnuts. The factors on which grade specifications are based are moisture, void nuts, number of nuts per kg, immature and damaged nuts. As the quality of raw nuts produced in Kerala is superior to that produced in other areas, two separate schedules have been prescribed for these two regions (Tables 10.3a and 10.3b). The Raw Cashewnuts Grading and Marketing Rules framed in 1966 are yet to be implemented. Introduction of grading will have to be taken up without further delay. This can be undertaken by the regulated markets and co-operative marketing societies in a phased manner for the benefit of the producers and sellers.

Organisation of co-operatives

Co-operative marketing in cashewnut has not developed to the desired extent as in the case of some other commercial crops, except in Kerala State. Out of the total marketable surplus, it is estimated that only a negligible quantity is being handled at present on co-operative basis. The producers are generally persons of small means. They do not have sufficient resources to keep the available produce with them and sell it at the appropriate time at a better price in a better market. It is, therefore, necessary that village co-operative cashew marketing societies with cashew growers as members be established in all the important producing centres.

TABLE 10.2. **Specifications for cashew kernels**

Reproduced below are extracts from the relevant notifications issued by the Government of India in regard to details of the 25 different grades of cashew kernels approved for export.

CASHEW KERNELS (WHOLE)

Grade designation	*Number of kernels per kg. or lb.*	*General characteristics*
W 180	375 to 395 (170 to 180)	Cashew kernels shall have been obtained through shelling and peeling cashewnuts *(Anacardium occidentale),* shall have the characteristic shape; shall be white, pale ivory or light ash in colour, reasonably dry, and free from insect damage, damaged kernels and black or brown spots. They shall be completely free from rancid kernels. The kernels shall be completely free from testa.
W 210	440 to 465 (200 to 210)	
W 240	485 to 530 (220 to 240)	
W 280	575 to 620 (260 to 280)	
W 320	660 to 705 (300 to 320)	
W 400	770 to 880 (350 to 400)	
W 450	880 to 990 (400 to 450)	
W 500	990 to 1100 (450 to 500)	

Tolerance : Broken kernels and kernels of the next lower grade, if any shall not together exceed 5 per cent at the time of packing

SCORCHED CASHEW KERNELS (WHOLE)

Grade designation	*Trade name*	*General characteristics*
SW	Scorched wholes	Cashew kernels shall have been obtained through shelling and peeling cashewnuts *(Anacardium occidentale),* shall have the characteristic shape; shall be reasonably dry and free from insect damage, damaged kernels, black spots and testa. They shall be completely free from rancid kernels. The kernels may be light brown, light ivory, light ash or deep ivory in colour due to scorching as a result of overheating.

Tolerance : Broken kernels and kernels of the next lower grade, if any shall not together exceed 5 per cent at the time of packing

(Contd.)

DESSERT CASHEW KERNELS (WHOLE)

Grade designation	*Trade name*	*Blemish*	*General characteristics*
SSW or SW IA	Scorched Wholes Seconds or Scorched Wholes I.A.	Slightly Shrivelled kernels	Cashew kernels shall have been obtained by shelling and peeling cashewnuts *(Anacardium occidentale),* shall have the characteristic shape; be reasonably dry and free from insect damage and testa. Slightly scorched kernels and kernels with slight speckling and discolouration permitted. They shall be completely free from rancid kernels. The kernels may also be immature. The kernels may be light brown, light blue or light ivory in colour due to scorching.
DW	Dessert wholes		Cashew kernels shall have been obtained by shelling and peeling cashewnuts *(Anacardium occidentale)* shall have the characteristic shape; shall be reasonably dry and free from insect damage and testa. Scorched, discoloured, speckled and shrivelled kernels permitted. Rancid kernels not permitted. The kernels may show deep black spots.

Tolerance : Broken kernels or kernels of the next lower grade, if any shall not together exceed 5 per cent at the time of packing

(Contd.)

CASHEW KERNELS (WHITE PIECES)

Grade designation	*Trade name*	*Description*	*General characteristics*
B	Butts	Kernels broken crosswise and naturally attached,	Cashew kernels shall have been obtained by shelling and peeling cashewnuts *(Anacardium occidentale)*, shall be white, pale ivory or light ash in colour, reasonably dry and free from insect damage, damaged kernels, and black spots. They shall be completely free from rancid kernels. The pieces shall be completely free from testa.
S	Splits	Kernels split naturally lengthwise.	
LWP	Large White Pieces	Kernels broken into more than two pieces and not passing through a 4–mesh 16 SWG sieve.	
SWP	Small White Pieces	Broken kernels smaller than those described as LWP but not passing through a 6–mesh 20 SWG sieve.	
BB	Baby Bits	Plumules and broken kernels smaller than those described as SWP but not passing through a 10–mesh 24 SWG sieve.	

Tolerance : Up to 5 per cent of the next lower grade or pieces at the time of packing

CASHEW KERNELS (SCORCHED PIECES)

Grade Designation	*Trade name*	*Description*	*General characteristics*
SB	Scorched Butts	Kernels broken crosswise and naturally attached	Cashew kernels shall have been obtained through shelling and peeling cashewnuts *(Anacardium occidentale)*, shall be reasonably dry and free from insect damage, damaged kernels, black spots and testa. They shall be free from kernels. The pieces may be light brown or deep ivory in colour due to scorching as a result of over-heating.
SS	Scorched Splits	Kernels split naturally lengthwise	
SP	Scorched Pieces	Kernels broken into pieces and not passing through a 4–mesh 16 SWG sieve	
SSP	Scorched Small Pieces	Broken kernels smaller than those described as SP but not passing through a 6–mesh 20 SWG sieve.	

Tolerance : Up to 5 per cent of the next lower grade or pieces at the time of packing

(Contd.)

DESSERT CASHEW KERNELS (PIECES)

Grade designation	*Trade name*	*Description*	*Blemish*	*General characteristics*
SPS	Scorched Pieces Seconds or Scorched Pieces IA	Kernels broken into, pieces but not passing through 4–mesh 16 SWG sieve	Pieces of shrivelled kernels, Maybe deformed due to immature nuts and black spots.	Cashew kernels shall have been obtained through shelling and peeling cashewnut *(Anacardium occidentale)*, shall be reasonably dry and free from insect damage and testa. Scorched pieces with surface speckling and discolouration permitted. The kernels may be light, brown, deep ivory or light to deep blue in colour. May be deformed due to immature nuts and may have spots. They shall be free from rancid kernels.
DP	Dessert Pieces	Kernels broken into pieces but not passing through 4–mesh 16 SWG sieve	More shrivelled than those described as SPS and deeply scorched	Cashew kernels shall have been obtained by shelling and peeling cashewnut *(Anacardium occidentale)*, and shall be reasonably dry and free from insect damage and testa. The kernels may be deeply scorched, may have surface speckling and discolouration, may be brown, deep ivory or light to deep blue in colour, may be deformed and shrivelled due to immature nuts and may have spots. They shall be free from rancid kernels.
DSP	Dessert Small Pieces	Kernels of the same description as above but smaller than DP and not passing through 6–mesh 20 SWG sieve	do	
DB	Dessert Butts	Kernels broken crosswise and naturally attached	do	
DS	Dessert Splits	Kernels split naturally lengthwise	do	

Tolerance : Up to 10 per cent of the next lower grade at the time of packing

Cashew kernels shall be packed in new, clean, dry and leak-proof tin containers and the containers shall be securely closed and sealed in such a manner that the cashew kernels remain in an inert atmospheric condition inside the container.

(Contd.)

TABLE 10.3a. **Grade designation and definition of quality of raw cashewnuts produced in areas other than mentioned in Table 10.3b.**

Grade designation	*Special characteristics*						
	Extraneous matter Maximum %	*Moisture Maximum %*	*Number of nuts/kg. Minimum %*	*Void (.) nuts Maximum %*	*Immature (x) nuts Maximum %*	*Broken(*) and damaged nuts Max. %*	*General characteristics*
Special	0.25	12	160	1.0	2.0	2.0	Raw cashewnuts shall be dried, ripe nuts of *Anacardium occidentale.* L. grown in the North and South Kanara districts of Karnataka State. The raw cashewnut shall:— (a) have the shape, colour and other characteristics of the variety (b) be well dried and matured (c) be free from musty odour (d) be free from moulds, diseases, decayed nuts, insect attack, etc.
Good	0.25	12	180	2.0	3.0	3.0	
Fair	0.25	12	210	3.0	4.0	4.0	

(.) Void nuts : Nuts in which there are no kernels.

(×) Immature Nuts : Nuts the kernels of which are shrivelled.

(*) Extraneous matter includes stones, dirt, dust, part of dried fruits and leaf etc.

Damaged : Nuts containing discoloured kernels and diseased nuts.

TABLE 10.3b. **Grade designation and definition of quality of raw cashewnuts, produced in Malabar and Konkan Coast**

Grade designation	*Special characteristics*						*General characteristics*
	Extraneous matter%	*Moisture Maximum%*	*Number of nuts/kg Minimum%*	*Void (.) Maximum%*	*Immature (x) nuts Maximum%*	*Broken and damaged/(*) diseased nuts Maximum%*	
Extra special	..	12	100	..	..	..	Raw cashewnuts shall be the dried ripe nuts of *Anacardium occidentale* L. grown in the Malabar Coast of Kerala State and in the Konkan Coast of Karnataka State. The raw cashewnuts shall (a) have the shape, colour and other characteristics of the variety; (b) the well dried and matured; (c) be free from any musty colour; (d) be free from moulds, diseases, decayed nuts, insect attack etc.
Special	0.25	12	150	1.0	2.0	2.0	
Good	0.25	12	160	2.0	3.0	3.0	
Fair	0.50	12	180	3.0	4.5	4.5	

Extraneous matter : Includes stones, dust, dirt, parts of dried fruits and leaf etc.

(.) Void nuts : Nuts in which there are no kernels

(×) Immature nuts : Nuts the kernels of which are shrivelled

(*) Damaged nuts : Nuts containing discoloured kernels and diseased nuts

Cashew marketing in Kerala

The steps taken by the Government of Kerala in the procurement of raw cashew-nuts during 1977 and 1978 seasons are commendable and worthy of emulation by other cashew growing states. During 1977 and 1978 seasons, the Government of Kerala appointed the Kerala state Co-operative Marketing Federation Limited, as the sole agent for cashew marketing. The Marketing Federation in turn appointed 1049 and 1132 Co-operative Societies throughout the state as sub-agents for the procurement of raw nuts during 1977 and 1978 seasons respectively and about 68,000 and 79,000 tonnes were procured during the two years. The Government of Kerala fixed the procurement prices as well as the issue prices of raw nuts from time to time depending upon the price of cashew kernels in the international market. The procurement price and the issue prices of raw cashewnuts in different districts of Kerala during the peak marketing period in 1977 and 1978 are given in Table 10.4. The procurement price is the price received by the grower and the issue price is the price paid by the processing unit. The procurement prices of raw cashewnut, commission charges, transport and other charges, and issue prices in different districts in Kerala during the peak marketing period in 1978 are given in Table 10.5.

It may be seen from the Table 10.5 that the producers' share in the price paid by the processing unit has ranged from 83.46% in Alleppey and Trivandrum districts to 87.49% in Cannanore district. The share of the commission charges of the primary co-operative societies was approximately 2.6%. The share of transport and other charges was ranging from 10.0% in Cannanore district to 13.9% in Alleppey and Trivandrum districts.

The producer's share in the processor's price of raw cashew nut is fairly high as it is above 80% in all the districts in Kerala. However, the cost of marketing can be considerably reduced.

Regulated marketing

In order to streamline the marketing system, and to increase the producer's share in the consumer's price by regulating the costs and margins of different market services and functionaries, many state governments have already enacted the Agricultural Produce Market Acts and the major agricultural commodities have been notified under these acts. Such regulatory measures have improved the efficiency of marketing system and helped to reduce the total spread between the producer's price and the price paid by the consumer. However, raw cashewnut has not been brought under regulation in the important cashew growing states. Only in Tamil Nadu raw cashewnut arrives in significant quantities in the regulated markets as it is a notified crop under the Agricultural Produce Market Act in that state. Cashew is a notified commodity in about 20 regulated markets in Tamil Nadu such as Jayankondam and Andimadom, Panruti, Vridhachalam, Cuddalore, Tanjavoor, Gandharvakottai, Vallam, Alangudi, Udayapalayam and Kadambuliyoor. The regulated markets receive cashewnuts from producers. The produce of each seller is given a lot number and the lot is sold to the trader who offers the highest price provided. the seller agrees to the price. The nuts are disposed off in closed bid auction system In the interest of promoting orderly marketing, it is necessary that the state governments should in areas where co-operative marketing societies have not been established or are

TABLE 10.4. **Procurement and issue prices of raw cashewnuts fixed by the Govt. of Kerala**

Name of Districts in the state	1977 SEASON				1978 SEASON			
	Procurement price Rs./ quintal with effect from 29.1.77	Issue Price Rs./ quintal with effect from 8.3.77	Procurement price Rs./quintal with effect from 2.4.77	Issue price Rs./ quintal with effect from 6.4.77	Procurement price Rs./quintal with effect from 22.4.77	Issue price Rs./ quintal with effect from 30.4.77	Issue price Rs./ quintal with effect from 20.5.77	Procurement price Rs./quintal with effect from 16.2.78	Issue price Rs./ quintal with effect from 16.2.78	Procurement price Rs./quintal with effect from 22.5.78	Issue price Rs./ quintal with effect from 22.5.78
1. Cannanore	400	451	500	559	600	671	685	610	698	410	698
2. Calicut	390	454	490	565	590	682	712	590	691	390	691
3. Malappuram	390	454	490	565	590	682	712	590	691	390	691
4. Palghat	390	459	490	572	590	689	712	590	698	390	698
5. Trichur	380	448	480	560	580	678	700	590	698	390	698
6. Ernakulam	380	443	480	554	580	670	716	580	679	380	679
7. Idukki	380	443	480	554	580	670	716	580	679	380	769
8. Kottayam	380	448	480	560	580	678	716	580	687	380	687
9. Quilon	380	458	480	573	580	693	742	580	694	380	694
10. Alleppey	370	446	470	561	570	681	730	570	683	370	683
11. Trivandrum	370	446	470	561	570	681	730	570	683	370	683

TABLE 10.5. **Share of the producers, commission agents, transport and other charges in prices paid by the processing units in Kerala State in 1978**

Particulars	Cannanore		Calicut & Malappuram		Palghat & Trichur		Ernakulam & Idukki		Kottayam		Quilon		Alleppey & Trivandrum	
	Rs./Qtl.	%	Rs./Qtl.	%	Rs. /Qtl.	%	Rs. /Qtl.	%	Rs. /Qtl.	%	Rs. /Qtl.	%	Rs. /Qtl	%
1. Price received by the grower	610	87.49	590	85.38	590	84.53	580	85.42	580	84.43	580	83.57	570	83.46
2. Commission to societies	18	2.58	18	2.61	18	2.58	18	2.65	18	2.62	18	2.59	18	2.63
3. Transport and other charges	70	10.02	83	12.01	90	12.89	81	11.93	89	12.95	96	13.84	95	13.91
4. Price paid by the processing unit	698	100.00	691	100.00	698	100.00	679	100.00	687	100.00	694	100.00	683	100.00

defunct, establish regulated markets for the indigenous produce, after declaring cashew as a notified commodity.

Transportation and storage

The growers and the itinerant merchants collect the nuts from the producers and transport them to the assembling markets by head load, bullock carts, water barges, buses or trucks depending on the quantity and cost of transportation. The transport from the assembling market to the processing units is generally by trucks or train.

Since the producers and itinerant merchants sell the raw nuts to wholesale dealer or the processing units immediately after collection, storage is generally done only by the processing units. The processing factories purchase their annual requirements and transport them to the drying yards in the premises of the factory. The nuts are then spread in the drying yard for complete drying in the sun for a day or two. They are then packed and stored in gunny bags, in lots of 80 kg each. In some places the raw nuts after drying are stored in heap in air-tight godowns, specially constructed for the purpose. The percentage of dryage in godown is reported to be ranging from two to six.

Packing

Raw cashewnuts

For purposes of transportation and storage cashewnuts in lots of 80 kg each are packed in gunny bags. As the outer shell enclosing the kernel is quite hard, gunny cloth packing is considered quite satisfactory.

Cashew kernels

The kernels are usually packed for export in cans of 25 pounds (11.35kg) net weight, and two cans to a wooden case. To prevent deterioration in quality and extend storage life of cashew kernels, air in the tin is exhausted by means of suction pump. Certain firms pack their kernels by pumping carbon dioxide into the tin after the air has been exhausted out. The improved method of packing now prevalent is vita-packing. It is reported that kernels packed in vacuum keep well for about an year, andthose with carbon dioxide for over two years.

Cashew kernels for internal markets are also packed in tins containing 9 to 11 kg. For retail selling smaller packing varying from 0.5 kg to 6.5 kg are also adopted. Many firms use polythene bags as the container instead of tins for smaller quantities.

Pricing and marketing efficiency of cashewnut

It is often asserted that the cashew processors in the country are monopolistic and exploitative. *But no empirical study has so far been made to test this contention. Very little data are available on the cost of marketing* including the processing cost of cashewnuts. Marketing efficiency is defined as the 'movement of goods from producers to consumers at the lowest cost consistent with the provision of services consumers desire.' It is also assumed that the prices offered to the cashew growers are not remunerative and they should be assured of a minimum support price. This price is supposed to cover

the cost of production and a reasonable margin of profit. Correct data are not available on the cost of production of cashewnut because most of the cultivators do not maintain proper accounts. Whatever quantity harvested is sold.

However, it has been estimated that the cost of cultivation in Kerala will be about Rs. 1069/– for one ha of 10 year old plantation when full bearing is expected. The grower will have to incur an expenditure of 75 paise per kg for collecting the nuts and the total cost of collection per ha will work out to Rs. 750/–. Therefore, the total cost of production of raw nuts works out to Rs. 1819/– per ha. Though with proper management, scientific planting techniques, timely fertiliser application and plant protection measures, yields upto 1500 kg per ha can be obtained, it has been estimated that the average yield will be from 100 kg per ha in the 5th year gradually increasing to 1,000 kg per ha in the 10th year. The estimated costs and benefits of cashew cultivation for one ha is shown in Table 10.6.

The wholesale prices of raw nuts in important markets in the country during the peak marketing period (Feb–July) for the last 10 years (1969–1978) are given in Table 10.7.

As the cashew industry is export-oriented, the internal prices depend very much on the international kernel prices. The international prices are much influenced by the prices prevalent in New York market. The monthwise prices of cashew kernel in New York market for the last seven years are given in Table 10.8. Therefore, there should be always a correlation between the raw nut prices in the country and the kernel prices in New York. The raw nut prices in the local markets are always likely to be equal or less than 'Parity Price. 'The parity price is that price of the raw nut which, after an allowance for the normal marketing cost, enables the processor to sell the kernels at their current prices. Whenever the prices of raw nut and the kernels are so adjusted, parity is presumed. The concept of parity is flexible and changes with fluctuations in costs. Therefore, for a processor-cum-exporter, the following equation gives the parity prices :

$$P_p = Q\ (K–T) – C$$

where P_p is the processor's parity price of raw nut (in rupees per quintal);

K is the price of one quintal of kernels in New York;

T is the cost of transporting one quintal of kernels ;

C is the cost of purchasing and processing one quintal of raw nut; and

Q is the kernel content in one quintal of raw cashewnut.

TABLE 10.6. **Input and output statement of cashew 1 ha model (in rupees)**

Particulars	Year I	II	III	IV	V	VI	VII	VIII	IX	X	XI onwards
1. Land development	500.00										
2. Inputs (a) Planting materials	80.00	20.00									
(b) Fertilisers	98.00	197.00	295.00	394.00	394.00	394.00	394.00	394.00	394.00	394.00	394.00
(c) Plant protection		20.00	50.00	80.00	100.00	160.00	180.00	200.00	225.00	240.00	240.00
3. Others	50.00	130.00	135.00	135.00	135.00	135.00	135.00	135.00	135.00	135.00	135.00
4. Wages (other than harvesting and collection)	790.00	270.00	280.00	280.00	290.00	300.00	300.00	300.00	300.00	300.00	300.00
5. Harvesting & collection					75.00	150.00	300.00	450.00	600.00	750.00	750.00
Total :	1518.00	637.00	760.00	889.00	994.00	1139.00	1309.00	1479.00	1654.00	1819.00	1819.00
6. Production of nuts					100	200	400	600	800	1000	1000
Operating revenue					500	1000	2000	3000	4000	5000	5000
Net operating revenue	−1518	−637	−760	−889	−494	−139	+691	+1521	+2364	+3181	+3181

TABLE 10.7. **Monthly average wholesale price of raw cashewnut in important markets in India***

Name of the market	1969						1970					
	Feb.	March	April	May	June	July	Feb.	March	April	May	June	July
						(Rs. per quintal)						
Tamil Nadu												
Panruti	194	179	150	161	160	177	210	204	278	159	158	175
Jayankondam	164	143	146	163	168	176	NT	169	168	140	147	160
Karnataka												
Mangalore	125	112	123	120	140	145	138	145	148	145	155	158
Maharashtra												
Malvan	178	138	150	150	150	150	160	160	183	200	200	200
Andhra Pradesh												
Palassa	207	208	208	209	209	209	210	210	211	209	208	208
Rajahmundry	..	..	..	..	..	..	..	..	..	..	..	..
Goa												
Sanquelim	..	138	143	143	138	143	NT	153	180	205	180	183
Ponda	..	..	..	..	..	..	..	..	..	..	..	..
Kerala												
Kasaragod	123	133	150	143	128	..	155	156	..	..	..	..
Kanhangad	128	136	152	139	125	..	155	158	..	..	..	..
Baliapatam	..	..	151	141	133	..	NT	168	..	..	..	..
Tellicherry	110	143	156	140	..	..	168	167	..	..	..	..
Calicut	126	135	145	130	105	..	155	154	..	..	..	..
Manjeri	..	..	..	..	..	..	..	..	..	..	..	..
Trichur	141	133	145	128	154	158	166	159	..	..	..	..
Irinjalakuda	140	135	146	133	121	120	170	166	..	..	..	..
Quilon	134	136	146	138	..	..	173	165	..	..	..	..
Adoor	125	130	142	142	138	..	168	156	..	..	..	..
Chengannur	135	128	136	135	..	..	168	150	..	..	..	..
Nedumangad	128	119	130	101	..	..	..	138	..	..	..	..
Kadakkal	..	..	..	..	..	..	170	165	..	..	..	..

*Monthly average prices are the average of minimum and maximum prices of each month.

(contd.)

TABLE 10.7. (contd.)

Name of the market	1971						1972					
	Feb.	March	April	May	June	July	Feb.	March	April	May	June	July
Tamil Nadu												
Panruti	175	175	169	156	149	166	217	215	201	181	183	188
Jayankondam	163	126	140	149	166	141	176	179	191	188	163	174
Karnataka												
Mangalore	..	..	135	133	133	140	130	138	168	170	NT	NT
Maharashtra												
Malvan	200	195	183	180	190	185	183	180	183	173	178	180
Andhra Pradesh												
Palassa	203	NT	NT	NT	NT	NT	203	NT	193	186	195	208
Rajahmundry	..	..	..	..	..	..	..	..	..	..	..	209
Goa												
Sanquelim	NT	151	158	158	155	160	NT	153	160	177	177	NT
Ponda	NT	148	155	153	150	150	NT	150	163	173	171	NT
Kerala												
Kasaragod	..	..	..	..	..	..	..	..	..	..	..	..
Kanhangad		..	..	..	..	..	..	..	181	158	135	NT
Baliapatam		..	..	..	..	..	..	..	188	173	163	NT
Tellicherry	..	..	..	..	..	..	..	..	..	..	..	..
Calicut	143	139	143	141	130	NT	148	167	176	157	NT	NT
Manjeri									167	143	120	130
Trichur	155	138	148	153	173	178	171	170	178	163	193	180
Irinjalakuda							173	174	178	155	185	180
Quilon							171	172	179	NT	160	NT
Adoor							160	168	172	170	180	NT
Chengannur									169	155	NT	NT
Nedumangad		123	120	125	130	120	168	159	164	113	130	NT
Kadakkal							176	178	178	170	200	NT

(contd.)

TABLE 10.7. (contd.)

Name of the market	1973 Feb.	March	April	May	June	July	1974 Feb.	March	April	May	June	Juy
Tamil Nadu												
Panruti	238	254	232	213	295	288	411	413	375	375	342	300
Jayankondam	207	216	220	261	292	313	380	331	367	396	316	284
Karnataka												
Mangalore	NT	185	NT	NT	NT	NT	NT	NT	358	370	370	NT
Maharashtra												
Malvan	195	193	223	290	300	310	325	340	350	335	345	350
Andhra Pradesh												
Palassa	216	219	239	300	NT	390	385	NT	310	298	293	280
Rajahmundry	NT	229	235	297	381	374	382	385	395	396	372	344
Goa												
Sanquelim	NT	NT	320	280	305	NT	NT	NT	NT	368	363	340
Ponda	NT	NT	224	275	305	NT	NT	NT	NT	363	358	360
Kerala												
Kasaragod	..	..	..	..	..	..	..	..	..	..	..	..
Kanhangad	NT	225	253	270	265	NT	NT	365	338	375	330	NT
Baliapatam	NT	241	..	..	..	NT	..	..	..	..	..	..
Tellicherry	NT	239	261	265	258	..	NT	378	365	383	NT	NT
Calicut	NT	NT	238	238	233	NT	NT	348	335	353	308	NT
Manjeri	NT	NT	220	255	..	..	NT	298	..	..	..	..
Trichur	201	208	233	250	308	NT	NT	NT	338	333	380	350
Irinjalakuda	201	210	228	240	220	NT	NT	NT	325	323	380	NT
Quilon	210	225	230	280	220	..	NT	NT	343	343	NT	NT
Adoor	190	217	222	255	NT	NT	NT	NT	323	355	348	320
Chengannur	NT	NT	..	..	..	..	..	..	..	..	..	..
Nedumangad	180	204	209	209	190	NT	NT	NT	305	275	235	230
Kadakkal	250	226	230	225	..	..	NT	NT	340	340	365	NT

(contd.)

TABLE 10.7. (contd.)

Name of the market	1975						1976					
	Feb.	March	April	May	June	July	Feb.	March	April	May	June	July
Tamil Nadu												
Panruti	NT	NT	NT	321	272	310	NT	NT	313	313	319	378
Jayankondam	278	291	301	284	281	277	300	325	324	313	314	350
Karnataka												
Mangalore	NT	NT	295	253	248	253	NT	225	249	276	NT	NT
Maharashtra												
Malvan	255	260	320	315	238	263	283	315	300	325	353	365
Andhra Pradesh												
Palassa	273	240	234	242	228	225	325	325	285	288	323	340
Rajahmundry	NT	NT	297	283	260	269	390	356	347	335	372	391
Goa												
Sanquelim	NT	NT	278	275	271	255	NT	300	315	323	310	310
Ponda	NT	NT	283	265	258	260	NT	303	308	323	310	310
Kerala												
Kasaragod	..	..	..	..	..	..	..	..	..	..	..	..
Kanhangad	NT	308	333	278	238	NT	NT	274	255	265	265	NT
Baliapatam			350	290	250	NT	NT	278	255	265	NT	NT
Tellicherry	NT	330	330	288	265	NT	NT	245	255	265	265	NT
Calicut	NT	250	320	258	213	NT	NT	253	245	245	240	NT
Manjeri			305	257	NT	NT	NT	NT	240	248	NT	NT
Trichur	255	NT	310	283	300	278	275	253	225	225	225	NT
Irinjalakuda	260	NT	310	275	295	268	258	245	255	255	255	NT
Quilon	NT	NT	370	NT	NT	NT	NT	280	265	265	265	NT
Adoor	250	NT	NT	300	325	NT	255	260	265	310	345	370
Chengannur	..	..	..	..	..	..	..	..	..	..	..	..
Nedumangad	NT	NT	NT	NT	NT	NT	NT	230	NT	240	240	240
Kadakkal	265	NT	NT	288	TN	NT	NT	263	255	268	290	NT

(contd.)

TABLE 10.7. (contd.)

Name of the market	1977						1978					
	Feb.	March	April	May	June	July	Feb.	March	April	May	June	July
Tamil Nadu	625	619	734	688	763	813	703	620	570	578	556	587
Panruti	468	653	713	691	735	735	532	455	656	647	563	669
Jayankondam												
Karnataka	NT	NT	775	690	NT	492	NT	533	555	411	NT	NT
Mangalore												
Maharashtra	340	348	625	730	740	738	NT	NT	NT	NT	..	..
Malvan												
Andhra Pradesh	500	500	580	650	730	730	719	656	647	697	563	631
Palassa	475	500	675	813	903	875	763	719	670	654	557	572
Rajahmundry												
Goa	380	498	723	785	763	760	500	560	582	583	513	525
Sanquelim	375	460	760	798	788	800	450	570	600	570	510	563
Ponda												
Kerala	400	400	500	600	600	600	610	610	610	610	410	410
Kasaragod	400	400	500	600	600	600	610	610	610	610	410	410
Kanhangad	400	400	500	600	600	600	610	610	610	610	410	410
Baliapatam	400	400	500	600	600	600	610	610	610	410	410	410
Tellicherry	390	390	490	590	590	590	590	590	590	590	390	390
Calicut	390	390	490	590	590	590	590	590	590	590	390	390
Manjeri	380	380	480	580	580	580	590	590	590	590	390	390
Trichur	380	380	480	580	580	580	590	590	590	590	390	390
Irinjalakuda	380	380	480	580	580	580	580	580	580	580	380	380
Quilon	380	380	480	580	580	580	580	580	580	570	380	380
Adoor	380	380	480	580	580	580	580	580	580	580	380	380
Chengannur	370	370	480	570	570	570	570	570	570	570	370	370
Nedumangad	380	380	480	580	580	580	580	580	580	580	380	380
Kadakkal												

(contd.)

TABLE 10.8. **Price of cashew kernels in New York Market A—320 counts (Cents/pound, C & F.) New York**

Months	*1972–73*	*1973–74*	*1974–75*	*1975–76*	*1976–77*	*1977–78*	*1978–79*
April	77	89	119	128	120	235	187
May	78	94	129	119	117	234	200
June	78	112	125	112	119	242	190
July	77	119	117	111	123	233	190
August	75	119	113	115	127	230	185
September	74	113	111	112	128	225	185
October	72	105	107	102	128	220	185
November	72	105	106	104	132	205	170
December	74	126	107	105	149	185	—
January	75	126	109	106	154	185	—
February	77	120	114	111	173	180	—
March	84	118	116	113	225	185	—

The cost of processing per bag of 80 kg of raw cashewnuts has been estimated in Kerala and is given in Table 10.9

TABLE 10.9. **Cost of processing 80 kg of raw cashewnut**

	Items of work	As on end of 1974 Rs.	From 1–1–1975 Rs.	After implementation of minimum wage from 1–9–1975 Rs.	As on November 1978 Rs.
1.	Raw nut clearance expenses	4.56	4.56	4.56	5.75
2.	Wages and benefits to workers	55.64	74.18	100.97	107.10
3.	Factory salaries and overheads	5.47	6.35	7.43	17.98
4.	Tin containers, labels cartons, strapping etc.	24.54	24.54	24.54	20.56
5.	Shipping and forwarding	3.93	4.00	4.00	5.55
6.	Administrative overheads	1.90	2.30	2.30	5.54
7.	Financial charges and depreciation	4.20	4.20	4.20	9.20
	Total	100.24	120.13	148.00	171.68

It can be seen that the cost of processing 80 kg of raw cashewnuts has increased from Rs. 100.24 at the end of 1974 to Rs. 171.68 by 1978 end. This increase is mainly due to the increase in the minimum wages offered to the labourers in the cashew factories.

It can be observed from the wholesale market price of raw nuts in the country that the kernel prices in the New York market and the processing cost which form a major share of the price spread between the producer in India and the ultimate consumer in New York, is observed by the cost of processing. As the total spread between the producer and consumer also is an indicator of measuring the marketing efficiency, the most efficient marketing system will be one having the minimum total spread consisting of various fixed costs and margins. Whether the present marketing system of cashewnut is efficient or not can be studied only when there is an alternative channel of cost of marketing which can be compared. In the absence of such alternative channel the marketing efficiency will be related to the pricing efficiency. Therefore, marketing and pricing policies will play very vital roles in the development of cashewnut.

The pricing efficiency is determined by the relationship of the parity price of the grower with that of the pricing unit and the total price spread between these two parity prices.

For a grower, the following equation gives the parity price :

$P_g = (F + P + A + C) - A$

Where P_g is the grower's parity price of raw nuts (in Rs. per tonne).

F is the cost of fertilisers at the rate of 250g N, 125g $P_2 O_5$ and 125g $K_2 O$ per tree yielding on an average 5 kg for 200 trees (1 hectare) at 10th year of planting.

P is the cost of plant protection chemicals.

K is the other operational expenses.

C is the contribution towards capital investment till the break even year.

A is the value of cashew apples.

The wages of the agricultural as well as the industrial labour in Kerala are higher than those in any other states. Therefore the parity prices of raw cashew nut for the grower and the processor-cum-exporter in Kerala are also applicable to the other states to the advantage of both the grower and the processor. If the market price falls below this parity price, it will not be an economic price for a cultivator. If the price fluctuates substantially, there are high costs of bearing the risks of these fluctuating prices. Thus the price policy must be complementary to policies of facilitating technological change in the marketing and processing channels. Price stabilisation and price supports have a great deal of effect on the efficiency of marketing system. A processor needs predictable price if he is to concentrate his attention on processing and a grower needs a remunerative price as an incentive to concentrate his attention in increasing the production.

The procurement price should be above the parity price of the growers and the issue price of rawnuts to the factory owners should be below the parity price of the processor. Therefore, the total cost of marketing from the grower to the processor should be less than $P_p - P_g$.

When there is an increase in the fixed costs in the marketing system which cannot be eliminated without a corresponding increase in the kernel prices, the only alternative is to reduce the unit cost of production.

A refined marketing system in cashew is lacking at present and considerable market survey and research is required to suggest a pricing policy beneficial to the grower and acceptable to the processor.

CHAPTER 11

CASHEW — THE NEXT PHASE

In the preceding chapters we summarised the results of cashew research and the constraints in production. It is important that we also analyse the gaps which exist between the potential yield and the average yield in the country. The national average at present is only 2.1 kg/tree/year and the average yields in different states are as follows:

State	*kg/tree*
Kerala	5.5
Karnataka	2.1
Andhra Pradesh	2.0
Goa	1.0
Tamil Nadu	0.6
Maharashtra	0.2
Orissa	0.2

Kerala records the maximum average yield, followed by Karnataka and Andhra Pradesh. Crop improvement programmes at various cashew research centres during the last three decades have helped to identify new selections and to evolve hybrids with very high yield potential. Some of the high yielding selections and hybrids are:

Selection/hybrid	*Yield(kg)*
Vengurla—2	43
BLA 139/1 (Anakkayam)	34
Hybrid 24 (Vengurla)	25
Hybrid 11 (Vengurla)	23
Hybrid 19 (Vengurla)	22
Hybrid 2/12 (Bapatla)	19
Hybrid 2/11 (Bapatla)	17

An average yield of 43 kg has been obtained from a tree in a regularly spaced 20 year old plantation at Vengurla. Exceptional high yielders like a 45 year old tree at Bapatla yielding 90 kg of raw nuts/year and a record yield of 125 kg reported from a single tree in a garden from Kottarakkara (Kerala) show the gaps between the realised yields and potential yields. There are two major gaps which call for serious attention. Compared to the maximum yield realised, the national and state averages are very low. The difference in the average yields between Kerala and the rest of the states is the first gap which, if bridged can make India not only self sufficient in raw nut production but will also help in stabilising the position in international trade. The necessary agro-technology is also available and all it needs is a sound developmental programme and social support.

The second gap which calls for immediate attention is the difference between the maximum yields obtained in research farms and the state averages. As mentioned in Chapter 5, cashew is mostly confined to Class IV and V lands and receives very little care. Most of the existing crop is self-sown and of unknown genetic stock. Under the new area expansion programmes if adequate care is taken to plant only superior planting materials and adequate management is assured including regular fertiliser application and plant protection measures, yields will be much higher.

The third gap is between the yields in research farm and the maximum recorded. Eventhough 125 kg/tree/year has been reported to be the highest, the actual biological maximum potential of cashew tree is yet to be worked out. Some of the record yields mentioned have been obtained from isolated trees with sprawling canopy and such plant structure may not be suitable for the trees in regularly spaced plantations.

The main constraints are the low soil fertility of marginal lands where cashew is grown, lack of proper management, poor yield potential of the planting materials, loss of crop due to pests, and lack of incentive to take advantage of the available new agro-techniques. The action programme required to increase production and productivity of cashew in the country can be categorised under the following headings: (i) expansion of cashew cultivation to new areas (ii) multiplication of high yielding selections and hybrids (iii) adoption of plant protection measures (iv) increased use of fertilisers (v) intensive development programmes, and (vi) stability of remunerative price for the produce to provide adequate incentive for adopting new technology.

(i) Expansion of cashew cultivation to new areas

The Raj Committee identified 91,200 ha land in Kerala, Karnataka, Andhra Pradesh and Tamil Nadu that can be utilised for new plantations (Bavappa, 1976). An area of 40,000 ha has been identified in the Malnad region of Karnataka and 28,000 ha in Kerala. The Committee has also indicated the possibility of identifying new areas in Orissa, Maharashtra and Goa.

(ii) Multiplication of high yielding varieties

The high yield potential of some of the new selections and hybrids has been discussed in the beginning of this chapter. Some of them have already been recommended for pre-release clonal multiplication at various research centres. It is necessary to supply clonal material from these high yielding selections, to growers at reasonable prices. Research on vegetative propagation has yielded encouraging results and we are at a stage wherein, there should not be any problem for large scale clonal propagation. However, the magnitude of the problem is so vast that an integrated approach to supply clonal progenies of high yielding selections and hybrids as well as the clonal seeds from tested parents appear to be necessary to meet the demand for planting material. Assuming an annual area expansion programme of about 20,000 ha, the requirement of planting material for new planting and gap filling would be well over five million per year.

There is already a proposal under the VI Plan to lay out field evaluation trials. Fifty plots of 100 plants each, in each of the cashew growing states are proposed. Clonal

progenies of high yielding selections and hybrids planted under the field evaluation trials would become a source of scion material for vegetative propagation of these high yielding varieties of cashew. The programme also envisages training of local people in vegetative propagation methods. Since the trial plots are to be located in different cashew growing areas in the state, budwood/scion material would become available locally for large scale multiplication of high yielding types. Availability of clonal progenies of high yielding selections and hybrids locally at a competitive rate encourages planting of clonal progenies. It will not be possible to produce clonal progenies to meet all requirements of planting material in the near future. We shall have to depend upon seedling progenies from high yielding selections to cover at least part of the area of new planting to be taken up immediately. A beginning has already been made in this direction and seed gardens have been planted at Santhigodu, Bagali and Karkala in Karnataka, Central State Farm, Aralam and Adur in Kerala and Kavali in Andhra Pradesh. Planting quality seeds collected from parent trees tested for their progeny performance appears to be a good alternative to planting clonal progenies. Seedling progenies of 16 high yielding selections from different cashew research stations have been put under multi-location trials to assess the seedling performance of individual parents.

An alternate approach to this problem is to propagate the superior types through tissue culture. However, this procedure is yet to be standardised.

(iii) Adoption of plant protection techniques

Tea mosquito, *Helopeltis antonii* is the most serious pest on cashew and is estimated to cause upto 30% damage in the case of severe infestation. The results of trials carried out under the All India Co-ordinated Spices and Cashewnut Improvement Project during the last three years have indicated that if only two improved agro-techniques are applied to cashew plantations, production of raw nuts could be doubled in a matter of 2–3 years. Two items under reference are: control of tea mosquito and fertiliser application. However, along with the control of tea mosquito it is also necessary to take into consideration other major pest problems and develop an integrated pest management programme so that the farmers do not have the problem of spraying a number of chemicals.

(iv) Fertiliser application

Cashew requires regular application of fertilisers for early, regular and higher yields (Mohapatra *et al.*, 1973). The present fertiliser recommendation is 250 g N, 125 g P_2O_5 and 125 g K_2O to be applied in two split doses annually for trees yielding 5–10 kg nuts. The need for fertiliser trials with high yielding selection and hybrids under different agro-climatic conditions, is obvious.

(v) Minikit trials in cashew

Minikit trials were conducted in Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, Maharashtra and Orissa to convince the farmers of the advantages of adopting recommended agronomic practices and plant protection measures. Minikit inputs include fertiliser and plant protection chemicals, and results from the trials indicated that the yield of cashew

could be substantially increased by plant protection measures and fertiliser application (Table 11.1).

TABLE 11.1. **Mean yield of cashewnut in the management minikit trials**

	Anakkayam and Mannuthy (Kerala)	Bapatla (AP)	Vengurla (Maharashtra)	Vittal (Karnataka)	Vridhachalam (Tamil Nadu)
Experimental plots	3.419a	6.107a	0.467a	1.527a	1.858a
Control plots	2.699a	3.370b	0.253a	1.000b	0.956b

Means in the same column not followed by the same small case letter are significantly different (P=0.01) (Source: Anon., 1977b)

Minikit programmes also include identification of poor yielding types in the existing plantation and systematic upgrading. A field evaluation trial to assess the effect of adopting total package of practices in cashew is envisaged. Fifty plots of 100 plants each is proposed to be established in each state. The objective is to demonstrate the economic feasibility and profitability of adopting total package of practices in cashew. The total package will include planting clonal progenies of high yielding types, regular fertiliser application, mulching, soil working and plant protection sprays.

(vi) Stability of remunerative price—an incentive to adopt new technology

Cashew production technology can be considered to have reached a take-off stage. The transfer of technology to the field, however, still remains to be a problem. As in many other crops, to bring in a change in the traditional method of cultivation, a greater impact of new technology is required. It is more so in a perennial crop like cashew where the return on the initial investment is a long-drawn process; and the cultivator is quite uncertain about the return because of the wide fluctuations in the price of the produce. No producer would be interested in investing on the crop unless he is assured of a steady and remunerative income. From a well managed cashew plantation, a producer may hopefully get back his investment along with a reasonable profit in about 8–10 years time. To provide adequate incentive, to the producer, therefore, the remunerative price should be ensured on a long term basis *ie.*, till about 10 years. If the apple and the by-products like CNSL and tannin from cashew testa are used properly, the income from cashew can be further raised substantially and the cashew cultivation would thus become an economic proposition. An integrated approach in linking production and processing including by-product utilisation and marketing will increase the income from cashew industry and thus provide the necessary incentive to adopt new technology. After all *incentive is income.*

REFERENCES

ABRAHAM, E. V. 1958. Pests of cashew (*Anacardium occidentale* L.) in South India. *Indian J. Agric. Sci.* **28** : 531–544.

ABRAHAM, E. V. 1959. Killer insects of cashew. *Indian Fmg.* **9**(3) : 14–15.

ABRAHAM, T. 1956. Air layering is a success with cashew. *Indian Fmg.* **5**(10) : 26–27.

ACHARYYA, N. AND DASH, P.C. 1972. Effect of two plant growth substances on cashew air layers. *Curr. Sci.* **41:** 534–535.

ADAMS, B.R., BOCK, K.R., GUTHRIE, E.J. AND OSBORNE, J.F. 1977. Leaf necrosis of cashew seedlings. in E. Afr. Agric. & For. Res. Organisation (EAAFRO), Nairobi, Kenya, *Ann. Report* 1975, p. 56–57.

AGGARWAL, J.S. 1954. The cashewnut and oil. *Oleagineux* **9:** 559–564.

AGGARWAL, S.N., SIVASAMBAN, M.A. AND AGGARWAL, J.S. 1966. *Paint Manuf.* **36**(1): 29–32.

AGNOLONI, M. AND GIULIANI, F. 1977. *Cashew cultivation.* Library of Tropical Agriculture, Ministry of Foreign Affairs. Institute Agronomic Per L' Olhemare. 168 pp.

AIYADURAI, S.G. 1966. *A Review of research on Spices and Cashewnut in India.* Indian Council of Agricultural Research, New Delhi. 228 pp.

AIYADURAI, S.G. AND KOYAMU, K. 1957. Variations in seedling trees of cashew. *South Indian Hort.* **5:** 153–157.

AJMANI, G.M. AND JATKAR, S.K. 1944. *J. Ind. Inst. Sci.* **26A:** 11.

ALBUQUERQUE, S.D.S., HASSAN, M.V. AND SHETTY, K.R. 1960. Studies on the apple characters of cashew *(Anacardium occidentale* L)., *Mysore Agric. J.* **35:**2–8.

ANONYMOUS. 1960. Report of Indian Council of Agricultural Research 1957–58. p. 7–57.

ANONYMOUS. 1964. *Cashewnut shell liquid patents Vols. I & II.* Cashew Export Promotion Council, Ernakulam, India.

ANONYMOUS. 1965. Annual Progress Report of the Central Cashew Research Station, Ullal, for the period of 1st July 1964 to 30th June, 1965. 45 pp.

ANONYMOUS. 1966. Annual Progress Report of the Central Cashew Research Station, Ullal, 1965–1966.

ANONYMOUS. 1967. Anthracnose—a deadly disease of cashew. *Cashew News Teller* **1**(3): 5–6.

ANONYMOUS. 1969. Annual Progress Report of the Central Cashew Research Station, Ullal, 1968–69.

ANONYMOUS. 1970. Cashew apple preparations. *Indian Cashew J.* **6**(1): 8–9.

ANONYMOUS. 1972. Forest Research Centre, Coimbatore Unit, Annual News Bulletin for the year 1971–72. *Indian Forester* **98:** 746.

ANONYMOUS. 1973. Cashewnut. In *Annual Report of Mahatma Phule Krishi Vidyapeeth,* 1971–72. p.136.

ANONYMOUS. 1977a. Production and utilisation of cashewnut shell liquid in India. A survey report published by the Cashew Export Promotion Council, Ernakulam. India.

ANONYMOUS. 1977b. Progress report 1976–77, All India Co-ordinated Spices and Cashewnut Improvement Project. Central Plantation Crops Research Institute. Kasaragod. 54 pp.

ANONYMOUS. 1978a. Progress Report 1977–78, All India Co-ordinated Spices and Cashewnut Improvement Project. Central Plantation Crops Research Institute. Kasaragod. 80 pp.

ANONYMOUS. 1978b. A survey of cashewnut shell liquid, patents. Cashew Export Promotion Council, Ernakulam, India.

AQUINO, M. de L.N. AND CAMELO, P. 1971. *Doencas do cajueiro em Pernambuco, I. Semana do caju,* 25–31 Outubro, 1971, Fortaleza.

AQUINO, M.de L.N. AND MELO G.S. de. 1974. A new disease of cashew. *Boletim Technico do Instituto da Pesquisas Agronomicas (Brazil)* **71:** 13.

ARAILDE, C.F. AND MATTOS, K. de A. 1971. *Fungos de revestimento sobre cajueiros na Regiao de Brasilia.* D.F.I. *Semana do Caju:* 25–31. Outubro 1971, Fertaleza.

ARAQUE, R. 1968. *Elmercy* (Cashew) *Ser. Cult. Venezuela* **15:** 1–20.

ARGLES, G.K. 1969. *Anacardium occidentale* (Cashew) Ecology and botany, in relation to propagation. *Pap. FAO Conf. Prop. Trop. and Sub-trop. Fruits* p. 1–24

ARGLES, G.K. 1976. *Anacardium occidentale*-Cashew. In *The Propagation of Tropical Fruit Trees* (R.J. Gardner *et al.,* Eds). Commonwealth Agricultural Bureaux, East Malling, Kent, UK p. 184–222.

ASCENSO, J.C. AND MILHEIRO, A.V. 1972. Cashewnut sowing trials. *Agronomia Mocambicana* **5**(2): 87–95.

ASCENSO, J.C., AND MILHEIRO, A.V. 1973. Preliminary note on budding of cashew seedlings. *Agronomia Mocambicana* **7**(69): 71–72.

ASCENSO, J.C. AND MOTA, M.I. 1972a. Studies on the flower morphology of cashew *(Anacardium occidentale* L). *Institute de Investigacao Agronomica de Mozambique, Leurenco Marques* **6**(2): 107–117.

ASCENSO, J.C. AND MOTA, M.I. 1972b. Phylogenetic derivation of the cashew flower. *Boletimda Sociedade Broteriana.* **42:** 253–257.

AUCKLAND, A.K. 1961. The influence of seed quality on the early growth of cashew. *Trop. Agric.* **38:** 57–67.

AVILAN, R.L. AND BRASIL SOB, M.O.C. 1976. Study of the effect of macroelement deficiencies on the growth and mineral composition of cashew *(Anacardium occidentale)* grown on nutrient solutions. *Agronomia Trop.* **26**(2): 143–154.

AYYANNA, T., NARAYANA, K.L. AND RAO, B.H.K. 1977. Insect pests of cashew in Andhra Pradesh and their control. Tech. Bull. No. 7, Andhra Pradesh Agricultural University, Rajendranagar, Hyderabad. 29 pp.

AYYANNA, T., SUBBARATNAM, G.V. AND RAO, B.H.K. 1977. Chemical control of *Macalla moncusalis* Walker and *Nephopteryx* sp. on cashew. *Cashew Bull.* **14**(9); 8–10.

AYYAR, T.V.R. 1932. Annotated list of the insects affecting the important cultivated plants in South India. *Agric. Dept. Madras Bull.* No. 27.

AYYAR, T.V.R. 1940. *Hand book of Economic Entomology for South India.* Govt. Press, Madras. 528 pp.

AYYAR, T.V.R. 1941. Insects associated with cashew plants in South India. *Proc. 28th Indian Science Cong. III.* 208 pp.

AYYAR, T.V.R. 1942. Insect enemies of the cashewnut plant *(Anacardium occidentale)* in South India. *Madras Agric. J.* **30:** 223–226.

BAILEY, L.H. 1958. *The Standard Encyclopedia of Horticulture* Vol. I. (17th edition) MacMillan, New York. 1200 pp.

BANO AND CHANDRA, B.K.N. 1973. Note on the record of two new host plants of *Oligonychus mangiferus* Rahman & Sapra (Acarina: Tetranychidae). *Indian J. Agric. Sci.* **43:** 966.

BASHEER, M. AND JAYARAJ, S. 1964. Cashewnut pests. In *Entomology in India* Silver Jubilee Number. *Indian J. Ent.* Entomological Society of India, New Delhi. p. 261–266.

BASTOS, C.N. AND FIGUEIREDO, J.M. 1967. Inhibition *in vitro* of *Colletotrichum gloeosporioides* Penz, causal agent of cashew anthracnose by a substance produced by *Bacillus subtilis* Cohn. *Fitopatologia Brasileira* **1:** 179–182.

BASU CHOUDHURI J.C. 1962. Preliminary investigation on the insect pests of cashew plants in Kerala. *Indian Forester* **88:** 516–522.

BASU CHOUDHURI, J.C. 1969. The cashew stem borer. In *The Southern Forest Rangers' College Magazine* p. 51–59.

BASU CHOUDHURI, J.C. 1973. Mycosis of stem and root borers of cashewnut, *Plocaederus ferrugineus* L. (Coleoptera-Cerambycidae). *J. Plant. Crops* (Supplement) **1:** 164–167.

BASU CHOUDHURI, J.C. AND MISRA, M.P. 1973. *Hyalospila leuconeurella* Ragonot (Lepidoptera: Pyralidae) and *Anarsia epotias* Meyr. (Lepidoptera: Gelechiidae) two pests of cashew apples and nuts in South India with notes on their control. *J. Plant. Crops* (Supplement) **1:** 168–170.

BATISTA, A.C. 1957. Foliage lesions on cashewnut caused by *Phomatospora anacardicola* sp. nov. *Ann. Soc. Biol., Pernambuco* **15:** 255–260.

BATISTA, A.C. AND VITAL, A.F. 1952. Monograph of the species of *Phyllosticta* in Pernambuco. *Bol. Soc. Aqric. Pernambuco,* **19**(1–2): 1–80.

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 p. 12–20.

BECCARI, F. AND GERINI, V. 1968. *Contributo all a conoseenza dell' entomofauna dell' Anacardium occidentale* L. *Tanzania enel monds, Riv. Agric. Subtrop. Trop.* **62**(46): 129–134.

BEESON, C.F.C. 1941. *The Ecology and Control of the Forest Insects of India and the Neighbouring Countries.* Govt. of India Press, New Delhi, 767 pp.

BHANDARY, K.R., SHETTY, K.P.V. AND SHET, M: 1974. Propagation of cashew by wedge grafting. *J. Plant. Crops* **2:** 37.

BHATTEE S.S. 1977. Vegetative Propagation of Cashew by bud-grafting of young seedlings in nursery. *Cashew Bull.* 14(2): 8–10.

BIGGER, M. 1960. *Selenothrips rubrocinctus* (Grand) and the floral biology of cashew in Tanganyika. *East African Agric. J.* **25:** 229–234.

de BLIC, A. 1972. A new utilisation of CNSL resins-protection of thatched roof. *Cashew Bull.* **9:**(4) 5–10.

BOBOYE, S.O. 1968. Studies on the biology and chemical control of red banded cacao thrips, *Selenothrips rubrocinctus* Grand. Nigeria. *Niger. Ent. Mag.* **1**(15): 77–81.

BOHLEN, E. 1973. *Cashew-Crop Pests in Tanzania and Their Control.* Verlag Paul Parey, Berlin. 62 pp.

BOWN, M.S.D. 1972. Mechanical processing of cashewnuts. *Peanut J. Nut. World* **51** (5): 21–26.

BROWNE, F.C. 1968. *Pest and Diseases of Forest Plantation Trees.* An annotated list of the principal species occurring in the British Commonwealth. Clarendon Press, Oxford.

BURKILL, I.H. 1935. *A Dictionary of the Economic Products of the Malay Peninsula. Vol. I.* Crown Agents of the Colonies, London. 232 pp.

CALZAVARA, B.B.G. 1970. *Fruteiras: abacaxizeiro, cajueiro, goiabera, maracujazeiro, murucizeiro Ser. Cult. Amazonia Inst. Pesquisas Exp. Agropec. Norte* (IPEAN)**1**:1.

CASADIO, G.P. 1971. The mechanical processing of cashew nuts. *Peanut J. Nut. World* **50**(8): 8–10.

CASTRO, Z.B. de, OLIVEIRA V. de P., CAVALCANTE, M.L.S., SANTOS, O.M. de L. CAVALCANTE, R.D. AND RODRIGUES, L.M.S. 1977. *Diplodium anacardiacearum* Bat. and Cavalcante, a new disease of cashew *(A. occidentale* L). in Ceara State. *Fitossanidade* **2**(1): 24.

CHAKRAVARTY, D.K., SADHU, M. AND BOSE, T.K. 1972. Studies on growth, flowering, sex ratio, and fruit set in cashew *(Anacardium occidentale* L). In (Abstr). III. *Inter. Symp. on Sub-Tropical and Tropical Hort.,* Hort. Soc. of India p. 103.

CHHONKAR, V.S. AND SINGH, R. 1967. Effect of plant growth regulators on air-layering in cashewnut *(Anacardium occidentale* L). *Indian J. Hort.* **24** : 26–29.

COPELAND, H.F. 1961. Observations on the reproductive structure of *Anacardium occidentale. Phytomorphology* **11**: 315–325.

CORDOBA, J.A. 1967. *El maranon su cultivo possibilidades de industrializacion en Columbia. Agricultura Trop* (Bogota). **23**: 390–403.

de COSTA, C. 1578. *Tratodo das Drogase Medicinas das Indias Orientais.* 1964 Edn. Junta de investigacoes do ultramar, Lisbon. 356 pp.

DAMODARAN, V.K. 1970. Research on Cashew, *Intensive Agriculture* **7**(12): 20–24

DAMODARAN, V.K. AND NAIR, M.P.B. 1969. Studies on the insecticidal control of *Helopeltis antonii* Signoret on cashew. *Agric. Res. J. Kerala* **9**: 28–30.

DAMODARAN, V.K., ABRAHAM, J. AND ALEXANDER, K.M. 1965. The morphology and biology of cashew flower *(Anacardium occidentalé* L). 1. Flowering habit, flowering season, morphology of flower and sex ratio. *Agric. Res. J. Kerala* **3**: 23-28.

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

DARLINGTON, C.D. AND JANAKI AMMAL, E.K. 1945. *Chromosome Atlas of Cultivated Plants.* George Allen and Unwin, London 397 pp.

DASARATHI, T.B. 1958. *A Study of the blossom biology and growth features of cashewnut (Anacardium occidentale* Linn). M. Sc. Thesis. Andhra University, Waltair (unpublished).

DASARE, B.D. AND KRISHNASWAMY, N. 1965. Studies on anion exchange resins: Part II, Preparation and properties of an exchanger based on Cashewnut shell liquid and tetraethylene pentamine. *Indian J. Tech.* **3:** 212–214.

DAVIES, J. A. 1960 Coleoptera associated with stored products in Uganda. *East Afr. Agric. J.* **25** (3): 199,

DAVIS, T.A. 1949. An unrecorded insect pest of the cashew tree *Anacardium occidentale* L. in South India. *Curr. Sci.* **18:** 133.

DE CANDOLLE, A.P. 1825. *Proxromus Systematis Naturalis,* Paris 2:62.

DHARMARAJU, E., AYYANNA, T. AND SREERAMULU, C. 1976. *Nephopteryx* sp. (Lepidoptera: Pyralidae) a serious pest of cashew. *Indian Cashew J.* **10**(3): 9–11.

DHARMARAJU, E., RAO, P.A. AND AYYANNA, T. 1974. A new record of *Nephopteryx* sp. as an apple and nut borer on cashew in Andhra Pradesh. *J. Res. Andhra Pradesh Agricultural University* **1**(4 & 5): 198.

DUNHAM, O. AND ANDRADE, S. N. de. 1971. Occorencia da mosca branca *(Aleurodicus cocois* Curtis) como pragade cagueiro *(Anacardium occidentale* L.) no Estado de Bahia; *Bol. Inst. Biol. Bahia* **10** (1): 32.

EARLY, M.P. AND PUNITHALINGAM, E. 1972. *Phomopsis anacardii* sp. nov. on *Anacardium occidentale* L. *Trans. Brit. Mycol. Soc.* **59:** 345–347.

EICHABUM, F.W. 1946. *Mem. Inst. Butantan.* **19:** 71.

ESTIBEIRO, V. 1970. Plant protection prophylactic measures on Cashew. *Cashew News Teller* **3**(11 & 12): 22–32.

ESURUOSO, O.F. 1974. Fungi associated with kernel rot disease of cashew *(Anacardium occidentale* L). in Nigeria. *Internat. Biodeterioration Bull.* **10**(2): 57–59.

EVARISTO, F. NEVES AND PAIS, H. 1970 Revisao do genero *Helopeltis* (Hemiptera: Miridae) Para Mocambique. *Agron. Mocambicana* **4** (3): 181.

FENNAH, R.G. 1962. Nutritional factors associated with seasonal population increase in cacao thrips *Selenothrips rubrocinctus* Grand (Thysanoptera) on cashew *Anacardium occidentale. Bull. Ent. Res.* **53**:681–715.

FLETCHER, T.B. 1914. *Some South Indian Insects.* Govt. Press, Madras, 565 pp.

GALANG, F.G. AND LAZO, F.D. 1936. Fruiting as related to vegetative growth in cashew. *Anacardium occidentale* L. *Philipp. J. Agric.* **7:** 21–33.

GEDAM, P. H., SAMPATHKUMARAN, P. S. AND SIVASAMBAN, M. A. 1972 Examination of Components of Cashewnut shell liquid by N M R. *Indian J. Chem.* **10:** 388–391.

GOKHALE, G.D., PATEL, M.M. AND SHAH, R.C. 1940. *Curr. Sci.* **9:** 362.

GOLATO, C. 1970a. Report on a phytopathological mission to Tanzania. Feb. 8–March 10, 1970. IAO, Firenze.

GOLATO, C. 1970b. A serious cashew disease in Tanzania. *Riv. Agricoltura Subtrop. Trop.* **64:** 334–340.

GOMES, P. 1944. *Cajueiros de scis mews. Chac. Quin.* **70:** 581–582.

GUBA, E.F. 1961. *Monograph of Monochaeta and Pestalotia.* Harward Univ. Press, 342 pp.

GULATI, A.S., AND RAO, B.C.S. 1964. Drug analogues from the phenolic constituents of cashewnut shell liquid. *Indian J. Chem.* **2:** 337–338.

GULATI, A.S. AND RAO, B.C.S. 1966. New dyes from phenolic components of cashewnut shell liquid. *Indian J. Chem.* **4:** 265–267.

GULATI, A.S. KRISHNAMACHARI, V.S. AND RAO, B.C.S. 1964. Quarternary nitrogen germicides derived from monophenolic components of cashewnut shell liquid. *Indian J. Chem.* **2:** 114–118.

GUNJATE, R.T. AND LIMAYE, V.P. 1979. Vegetative propagation in cashew. *Intensive Agriculture* (in press)

HALLIER, H. 1905. Phylogenetic studies of flowering plants. *New Phytol.* **4:** 151.

HARVEY, M.T. AND CAPLAN, S. 1940. Cashewnut shell liquid. *Industr. Eng. Chem.* **32**(10): 1306–1310.

HEMALATHA, N.I. AND AGGARWAL. J.S. 1969. *Paint Manuf.* **39**(11): 41.

HEMALATHA, N. I., SUBBA RAO, R. AND AGGARWAL, J.S. 1971. Sulphonated 3—Pentadecylphenol as a surfactant and a coupling agent for azopigments. *Ind J. Tech.* **9:** 107–109.

HUTCHINSON, J. 1959. *The Families of Flowering Plants,* Vol. I Oxford Uni. Press 510 pp.

IBIKUNLE, B.O. AND KOMALAFE, D.A. 1973. Some experiments on the germination of cashewnuts *(Anacardium occidentale* L). *Nigerian J. Sci.* **7**(1): 19–29.

ISAIAH, N.H. AND AGGARWAL, J.S. 1969. Phenolic resins from hydrogenated cardanol (3–pentadecylphenol). *Paint Manuf.* **39** (11): 41.

ISAIAH, N.H., DAKSHINA MURTHY, H. AND AGGARWAL, J.S. 1968. Phenolic resins from cardanol. *Paint Manuf.* **38**(6): 29–32.

IZZO, P.T. AND DAWSON, C.R. 1949. *J. Org. Chem.* **14:** 1039.

JAIN, N.L., BHATIA, B.S. AND ANAND, J.C. 1951. *J. Sci. Industr. Res.* **10A:** 209–210.

JAIN, N.L., DAS, D.P. AND LAL, G. 1952. *Bull. CFTRI* **1**(11): 34–44.

JAIN, N.L., DAS, D.P. AND LAL, G. 1954. Proc. Symp, Fruits and Vegetable Preservation Industry. CFTRI, Mysore. 75–80.

JAIN, R.K. AND GEORGE,J. 1972. A CNSL based sealant for cracks and joints in buildings. *Cashew Bull.* **9**(2): 4–7.

JOHNSON, D. 1972. Origin and spread of cashew, *Anacardium occidentale* L. *Indian Cashew J.* **10**(4): 5–8.

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

JOHNSON, D. 1977. Cashew apple products in Brazil. *Indian Cashew J.* **11**(2): 5–7.

JONES, T. A. 1961 A note on *Analeptis trifasciata* Fabr. and *Paranaleptis reticulata* Thomas (Coleoptera: Lamiinae), two girdling beetles in Tropical Africa. *East Afr. Agric. For.* J. **27** (1): 36.

JOUBERT, A. S. AND THOMAS, D. DES. S. 1965. The cashew nut. *Farming S. Afr.* **40:** 6–7.

JULIO da PONTE, J. 1971. *As. doencas do cajueiro (A. occidentale* L.) *no Nordeste do Brasil 1. Semana do Caju* 25–31, Outubro 1971, Fortaleza.

KAMATH, H.R. 1956. Cashewnut industry and utilisation of byproducts. *Indian Exp. Tr. J.* **10**(7): 12–13 and 28–30.

KHAN, K.F. 1963. Common pests of the cashew trees and their control (unpublished). *Indian Central Spices & Cashewnut Committee, Ernakulam.*

KHOSLA, P.K., SAREEN, T.S. AND MEHRA, P.N. 1973. Cytological studies on Himalayan Anacardiaceae. *Nucleus* **16:** 205–209.

KOTESWARA RAO, M.V.R. 1965. Synthesis and antimicrobial properties of some organic compounds. *Chemical Reports to CSIR, India.*

KOTESWARA RAO, M.V.R., SARMA, M.L., SRIDHARAN, K., RAO, N.A.N. AND VIJAYA RAGHAVAN, P.K. 1966. *Def. Sci. J.* **16:** 181.

KRISHNASWAMY, N., GOVINDAN, K.P. AND PANDYA, R.N. 1957. *Chem. and Ind., No.* **44:** 1456

KRISHNASWAMY, M.A., PARTHASARATHY, N., PATEL, J.D. AND NAIR, K.K.S. 1973. Further studies on microbiological quality of cashewnut *(Anacardium occidentale) J. Food Sci. & Technol.* **10**(1): 24–26.

KULAKARNI, N.G., KRISHNAMURTHY, N. AND CHATTERJEE, P.C. 1973. *Paint Manuf.* **43:** 18

KUMARARAJ, K. AND BHIDE, V.P. 1962. Damping off of cashewnut *(Anacardium occidentale* L). seedlings caused by *Phytophthora palmivora* Butler in Maharashtra State. *Curr. Sci.* **31:** 23.

KUMARAN, P.M., VIMALA, B. AND MURTHY, K.N. 1976b. On the occurrence of pistillate and neutral flowers in cashew. *J. Plant. Crops* **4:** 82–84.

KUMARAN, P.M., NAYAR, N.M., NAMBIAR, M.C., MOHAN, E. AND VIMALA, B. 1976a. Cashew-Varietal improvement. Central Plantation Crops Research Institute, Annual Report for 1975, Kasaragod, India p. 125

KUMARAN, P.M., NAMBIAR, M.C., MOHAN, E. AND VIMALA, B. 1977. Cashew-varietal improvement. Central Plantation Crops Research Institute, Annual Report for 1976. Kasaragod. 143–147.

KURUP, K.R., AND VISWANATHAN, K. 1970. The cashew in Kerala. *Intensive Agriculture* **11:** 11–16.

LAKSHMINARAYANA, S.K., GOVINDARAJAN, V.S., GUPTE, S.M., AND NAMBUDIRI, E.S. 1965. Report of the CFTRI (Mysore). Study team on cashew processing industry (1965) 12 pp.

LEFEBVRE, A. 1971. Multiplication vegetative de l'anacardier, Le greffage da bourgerous terminaux (topgrafting). *Fruits* **26:** 859–863.

LEFEBVRE, A. 1973. Little leaf abnormality of the cashewnut tree. *Fruits d' Outre mer* **28:** 631–636.

LIMA, D. de A. 1954. Contribution to the study of the flora of Perhembuco, Brazil. *Mon. Univ. Rur. Pern. Recife* **1:**

LIMA, J.A. de A., MENEZES, M., KARAM M de Q., OLIVERIA V de P. AND RODRIGUES, M.G.R. 1975. Toxic effect of some fungicides on *Colletotrichum gloeosporioides* Penz. causal agent of cashew anthracnose. *Fitossaidade* **1**(2): 62–66.

LIMA, O.G. de, MAGALHAES NETO, B., FARIAS, L., ALBUQUERQUE, I.L. de, AND SIMOCS FILHO, S. 1952. Introdudao as estudo dos cajus de Perambuco *(Anacardium occidentale). Mon. ESC quim. Pern. Univ. Recife* **1:** 1–20.

van LINSCHOTEN, J.H. 1598. The voyage of 'John H. van Linschoten to the East Indies' (London, 1885).

LOUREIRO, J. de. 1790. *Flora Cochinchinesis.* edition of 1793. *Impensis Harede et Spener,* Berlin, 432 pp.

LUDOWJIK, H. 1927 The cashewnut. *Trop. Agriculturist* **69** 43–46.

MADHUSUDHA N, V., SUNDARA RAMAIAH, M., BHOJARAJ NAIDU, AND SIVASAMBAN, M.A. 1973. *Ind. J. Tech.* **11;** 397.

MAHENDRU, S.N. 1975. Utilise cashew byproducts. *Cashew Bull.* **7**(8): 7–8.

MAHOPATRA, G. AND BHUJAN. 1974. Land selection for cashew plantation—A survey report. *Cashew Bull.* **11**(8): 8–15.

MAITY, S.H. 1960. Studies on the growth and bearing habits of (1) Cashew (2) Gauva and (3) Custard apple. M.Sc. (Ag). Thesis, Calcutta University (Unpublished).

MANERKAR, K.M. 1973a. Goa's caju fenni. *Cashew Bull.* **10** (1): 5–6.

MANERKAR, K.M. 1973b. Quality control for caju fenni manufacture. *Cashew Bull.* **10**(11): 6–9.

MANERKAR, K.M. 1975. *Indian Cashew J.* **9**(2): 9–11

MATHEW, A.G., SHIVASANKAR, S., RAMESH,A., FAZLULLA KHAN, AND NATARAJAN, C.P. 1972. Drying of shelled cashew kernels in throughflow drier. *J. Plant. Crops* Suppl. **1**:181–183.

MATHUR, H.H. AND AGGARWAL, J.S., 1953. Phenolic modified rosin for oil varnishes. *J. Sci. Industr. Res.* **128**:411–413.

MATTA, E.A.F. de AND LELLIS, W.T. 1973. Fungicides and fertilizers for the control of cashew blight. *Bol. Inst. Biol. Bahia,* **12** (1): 37–49.

MEDEIROS, A.G. 1951. Note on the induction of gummosis in *Anacardium occidentale* by *Diplodia natalensis* An: III *Reuniao annual de Soc. Bot. Brasil,* **12:** 71.

MENEZES, M. KARAM, M de Q., AND MOURA, M.C. 1975 Competition of fungicides in the control of anthracnose of cashew *(Anacardium occidentale* L). in Tianga country, Ceara state, Brazil. *Fitossanidade* **1**(3): 77–78.

MENEZES, M, KARAM, M.de Q., LIMA, J.A. de A. AND PARENTE, J.I.G. 1975. Study of the time and frequency of sprays to control cashew anthracnose 1. *Fitossanidade* **1**(3): 70–71.

MISRA, M.P. AND BASU CHOUDHURI, J.C. 1974. New pest and distributional records of *Lymantria obfuscata* Walker (Lepidoptera: Lamantriidae) on cashew from south India. *Indian Forester* **100:** 391–393.

MOHAPATRA, A.R., VIJAYAKUMAR, K. AND BHAT, N.T. 1973. A study on nutrient removal by the cashew tree. *Indian Cashew J.* **9**(2): 19–20.

MORADA, S.K., 1941. Cashew culture. *Philipp. J. Agric.* **12:** 89–103.

MORTON, J.F. 1961. The cashew's brighter future. *Econ. Bot.* **15:** 57.

MORTON, J.F. 1970. Prospects for cashew advancement in Colombia and Venezuela. *Proc. Fla. State Hortic. Soc.* **83:** 405–410.

MOTA, M. 1956. *O cajueiro No rdestino Ministerio do Educacao e cultiva. Department de unprensa National,* Rio-de—Janerio 166 pp.

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

MURTHY, B.G.K. AND AGGARWAL, J.S. 1959. Analysis and upgrading of cashewnut shell liquid. *Paint India* **9** (6): 26–29.

MURTHY, B.G.K. AND SIVASAMBAN. 1978. Cashewnut shell liquid and its utilisation. Paper presented at the Seminar on Post Harvest Technology on Oct. 20–21, 1978 at College of Horticulture, Trichur.

MURTHY, B.G.K. SIVASAMBAN, M.A. AND AGGARWAL, J.S. 1968. Identification of some naturally occuring alkyl substituted phenols in cashewnut shell liquid by chromatographic techniques. *J. Chromatog.* **32**:519–528.

MURTHY, B.G.K., SIVASAMBAN, M.A., AND AGGARWAL, J.S. 1969. Process for the production of pale coloured adhesives from cardanol. *Indian Paint* 119143.

MURTHY, B.G.K., MENON, M.C., AGGARWAL, J.S. AND ZAHEER, S.H. 1961. Cashewnut shell liquid and cardanol. *Paint Manuf*: **31**: 47.

MURTHY, B.G.K., SIVASAMBAN, M.A., AGGARWAL, J.S., GULATI, S.P. AND RAMAIAH, M.S. 1969. Process relating to the use of cardanol for the production of pale coloured coating material. *Indian Paint.* 112036.

MURTHY, M.M.K., SAYI, I.V., RAO., S.V., AND RAO, B.H.K. 1974. Note on the biology of shoot and blossom webber *Macalla moncusalis* Walker (Lepidoptera: Pyralidae') of cashew. *Indian J. Ent.* **36** (1): 76–77 (Published in 1975).

NAGABHUSHANAM, S., VENKAT RAO, P. 1977. Propagational trials in cashewnut. *Indian Cashew J.* **11**(3): 7–11.

NAIK, K.C. 1949. *South Indian Fruits and Their culture.* P. Varadachari & Co., Madras.

NAIR, C.P.R., ABRAHAM, V.A. AND PILLAI, G.B. 1974. Biology of *Metanastria hyrtaca* Cram, a defoliator of cashew. *J. Plant. Crops* **2**: 32–33.

*NAIR, M.R.G.K. AND REMAMONY, K.S. 1964. Paradasynus sp. (Hemiptera: Co*reidae) as a pest of cashew in Kerala. *Indian J. Ent.* **26:** 461–462.

NAIR, T.G. AND JOHN, J.P. 1958. Cashew grafts and layers excel seedlings. *Indian J. Agric. Sci.* **28:** 129–132.

NAMBIAR, K.K.N. 1978. Controlling cashew diseases. *Indian Fmg.* **28**(3): 17–18.

NAMBIAR, K.K.N., SARMA, Y.R. AND PILLAI, G.B. 1975. Inflorescence blight of cashew *(Anacardium occidentale* L). *J. Plant. Crops* **1**: 44–46.

NAMBIAR, M.C. 1976. Technology for increasing cashew production and productivity. In *Increasing Production and Productivity of Cashew in India.*CPCRI, Kasaragod. p.21–24.

NAMBIAR, M.C. 1977. Cashew. In *Ecophysiology of Tropical Crops.* Academic Press, Inc., San Francisco, p. 461–478.

de NARONHA, C. 1973. Raw materials for fenni. Paper presented at the Symp. on 'Alcoholic beverage Industries in India' organized by AFST and CFTRI, Mysore. 1972. p. 21–27.

de NARONHA, C. 1975. Cashew feni. *Cashew Bull.* **12**(12) : 5–6, 9.

NATARAJAN, C. P. 1977. Status of cashew industry in India. In *Seminar on Cashew,* Export Inspection Agency, Cochin

NORTHWOOD, P.J.1964. Vegetative propagation of cashew *(Anacardium occidentale* L.) by the air layering method. *East African Agric. For. J.* **30** : 35–37.

NORTHWOOD, P. J. 1966. Some observations on the flowering and fruit-setting in the cashew *Anacardium occidentale* L. *Trop. Agriculture* (Trin.) **43** : 35–42.

NORTHWOOD, P. J. 1967. The effect of specific gravity of seed on the growth and yield of cashew *(Anacardium occidentale* L.). *East. African Agric. For. J.* **33** : 159–162.

NORTHWOOD, P. J. AND KAYUMBO, H. Y. 1970. Cashew production in Tanzania. *World Crops* **22**(2) : 89–91.

OHLER, J. G. 1977. Cashew *(Anacardium occidentale* L.). In *Plant Health and Quarantine in International Transfer of Genetic Resources* (Eds. William B Hewitt and Luigichiarappa). CRC Press, Inc., Ohio. p. 81–102.

OKWELOGU, T. N. AND MACKAY, E. J. 1969. Cashewnut moisture relations. *J. Sci. Fd. Agric.* **20** : 697–702.

OLUNLOYO, O. A. 1975. A leaf blight disease of *Anacardium occidentale* caused by *Pestalotia paeoniae. Pl. Dis. Reptr.* **59** : 829–830.

OLUNLOYO, O. A. 1976. Incidence and control of root rot diseases of cashew seedlings *(Anacardium occidentale)* in the nursery. *Turrialba* **26** : 33–38.

OLUNLOYO, O. A. 1978. The relation of sugery exudate and insects to fungal infection of developing cashewnuts *(Anacardium occidentale)* in the plantation. *Pl. Dis. Reptr.* **62** : 416–420.

OLUNLOYO, O. A. AND ESURUOSO, O. F. 1975. *Lesidiplodia* floral shoot die back disease of cashew in Nigeria. *Pl. Dis. Reptr.* **59** : 176–179.

PALANISWAMY, V. AND HAMEED, A. S. 1976. Study of propagation of cashew by patch budding. *South Indian Hort.* **23** :(1) : 24–25.

PARENTE, J. I. AND RIBEIRO DOS SANTOS, J. H. 1970. A importancia da cultura cajueiro em especial para O nordeste brasileiro. *Correio Agricola* (Bayer) **3** : 70.

PATIL, S. I., MENON, M. C. AND AGGARWAL, J. S. 1961. Surface coatings from CNSL-III Oleoresinous varnishes and paints. *Paint India* **11**(4): 17–21.

PAUL, V. J. AND YEDDANAPALLI, L. M. 1954. Olefinic nature of anacardic acid from Indian cashewnut shell liquid. *Nature* **174** : 604.

PAVITHRAN, K. AND RAVINDRANATHAN, P. P. 1974. Studies on the floral biology in cashew, *Anacardium occidentale* Linn. *J. Plant. Crops* **1** : 32–33.

PEIXOTO, A. 1960. Caju, Rio de Janeiro, *Minist. Agricultura Servico de* Informacao Agricola.

PHADNIS, N. A. AND ELIJAH, S. N. 1968. Development on cashewnut in Maharashtra State. *Cashew News Teller* **1**(8, 9, and 10) : 7–12.

PHADNIS, 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. 1975. Pests of cashewnut and how to combat them. *Cashew News Teller* (Oct-Dec.) : 31–33.

PILLAI, G. B. AND ABRAHAM, V. A. 1975. Tea mosquito a major menace to cashew. *Indian Cashew J.* **10**(1) : 5–7.

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.

PILLAI, P. K. T. AND PILLAI, G. B. 1975. Note on the shedding of immature fruits in cashew. *Indian. J. Agric. Sci.* **45** : 233–234.

PILLAI, P. P. 1935. *J. Ind. Chem. Soc.* **12** : 226.

PINHEIRO, M.F.V. 1968 A entomofauna da castanha de caju em armazens e fabricas. *Garcia de Orta* **16** : 293.

POLANCO, C. 1973. Two new leaf pathogens of cashewnut in Venezuela. *Agronomia Trop.* **23** : 373–378.

POPENDE, W. 1924. Economic fruit-bearing plants of Ecuador. *Contris. U.S. Natl. Herb.* **24**: part 5.

PRUTHI, J. S., CHAKRABORTHY, R. N., SONDHI, S. P., SASTRY, L. V. L. AND SIDDAPPA G. S. 1963. *Food Tech.* **17**(11) : 95–98.

PURSEGLOVE, J.W. 1974. *Tropical Crops–Dicotyledons.* Longmans, London. p. 19–23

PUTTARUDRAIAH, M. AND APPANNA, M. 1955. Two new hosts of *Helopeltis antonii* Signoret in Mysore. *Indian J. Ent.* **17** : 391–392.

RAI, B. G. M. 1970. Cashew through vegetative propagation. *Intensive Agriculture* **7** : 17–19.

RAMAKRISHNAN, T. S. 1955. Decline in cashewnut. *Indian Phytopath.* **8** : 58–63

RAMANUJAM, S. AND AJMANI, B. B. 1958a. *Ind. Pat.* **7** : 685.

RAMANUJAM, S. AND AJMANI, B. B. 1958b. *Ind. Pat.* **60** : 614.

RAMANUJAM, S. AND RAMAMURTHY, A. 1958. *Ind. Pat.* **60** : 613.

RAMANUJAM, S. AND RAMAMURTHY, A. 1959. *Ind. Pat.* **61** : 682.

RAMALINGAM, T., MURTHY, B. G. K. AND SIVASAMBAN, M.A. 1971a. *Paint India* **21**(2): 15.

RAMALINGAM, T., MURTHY, B. G. K. AND SIVASAMBAN, M.A. 1971b. *Paint India* **21**(8): 22.

RAMALINGAM, T., MURTHY, B. G. K., SIVASAMBAN, M. A. AND AGGARWAL, J.S. 1970. Cashewnut shell liquid distillation residue—its utilisation in coating. *Paint India* **20**(10) : 29–31.

RANGANATHAN, S. K. AND TANDON, K. G. 1946. *Paint Tech.* **11** : 94.

RANGASWAMI, G., SESHADRI, V. S. AND LUCY CHANNAMA, K. A. 1970. Fungi of south India. UAS Bangalore and USDA, 193 pp.

RAO, A. G., KRISHNA, J. G. AND AYYANNA, T. 1973. Studies on the comparative biology of *Macalla moncusalis* Walker on cashew *(Anacardium occidentale L.)* and mango *(Mangifera indica* L.) *Andhra Agric. J.* **20** : (5 & 6) 120–127.

RAO, A. R. 1969. Pests and diseases on cashew. *Lal Bagh* **14**(4) : 9–10.

RAO, C. B., DASARATHI, T.B. AND RAO, Y.Y. 1962. Studies on fruit development in cashew *(Anacardium occidentale* Linn.) *South Indian Hort.* **10** : 18–21.

RAO, M. M. 1959. Production of budded plants on clonal root stock in cinchona. *South Indian Hort.* **7** : 53–58.

RAO, P. A. 1978. Cashewnut a new host record of tobacco caterpillar, *Spodoptera litura* F. *Cashew Bull.* **15**(8) : 8–9.

RAO, P. A., DHARMARAJU, E. AND AYYANNA, T. 1976. Biology of *Metanastria hyrtaca* Coam. a serious pest on cashew. *Andhra Agric. J.* **23**(6) : 61–68.

RAO, P. A., DHARMARAJU, E. AND AYYANNA, T. 1977. Studies on the biology and bionomics of *Thalassodes* sp. a serious pest of cashew. *Andhra Agric. J.* **24**: 165–170

RAO, P.A., DHARMARAJU, E. AND AYYANNA, T. 1978. Biology of the newly recorded pest *Bombotelia jocosatrix* [Guen. a leaf feeder on cashew *(Anacardium occidentale* L.) *Cashew Bull.* **15**(5): 10–15.

RAO, V. N. M. 1955. Cashewnut cultivation in South India. *ICAR Farm Bull.* No. 9, 18 pp.

RAO, V. N. M. 1956. Multiply better yielding cashewnut. *Indian Fmg.* **6** : 15–17.

RAO, V. N. M. 1958. Studies on the vegetative propagation of cashew *(Anacardium occidentale* L.) 1: Air-layering by cincturing and etiolataion of shoots. *Indian J. Agric. Sci.* **28** : 181–197.

RAO, V. N. M. 1974a. Establishment and management of cashew plantations. Mimeo. Report of the All India Summer Institute on Improvement and Management of Plantation Crops. Central Plantation Crops Research Institute, Kasaragod. p.123–127.

RAO, V. N. M. 1974b. Crop improvement of cashew. Mimeo. Report of the All India Summer Institute on Improvement and Management of Plantation Crops. Central Plantation Crops Research Institute, Kasaragod. p. 128–134.

RAO, V. N. M. AND HASSAN, M. V. 1956. A note on the variations in seed characters of 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.

RAO, V. N. M., RAO, I. K. S., AND HASSAN, M. V. 1957a. Studies on certain aspects of germination of seeds in cashew *(Anacardium occidentale* L.) *Indian J. Agric. Sci.* **27** : 25–34.

RAO, V. N. M., RAO, I. K. S. AND HASSAN, V. M. 1957b. Studies on seed viability in cashew. *Indian J. Agric. Sci.* **27** : 289–294.

RAO, Y. R. 1915. *Helopeltis antonii* as a pest of neem trees. *Agric. J. India* **10** : 412–416.

REMAMONY, K. S. 1965. Biology of *Anarsia epotias* Meyr. (Lepidoptera: Gelechiidae). *Agric. Res. J. Kerala* **3** : 46–47.

REMAMONY, K. S. AND ABRAHAM, C. C. 1977. New record of *Pachypeltis maesarum* (Kirakaldy) (Miridae: Hemiptera) as a pest of cashew in Kerala. *Sci. & Cult.* **43**: 553.

RENDLE, A. B. 1952. *The Classification of the Flowering Plants.* The University Press, Cambridge, 640 pp.

RILEY, E. A. 1960. A *revised list of plant diseases in Tanzania.* CMI Mycol. Papers No. 75.

ROBBS, C. F. 1954. *Phytopathogenic bacteria of Brazil. Agronomia Riode J.* **13**: 265–282.

ROCCHETTI, G. AND PANERAI, L. 1970. Further studies on the germination of cashew-nut. *Riv. Agric. Sub. Trop.* **64**: 151–160.

RODRIGUES, M. da C. 1967. The mites of cashew in Mozambique. Part I. *Agronomia Mocamb.* **1**(1) : 21–26.

ROWE-DUTTON, P. C. 1976. *Artocarpus heterophyllus, Jack* fruit. In *The Propagation of Tropical Fruit Trees* (Gardner, R. J. *et al.*, eds.). p 269–290 CAB, East Malling. Kent, U. K.

RUHEMANN, S. AND SKINNER, S. 1887. *J. Chem. Soc.* **51** : 663.

RUMPHIUS, G. E. 1962. Herbarium amboinense *Uitgevery en Drukkerij Hollandia,* N. V. Baarn.

RUSSLE, D. C. 1969. *Cashewnut processing.* Agricultural Service Bulletin No. 6, FAO, 86 pp.

SANTOS, R., AND DOS RIBEIRO DOS. 1968. Baixa fructicacao em cajueiro. *Agron. Bot. Inf. Inst. Agron. Brazil* **20** : 10.

SASTRI, L. V. L., CHAKRABORTHY, R. N., PRUTHI, J. S. AND SIDDAPPA, G. S. 1963. Preservation and storage of cashew apple juice and its blends. *Ind. J. Tech.* **1** : 431–433.

SASTRY, L. V. L., SHETTY, L. N., SATYAVATI, V. K., PRUTHI, J.S. AND SIDDAPPA, G. S. 1962. *Ind. J. Appl. Chem.* **25** : 4–6; 119–122.

SATHE, P. G. AND SRINIVASALU, B. V. 1971. A new fungus on *Anacardium occidentale.* L. *Sci. & Cult.* **37** : 248.

SATHIAMMA, B. 1977. Nature and extent of damage by *Helopeltis antonii S.* the tea mosquito on cashew. *J. Plant. Crops.* **5** : 58–59.

SATHIAMMA, B. 1978. Occurrence of insect pests on cashew. *Cashew Bull.* **15**(4): 9–10.

SATYAVATI, V. K., MOOKERJI, K. K. AND BANDOPADHYAYA, G. G. 1963. Annual Report., CFTRI, 1962 : 433.

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

SEN. S. K., CHAKRAVARTHI, S. P. 1972. Effect of growth regulators on air layering in cashew. *Proc. Inter. Symp. Subtropical Hort.* Bangalore.

SHANMUGAVELU, K. C. 1970. Effect of gibberellic acid on seed germination and development of seedlings of some tree plant species. *Madras Agric. J.* **57** : 311–314.

SHANMUGAVELU, K. G. AND RAO, V. N. M. 1977. *Spices and Plantation Crops.* Popular Book Depot, Madras 298. pp.

SHETTY, K. T. AND BHATKAL, R. 1965 Cashew: note on raising seedlings and planting. *Lal Bagh* **10** : 34–35.

SHIVADASANI, H. B. 1972. Cashewnut shell liquid in break linings. *Indian Cashew J.* **8**(3) : 7–9.

SHIVANNA, C. S. AND GOVINDARAJAN, V. S. 1973. Processing of Cashewnuts. *Indian Fd. Packer* **27**(5) : 21–48.

SHIVASANKAR, S., MATHEW A. G., AND NATARAJAN, C. P. 1975. Storage aspects of processed cashewnuts. *Indian Cashew J.* **10**(2) : 7–10.

SIDDIQUE, S. AND KHAN, A. A. 1942. *Ind. Pat.* **28** : 424.

SINGH, S., SEHGAL, H. S., PANDEY, P. C. AND BAKSHI, B. K. 1967. Anthracnose disease of cashew *(Anacardium occidentale* L.) its cause, epidemiology, and control. *Indian Forester* **93**: 374–376.

SIVASAMBAN, M. A., MURTHY, B. G. K., AGGARWAL, J. S., ZAHEER, S. H. AND SHARMA, P. G. 1961a. Surface coatings from cashewnut shell liquid. *Paint India* **11**(1): 121–125.

SIVASAMBAN, M. A., MURTHY, B. G. K., AGGARWAL, J. S., ZAHEER, S. H. AND SHARMA, P. G. 1961 b. *Paint India* **11**(3) : 17–20.

SLETZINGER, M. AND DAWSON, C. R. 1946. *J. Am. Chem. Soc.* **68** :345.

SMIT, A. J. H. 1931. *Proc. Akad. Sci. Amsterdam* **34** : 165.

SMITH, F. G. 1958. Bee keeping operation in Tanganyika, 1949–1957. *Bee World* **39** : 29–36.

SPIEGEL, J. AND DOBRIN, C. 1896. *J. Chem. Soc.* **70** : 653.

SREERAMULU, C., AYYANNA, T. AND DHARMARAJU, E. 1976. Cashew apple feeders. *Cashew Bull.* **13**(2): 7.

SREERAMULU, C., PREMKUMAR, T., MARIAMMA DANIEL, AND SATHIAMMA, B. 1975. Record of three new pests of cashew., *Popillia complanata* Newm., *Pingasa ruginaria Gn.,* and *Estigmene lactinea* C. *J. Plant. Crops* **3** : 38.

SUBBARAO, M. S., 1972. Symposium on 'Alcoholic beverages industries' Organised by AFST and CFTRI. p. 35–38.

SUBRAMANIAN, S. S. AND NAIR, A. G. R. 1969. Catchine from cashewnut testa. *Curr. Sci.* **38** : 494–495.

SUNDARA RAMAIAH, M., MADHUSUDHAN, V., BHOJARAJ NAIDU, N. AND SIVASAMBAN, M. A. 1973. Properties of paints based on cardanol and 3–pentadecylphenol, the derivatives of cashewnut shell liquid. *Paint Manuf.* **43**(1) : 36.

SUSAMMA PHILIP. 1973. Seedlings blight of cashew *(Anacardium occidentale* L.) due to *Cylindrocladium scoparium. Curr. Sci.* **42** : 440.

SWAINE, G. 1959. Preliminary note on *Helopeltis* spp. damaging cashew in Tanganyika Territory. *Bull. Ent. Res.* **50** : 171–181.

TAVARES, S. 1959. *Madeiras do nordeste do Brazil. Mon. Univ. Rur. Pern. Recife.* **5**: 9–171.

THANKAMMA, L. 1974. *Phytophthora nicotianae* Var. *nicotianae* on *Anacardium occidentale* in South India. *Plant Dis. Reptr.* **58** : 767–768.

TATCHENKO, B. 1949. The cashew. *Fruits d'Outremer* **4**(6) **4**(8) : 198–205.

THEVET, A. 1558. *Singulaidades da 'Franca Antartica.* (ed. 1944). Compodia editora national, Sao Paulo. 502 pp.

THOMAS, D'SA. 1971. Cashew feni. *Cashew Bull.* **8**(2) : 7–8.

THOMPSON, A. K. 1969. Stages of development of the fruit of cashew *(Anacardium occidentale* Linn.). *Proc. Trop. Reg. Amer. Soc. Hort. Sci.* **12** : 209–215.

TSAKIRIS, A. AND NORTHWOOD, P. J. 1967. Cashewnut production in Southern Tanzania IV. The root system of cashew tree. *E. African Agric. For. J.* **33** : 83–87.

TULEY, P. AND IWENJORA, F. O. 1963 Damages to Cashew by *Analeptes trifaciata* F. *J. West African Sci. Assn.* **8** (1) : 58

TURNER, D. J. 1956. Some observations on the germination and grading of cashewnuts. *E. African Agric. J.* **22** : 35–39.

TYMAN, J. H. 1976. *Anal. Chem.* **48**(1) : 30.

VENKATARAMAN, T. M. 1978. Cashew development programmes in India—a review. *Cashew News Teller* **12**(1–3) 23–25.

VERMA, J. P. 1969. *Indian Cashew J.* **6**(3): 17.

WALLACE, G. B. AND WALLACE, M. M. 1955. The sudden death disease of cashew trees in Tanganyika. A preliminary note. *E. African Agril. For. J.* **21** : 42–43.

WASSERMAN, D. AND DAWSON, C. R. 1946. Cashewnut shell liquid. *Ind. Eng. Chem.* **37** : 396–399.

WATT, G. 1889. A *Dictionary of The Economic Products of India* (Repr. 1972). Cosmo Publ. Delhi. pp. 559.

WESTERGAARD, P. N. AND KAYUMBO, H. Y. 1970. The cashewnut industry in Tanganyika—A preliminary note. *E. African Agr. For. J.* **21** : 1.

WILSON, R. J. 1975. Markers for cashew kernel and cashewnut shell liquid.G(VK) No. 91. TPI (LONDON). 128 pp.

WOODROOF, J. G. 1967. *Tree nuts : Production, Processing, Products,* Vol. I. The Agri. Publ. Co. Inc., West Port, Connecticut. pp. 356.

WOODROOF, J. G. 1970. Tree nuts. *Indian Cashew J.* **6**(4) : 7–11.

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