CASHEW RESEARCH AND DEVELOPMENT IN HUMID TROPICS

WITH EMPHASIS ON CASHEW APPLE PROCESSING

Jose Mathew

C. Mini

Mareen Abraham

Cashew Research Station
Kerala Agricultural University, Madakkathara, Thrissur- 680 651
(e-mail: crsmadakkathara@kau.in)

and

National Horticulture Mission
New Delhi

English

Cashew research and development in humid tropics with emphasis on cashew apple processing

1st Edition : 2009 (250 copies)

Authors:

Dr. Jose Mathew
Professor & Head
Cashew Research Station, Madakkathara, 680 651, Kerala
(e-mail: josemannuthy@yahoo.co.in)

Dr. C. Mini
Associate Professor (Horticulture)
Cashew Research Station, Madakkathara, 680 651, Kerala
(Present address : College of Agriculture, Vellayani - 695 522, Kerala)
(e-mail: minichandran123@rediffmail.com)

&

Dr. Mareen Abraham
Associate Professor
Cashew Research Station, Madakkathara, 680 651, Kerala
(Present address: College of Agriculture, Vellayani - 695 522, Kerala)

Published by:
Director of Extension, Kerala Agricultural University
Mannuthy, Thrissur - 680 651

Printed at Lumiere Printing Works, Thrissur

Financed by:
National Horticulture Mission, New Delhi

Correct citation: Mathew, J., Mini, C. and Abraham, M. 2009
Cashew research and development in humid tropics with emphasis on cashew apple processing.
Kerala Agricultural University, Vellanikkara - 680 656, Thrissur

FOREWORD

Cashew is a high value commercial horticultural crop of India. It was introduced to India from Brazil by Portuguese travelers during the 16th century to the erstwhile Cochin state as a crop for afforestration and soil conservation from where it spread to Goa and other parts of India. Though the first factory for processing of cashew was started in Mangalore, the cashew industry was mainly developed at Quilon in Kerala. Thus Kerala was in the forefront in developing cashew cultivation, processing and export in India. It was the leading state in area and production of cashew till recent periods and still continue its dominant role in the processing and export of cashew.

Cashew research in India was started in 1952 with the starting of an adhoc scheme by ICAR at Kottarakkara (Kerala), Ullal (Karnataka), Bapatla (Andhra Pradesh), Daregaon (Assam) and Vengurla (Maharashtra). With the termination of the scheme in 1962, Government of Kerala has started a Cashew Research Station at Anakkayam in 1963.. Subsequently Kerala Agricultural University has started a Cashew Research Station at Madakkathara in 1973. Cashew research programmes were started at Pilicode in 1993 initially under the National Agricultural Research Programme and subsequently under the All India Co-ordinated Research Project on Cashew.

A lot of research and development activities has been undertaken in cashew at Kerala Agricultural University under different research centres to improve the productivity of the crop and to promote its cultivation and export. Lot of information has been generated and data accumulated about the crop over the years. The information is lying scattered in research papers, reports and thesises. I am happy to note that Cashew Research Station, Madakkathara has come forward to publish a compendium of the research and development works conducted in cashew in humid tropics with emphasis on Kerala by different organizations.

A special feature of this book is the detailed coverage on the processing of cashew apple. The Cashew Research Station, Madakkathara is the leading research centre on cashew apple processing even at the international level.

I am sure that this book will serve as a valuable reference material for those who are working in cashew research and development. It will also help to identify the research and development gaps while formulating research, development and export strategies.

I am thankful to the national and State Horticulture Missions for funding this publication.

I congratulate the authors Dr. Jose Mathew, Dr. C. Mini and Dr. Mareen Abraham for their sincere efforts in bringing out this publication.

I wish this book to be comprehensive enough to attract the attention of a wide circle of readership like scientists, farmers, development officials, entrepreneurs and farmers.

K.R. Viswambharan
Vice Chancellor
Kerala Agricultural University

PREFACE

The state of Kerala has played a pivotal role in developing the cultivation, processing and export of cashew in India since the crop was first introduced to the erstwhile Cochin state in the 16th century. Kerala was the leader in area and production till 1998- 99 and still holds the top position in processing and export.

The contribution of Kerala in the development of technologies in cashew is equally remarkable during the last six decades since organized research was started at Kottarakkara in 1952. It has developed large number of technologies in the areas of crop improvement, crop management, crop protection and processing of cashew, contributing significantly to improvement in productivity and income from cashew. Its contributions are particularly remarkable in the areas of varietal improvement, production of planting material and cashew apple processing. Out of 44 high yielding varieties released in India, Kerala Agricultural University is credited with the release of 15 varieties.

The Cashew Research Station, Madakkathara has developed large number of technologies for the processing of cashew apple to value added products. The station is credited with the establishment of the first commercial cashew apple processing unit which is running with good profit for the last ten years. With the constant research and transfer of technology initiatives of the Madakkathara station, it is of great proud that few cashew apple processing units have been started by private sector and Self Help Groups.

An attempt has been made in this book to give a comprehensive account of the cashew scenario in humid tropics with emphasis on Kerala. While research has been given more importance, other areas are also dealt with sufficient details.

The twenty one chapters in the book has been written by the experts in each field. We are very much thankful to each of them.

The publication of this book with special emphasis on cashew apple processing has been undertaken under the National Horticulture Mission- funded project on "Transfer, demonstration and refinement of technologies for cashew apple processing". We extend our thanks to National and State Horticultural Missions for the financial assistance in publishing this book.

We are grateful to Sri. K.R. Viswambharan, Hon. Vice Chancellor, Kerala Agricultural University for writing a forword to this book.

We are thankful to Dr. D. Alexander, Director of Research and Dr. M.K. Sheela, Director of Extension for the timely administrative supports and encouragements in bringing out this publication.

We also extend our thanks to all those who have directly or indirectly contributed in the publication of this book.

We sincerely hope that this book will be of use to all those who are interested in the scientific cultivation, processing and export of cashew.

Authors

Contents

CASHEW RESEARCH IN INDIA – AN OVERVIEW

M. Gopalakrishna Bhat
National Research Centre for Cashew, Puttur 574 202, Karnataka

Introduction

Cashew is a very important foreign exchange earning horticultural plantation crop of India. Cashew, a native of Brazil was introduced into India by Portuguese travelers during 16th Century. Since its introduction, cashew has very well adapted to the Indian climatic conditions and is grown both in the east coast and west coast regions of India. India was the first country to exploit the international trade of cashew kernels in the early part of 20th Century. Now India is the largest producer, processor, consumer and exporter of cashew in the world.

Cashew research in India started way back in 1950s through ad-hoc schemes sanctioned by ICAR. Efforts were intensified with the establishment of Central Plantation Crops Research Institute (CPCRI) at Kasaragod in 1970 and starting of All India Coordinated Spices and Cashewnut Improvement Project (AICS & CIP) in 1971with headquarters at CPCRI. Cashew research was further strengthened with the implementation of World Bank aided Multi State Cashew Project (MSCP) in 1982. The softwood grafting technique, which revolutioned the availability of good and true to type planting material of cashew in the country was standardized under MSCP project.

An important milestone in cashew research in India was the establishment of an independent research institute for cashew, i.e., National Research Centre for Cashew (NRCC) at Puttur, Karnataka in 1986 and the bifurcation of the then existing All India Coordinated Spices and Cashewnut Improvement Project. The headquarters of the newly started All India Coordinated Research Project on Cashew (AICRP on Cashew) was also shifted to NRCC, Puttur in 1986. There are at present eight centres and one sub-centre under AICRP on Cashew located in eight cashew growing states of India.

World Cashew Scenario

Cashew is grown in India, Brazil, Vietnam, Tanzania, Mozambique, Indonesia, Sri Lanka and other tropical Asian and African Countries. The world production of cashew is estimated to be around 20.8 lakh tons. Between 1980 and 1995, world raw nut production has increased from 4.22 lakh tons to 8.78 lakh tons registering an increase of 108 per cent. Growth rate between 1995 and 2000 is less (24%), as compared to the growth rate between 1980 and 1995. Since 2000, the raw nut production registered an increase by 40 per cent. India's share in the world raw nut production accounts to about 25%. Raw nut production in South East Asian Countries has registered approximately 10-fold increase since 1980. Latin American Countries have registered approximately three-fold increase during the same period. In recent times, India is facing stiff competition from Vietnam and Brazil in international cashew trade.

Indian Cashew Scenario

In India cashew is grown mainly in Maharashtra, Goa, Karnataka and Kerala along the west coast and Tamil Nadu, Andhra Pradesh, Orissa and West Bengal along the east coast. To a limited extent it is grown in Manipur, Meghalaya, Tripura, Andaman and Nicobar Islands and Chattisgarh and also in plains of Karnataka. At present Maharashtra is ranking first in area, production and productivity in the country. India's raw nut production has increased from 0.79 lakh tons in 1955 to 5.73 lakh tons in 2006. Between 1990 and 2006, the raw nut production has almost doubled.

In 1955, cashew in India was grown in an area of 1.1 lakh ha. In the year 2006, cashew was grown in an area of 8.6 lakh ha. Over the last 45 years, area under cashew has registered an increase of 600 per cent. Area under cashew has been steadily increasing. Between 1970 and 1980, although area under cashew increased, the per cent

increase in production was negative. During 1995-2004, increase in both area and production was phenomenal. Upto 1970, the productivity of cashew was around 630 kg/ha. Between 1975 and 1985, the productivity was low (430 kg/ha). Since, 1985, the productivity has been steadily increasing from 430 kg/ha to 815 kg/ha. in 2006. This is mainly due to improved technologies available and replanting of large areas of old plantations and the availability of necessary high yielding planting materials through government agencies and private nurseries. Research institutions and private nurseries are producing 6 to 7 million grafts annually.

India has been exporting cashew kernels since early part of 20th century. Over the years, both the export earnings as well as quantity of kernels has been increasing. The established processing capacity of raw nuts is around 12 lakh tons. However, domestic production of raw nuts is around 5.7 lakh tons only. Thus, presently India is importing raw nuts from African and other countries to the tune of 5.8 lakh tons to meet the demand of cashew processing industries. Export earnings has been on the increase since 1955. India has earned an all time high export earnings of Rs. 2709 crores during 2004-05. Cashew industry provides employment to over 5.5 lakh workers annually, mostly women. Between 1980 and 1985, although export earnings increased, quantity of cashew kernels exported decreased. Since 1985, there has been a steady growth in the quantity of cashew kernels exported. Inspite of the domestic production of over 5 lakh tons and import of around 6 lakh tons of raw cashewnuts, the total availability of raw cashewnuts is not able to keep pace with the requirements of cashew industry. Since African countries have started taking up cashew processing themselves, availability of raw cashewnuts for importing by India may gradually decline or may all together stop. Hence, there is urgent need to increase the domestic raw cashewnut production and become self sufficient in raw cashewnut production. Availability of land area to expand cashew cultivation in India may not be much except in states like Chattisgarh or waste lands available to certain extent in coastal regions and some non-traditional areas. Hence, it is essential to increase productivity per unit area.

Research Achievements

The major achievements in research and development in the country are as follows:

- Cashew germplasm collection in National Cashew Field Gene Bank (NCFGB) at NRCC, Puttur is 506 accessions. A total of 433 cashew accessions have been assigned with National Collection numbers. A total of 285 accessions have been characterised as per IPGRI descriptors. Three germplasm catalogues for 255 accessions have been brought out. Further, over 1300 cashew accessions are conserved in Regional Cashew Field Gene Bank in different centres under AICRP on Cashew.
- A total of 44 high yielding cashew varieties have been released in the country for commercial cultivation.
- Soft-wood grafting method has been standardised and its feasibility for the commercial multiplication has been demonstrated and this technique is being commercially utilized for large scale production of planting material in cashew in the country.
- In micropropagation, regeneration of cashew from the seedling explants (nodal cultures) has been standardised. Micrografting technique for *in vitro* multiplication of cashew has been standardised and cashew plants raised by micro grafting have been potted.
- Inter cropping field crops such as groundnut, black gram and green gram; vegetables such as cucumber and bottle gourd; tuber crops; fruit crops such as pineapple and spices such as turmeric, ginger and pepper have been found to be suitable and profitable in cashew plantations, increasing the total return from unit land area during the early stage of cashew plantation.
- High density planting (625 trees/ha at 4m x 4m spacing) was shown to be better than normal spacing (8m x 8m) resulting in a yield increase by 2.5 times over control in the initial ten years.
- Providing irrigation of 200 litres of water per tree once in 15 days after flowering during the summer months is found to increase the cashew yields profitably. Irrigating cashew at 60-80 litres of water per tree once in four days through drip after flowering till fruit set and development in combination with the application of 750 : 187.5 : 187.5 g of NPK/tree led to significantly higher yields.
- The rearing technique for Cashew Stem and Root Borer (CSRB) on host bark has been standardised. Volatiles and extracts in hexane from both healthy bark and frass on testing by EAG elicited response from adult female beetles of CSRB. Laboratory

rearing techniques for Tea Mosquito Bug (TMB) has been standardized.

- Effective and economic spray schedule has been developed for control of TMB. Recently, new molecules of insecticides have been tested for control of TMB. Among the new insecticides evaluated against this pest, λ-cyhalothrin was found to be very effective in reducing the damage.
- It was found possible that spread of the pest Cashew Stem and Root Borer could be prevented by adopting phytosanitation.
- Sweetened and flavoured spread could be prepared from cashew kernel baby bits. Optimum coating of baby bits with honey and cane sugar occurs at 100°C at 70% concentration. Cashew kernel baby bits could be coated with different combinations of flavours and colours. Cardamom flavoured and apple green / saffron coloured and sweetened cashew kernel baby bits are most preferred. Sweetened and flavoured cashew kernel baby bits could be stored without quality deterioration for twelve months at ambient temperature.
- Cashew Research Station, Madakkathara, under Kerala Agricultural Uniersity have developed technologies for effective utilisation of cashew apple. Cashew apple syrup, drink, jam, pickle and candy have been commercially produced and marketed by Madakkathara Centre and are getting good consuemr response.
- Cashew apple pomace, which is rich in fibre could be blended with cereals (ragi, rice and wheat) and pulses (green gram) upto 10% without affecting the quality in terms of *in vitro* digestibility of both proteins and carbohydrates. Cashew apple pomace based blends could be stored upto one year without affecting the quality.
- Studies on mineral composition have indicated that cashew kernels are rich in P and K and considerable variation is exhibited among released varieties. Similarly, cashew apple pomace of released varieties have been analysed for mineral composition.
- Database on processing aspects of cashew processing industries has been established. Data base includes details on prevailing processing aspects, system of storage and personal hygiene.
- The existing hand cum pedal operated cashew nut sheller has been modified by fixing a CAM.
- Apple residue and leaf litter could be effectively utilised for the production of vermicompost with 1.69% N, 0.44% P and 0.58% K, in 95 days.
- Yield forecasting model for cashew has been developed.

Gaps

- Senile and seedling origin plantations of non-descript types with low yield.
- Grown in poor soil and neglected conditions.
- Inadequate transfer of cashew production technology.
- Non adoption of recommended package of practices to the extent required.
- Absence of compact and dwarf high yielding varieties.
- Wastage of cashew apple which is rich in nutrition.

Future Strategies

Keeping in view of the changing global scenario and the need to produce cashew at an internationally competitive price by reducing the cost of production and increasing the productivity, research programmes are to be reoriented in the country. Technologies developed in the research centers have to be effectively transferred to the farmers' fields to achieve higher yields.

Some of the areas which need to be given emphasize in future research programmes are given below:

- Collection, conservation, evaluation and cataloguing of both exotic and indigenous cashew germplasm especially dwarf and compact cashew types.
- Development of compact and dwarf varieties suitable for high density planting.
- Evolving varieties with high yield, resistance to biotic and abiotic stresses, better flowering behaviour/characters (synchronized and staggered) and better kernel quality for internal consumption and export.
- Standardization of protocol for regeneration of cashew from matured tree source.
- Integrated Plant Nutrient Management (IPNM) including nutrient budgeting, orchard management, weed management, irrigation management, correction of micronutrient deficiencies and soil and

water conservation techniques for achieving high yield.

- Canopy management and rejuvenation of old cashew plantations/orchards.
- Canopy architecturing and management to suit the requirement of different plant densities and system of planting.
- Detailed studies on high density planting system to increase productivity of cashew.
- Integrated cashew based farming system research including cashew based cropping system (mixed and intercropping).
- Organic farming research including, biodynamic farming research in cashew for producing quality nuts especially for international market.
- Studies on kairomones and pheromones for effective and economic control of Tea Mosquito Bug and Cashew Stem and Root Borer.
- Development of eco-friendly IPM strategies including entomo-pathogenic nematodes (EPN) for control of major insect pests.
- Studies on pest complex in post-harvest and pre-processing stages.
- Development of value added products from lower grade kernels.
- Developing technologies for alternate use of by-products of cashew processing industry such as cashew kernel rejects, Cashew Nut Shell Liquid (CNSL), cashew shell cake and cashew kernel testa.
- Utilization of cashew apple in order to make use of the nutrients and vitamins available in it and also to increase the income of the farmer.
- Development and refinement of on-farm processing machinery.
- Development of farmer friendly technologies through farmers' participatory technology development programmes.
- Extension efforts to bridge the gap between actual yield and potential yield.
- Developing training methodologies for transfer of technology in cashew.

Development Strategies

Efficient transfer of technology holds the key for increasing the productivity and production of cashew in the country.

- Large plantations under Cashew Development Corporations and Forest Corporations are mostly of seedling origin and are in senile conditions. Hence, massive replanting programmes to replace the senile cashew plantations of seedling origin with grafts of improved varieties are needed.
- Production and supply of quality planting material.
- Area expansion under cashew in traditional and non-traditional areas.
- Organizing intensive thematic campaigns and farmers' training programmes.
- Introduction of Crop Insurance Policy for cashew.
- Declaration of plantation crop status to cashew by all cashew growing states, as done by Kerala.
- Introduction of central sector scheme for soil and water conservation measures and management of CSRB in Government owned cashew plantations.
- Participation of cashew industry in promotional efforts.
- Development of better packaging and marketing strategy to retain the supremacy of Indian cashews in international market.
- Post-harvest Management.

The targets for rawnut production are 10 lakh tons for the year 2010 and 15 lakh tons for the year 2015. This can be achieved if the technologies developed at research centres are transferred to farmers' fields and all the senile plantations of seedling origin under Cashew Corporations / Forest Departments are replaced with cashew grafts of improved high yielding varieties.

***

CASHEW RESEARCH IN KERALA

Jose Mathew, Gregory Zachariah, A. Sobhana and Haseena Bhaskar
Cashew Research Station, Madakkathara 680651, Thrissur, Kerala
(e-mail:crsmadakkathara@kau.in)

Cashew research in Kerala was started in 1952 with the setting up of a research station at Kottarakkara, together with three other stations at Vittal (Karnataka), Bapatla (Andra Pradesh) and Vengurla (Maharashtra), under an ICAR adhoc project. The financial assistance of ICAR to the above project was terminated in 1962. Subsequently, the Government of Kerala has started a full-fledged Cashew Research Station at Anakkayam in 1963 under a scheme included in the third five year plan.

Cashew Research Station, Anakkayam, was one of the four centers, of the All India Co-ordinated Spices and Cashew nut Improvement Project of the ICAR, when the latter was started in 1971. The station has been brought under the Kerala Agricultural University, when the University was established in 1972. Cashew Research Station at Madakkathara was started under Kerala Agricultural University on 1.5.1973. Subsequently the centre of the All India Co-ordinated Spices and Cashew nut Improvement Project was shifted to Madakkathara from Anakkayam.

In addition to the research programmes conducted at the Cashew Research Stations of Anakkayam and Madakkathara, several research projects on cashew were carried out under the Kerala Agricultural Development Project (KADP), Vellanikkara during 1978-79. The World Bank aided Multi State Cashew Research Programme (MSCRP) was implemented at Madakkathara during 15.2.82 to 3.9.86 during the 8th five year plan. The All India Co-ordinated Spices and Cashew nut Improvement Project was bifurcated in 1986 and an independent All India Co-ordinated Research Project (AICRP) on Cashew was started in 1986 with its head quarters at National Research Centre for Cashew, Puttur, Karnataka. Since then, Madakkathara station is continuing as one of the centers of AICRP on Cashew. During 1989 research and extension programmes in cashew were started at RARS, Pilicode under National Agricultural Research Project (NARP). During February 1993, Regional Agricultural Research Station, Pilicode has been recognized as a sub-centre of the AICRP on Cashew.

1. CASHEW RESEARCH STATION, MADAKKATHARA

A. Research highlights

The highlights of research findings from Cashew Research Station, Madakkathara is given below:-

A. Crop improvement

1. The station has released 11 high yielding varieties of cashew which is widely cultivated in the state.

   i. **Madakkathara 1:** A selection released during 1990. The mean annual nut yield / tree is 13.8 kg. The nut weight is 6.2 g and the shelling percent is 26.8. The export grade is W 280.
   ii. **Madakkathara 2 (NDR 2 –1):** A selection released during 1990.The mean annual nut yield /tree is 17.0 kg. The nut weight is 7.25 g and the shelling percent is 26.0. The export grade is W 210.
   iii. **Dhana (H- 1608):** A hybrid released during 1993. The mean annual nut yield / tree is 10.7 kg. The nut weight is 8.2 g and the shelling percent is 29.8. The export grade is W 210.
   iv. **Kanaka (H – 1598) :** A hybrid released during 1993. The mean annual nut yield / tree is 12.8 kg. The nut weight is 6.8 g and the shelling percent is 30.6.The export grade is W 280.
   v. **Sulabha (K –10-2):** A selection released during 1996. The mean annual nut yield / tree is 21.9 kg. The nut weight is 9.8 g and the shelling percent is 29.4. The export grade is W 210.
   vi. **Priyanka:** A hybrid released during 1995. The mean annual nut yield / tree is 17.0 kg. The nut weight is 10.8 g and the shelling percent is 26.6. The export grade is W 180.
   vii. **Amrutha:** A hybrid released during 1998. The

mean annual nut yield / tree is 18.4 kg. The nut weight is 7.2 g and the shelling percent is 31.6. The export grade is W 210.

viii. **K-22-1:** A selection released during 1987. The mean nut yield/ tree is 13.0 kg. The nut weight is 10.2g and shelling percentage is 26.5. The export grade is W 280.

ix. **Raghav (H-1610):** A hybrid released during 2002. The mean annual nut yield tree in 14.6 kg. The nut weight is 9.2 g and the shelling percent is 26.6. The export grade is W 210.

x. **Damodar (H-1600):** A hybrid released during 2002. The mean annual nut yield /tree in 13.7 kg. The nut weight is 8.2 g and the shelling percent is 27.3. The export grade is W 240.

xi. **Poornima (H 1593):** A hybrid released during 2006. The mean annual nut yield per tree is 14.08 kg/ha. The nut weight is 7.8 g and kernel weight is 2.6 g. The shelling percent is 31%. The export grade is W 210.

2. A clonal germplasm conservation block with 128 accessions is being maintained and evaluated at the station.

3 A total of 1587 hybrid seedlings were evolved and planted in the field during the period 1993-2008 and are being continuously evaluated for their yield and characters.

B. Plant propagation

1. Technology for softwood grafting

The technique of softwood grafting was developed in the late 80s, which is found to be the best method for the vegetative propagation of cashew. Anakkayam-1, Madakkathara-1 and K-22-1 were identified as the best rootstocks at 45 days after sowing during March-April. Plants with more height, girth and internodal length are the best. Ideal age of the scion is identified as 3 to 4 months. Nuts having maximum weight, volume and L/B ratio give vigorous seedlings in the nursery.

2. Technology for flush grafting

Flush grafting, developed and perfected at this centre, overcomes the limitations of softwood grafting. Flush grafting enables large-scale multiplication of elite types, as scions of three weeks old (flushes) can be successfully grafted on 21 day old rootstock. The ideal season is January to September.

3. Technology for air layering in cashew

Studies on effects of hormones on rooting of air layers reveated that the application of 250 ppm IBA /IAA at the girdled portion or the selected shoot promotes rooting. Wood shaving was found to be the best medium for air-layering followed by sand: sawdust in equal proportion. For transplanting the rooted air-layers, polythene bags filled with ordinary potting mixture (sand, topsoil and powered cowdung at 1:1:1 ratio) were found to be the best.

4. Technology for top working in cashew

Top working, a technique developed for rejuvenating unproductive casnew trees, has been refined at the station. The trees are to be cut at one metre height during January Softwood grafting is to be done during March-April on the new shoots.

C. Crop management

1. Standardization of planting densities for cashew

The planting may be done at a spacing of 7.5 m for poor and 10 m for rich and deep soils and sandy coastal area. On very sloppy lands, the rows may be spaced 10-15 m apart with spacing of 6-8 m between trees in a row. Either the square or triangular system of planting can be adopted.

2. Development of high density planting technique

High density planting ensures optimal utilization of solar radiation and land in the initial years. It yields almost double during the early years, as compared to normal planting. It involves thicker planting during early years and selective felling during later years, on development or canopy pressure and root level competition. Cashew will be planted initially at a spacing of 4m x 4 m or 5m x 5m. and maintained up to a period of six to seven years. Later, trees are removed in a planned manner, to provide a spacing of 8m x 8 m or 10m x 10m.

3. Formulation of a fertilizer schedule for cashew

A fertiliser dose of 750g N, 325 g of P_2O_5 and 750g K_2O per plant is recommended for cashew. 1/5th of the dose is to be applied after the completion of the first year, 2/5th dose during second year and thus reaching full dose from 5th year onwards. Broadcast the fertiliser within an area of 0.5 to 3m (15cm deep) around tree and incorporate by raking.

4. Intercropping

Pineapple is the most profitable intercrop in cashew

plantations in the early stages of growth. Paired row of pineapple suckers can be planted in each trench at 60 cm between rows and 40 cm between two suckers within the row. These trenches can be opened across the slope at 1.0 m spacing between two rows of cashew. Lemongrass and tapioca are also suitable as intercrops. Coleus has been identified as another intercrop with high yield and good economic return.

4. Root activity studies

Studies on the root activity of cashew using radio isotopes revealed that 75% of the feeder roots are located within a depth of 30 cm from soil surface.

5. Pruning

Pruning of light branches is found to result in the production of vigorous proleptic branches that are sturdy and productive. The best time of pruning is in the dormant stage preferably during the month of August. By pruning 25% of five branches at an interval of three years, coupled with high density management practices, the yield of cashew can be almost doubled.

6. Regulation of flowering

A comprehensive package for regulating flowering in cashew is evolved. It involves spray application of cultar at the rate of 1g/litre together with KNO_3 1% to mature lateral shoots of cashew before flushing during late October.

7. Vermi compost from cashew apple residue

The cashew apple residue from the processing unit has been successfully utilized for the production of vermicompost having nutrient composition of 1.69% N, 0.44% P, and 0.58% K.

D. Crop Protection

1. A large number of insecticides have been evaluated for the control of tea mosquito bug (TMB). Some of the insecticide which has been recommended by the station for the effective and economic control of TMB includes monocrotophos, endosulfan, carbaryl, quinalphos and phosphamidon.
2. A rational rotation of insecticides is recommended for the control of TMB to counteract the tendency of the pest to develop field resistance. The spray schedule includes 0.05% endosulphan, 0.1% carbaryl; 0.05% quinalphos and 0.03% phosphamidon. (*use of endosulphan on cashew stands temporarily withdrawn at present)
3. Formulated the following technology package to control the pest- disease complex of TMB and Anthracnose in cashew.
   - Remove and destroy the affected plant parts to reduce the source of inoculum
   - Prophylactic spray of 1% Bordeaux mixture or 0.3% Copper oxychloride during second week of May (before monsoon)
   - First combined spray with Monocrotophos 0.05% and Copper oxychloride 0.2% during October-November (flushing stage)
   - Second combined spray with Quinalphos 0.05% and Mancozeb 0.2% during December- January (flowering stage)
   - Third spray during nut initiation stage (January-February) with Carbaryl 0.1%.
4. Formulated an integrated package for the control of cashew stem and root borer. Removing the dead trees and trees in advanced stages of infestation at least once in 6 months can reduce further infestation. Prophylactic treatment by swabbing the trunk region (up to 1m height from the ground level) and exposed roots, with a suspension of mud slurry + carbaryl 0.2% or coaltar and kerosene (1:2) or 5% neem oil twice a year during March- April and November – December along with soil application of Sevidol 4 G @ 75 g/tree is found to check the incidence of cashew stem and root borer.
5. Recommended control measures for the management of pests and diseases of cashew nursery.
6. Twenty insects have been recorded as pests of cashew at the station
7. Pest calendar has been prepared for the seasonal occurrence of insect pests of cashew

E. Processing technology

The station is in the forefront in the national and international level in developing technologies for the production of various value added products from cashew apple and employing these technologies for commercial production.

For intensifying research and transfer of technology

activities in cashew apple processing, a cashew apple processing unit with FPO license was established at the station in 1997 and commercial production was started in 2000. It is the only unit in India, which is producing cashew apple products in a commercial scale. The first product of the unit was cashew apple syrup. Subsequently, the activities of the unit have been expanded to make it economically more viable by diversifying the product range. At present, the unit additionally undertakes commercial production of Cashew apple–Mango (*Cashewman*) Mixed Jam, Cashew Apple Pickle, Cashew Apple Drink (Ready-To-Serve (RTS) form) and Cashew Apple Candy and sell them through KAU Sales Counters and exhibitions organized by KAU such as Thrissur Pooram Exhibition.

Under a mega project funded by National Horticulture Mission entitled "Transfer, demonstration and refinement of technologies for cashew apple processing" implemented at the station during 2007-08, the following ten technologies has been developed for cashew apple processing:-

1. Clarification of cashew apple juice with sago
2. De-tanning of whole ripe/ green cashew apples
3. Off- season storage of cashew apple juice, pulp and green pieces
4. Modified procedure for preparation of cashew apple syrup
5. Procedure for preparation of cashew apple RTS beverage
6. Procedure for preparation of cashew apple- pine apple squash
7. Procedure for preparation of cashew apple- pineapple blended RTS
8. Procedure for preparation of cashew apple - mango mixed fruit jam
9. Procedure for preparation of cashew apple pickle
10. Procedure for preparation of cashew apple candy

Under the project, several transfer of technology initiatives on cashew apple processing has been implemented. A brief resume of the activities undertaken under the project is presented elsewhere in this book.

B. Concluded research projects

The following is the list of concluded research projects at the station:-

I. Propagation

1. Propagation trials in cashew
2. Standardization of air layering technique in cashew with a view to reduce post separation
3. Mortality
4. Standardization of seedling selection technique
5. Correlation studies between size, shape and weight of seed nuts with vigour of seedling,
6. Early bearing and yield of cashew trees
7. Studies on root stock- scion interaction
8. Screening of varieties for identification of dwarf rootstock
9. Studies to find out the best season for soft wood grafting
10. Varietal response to soft wood grafting
11. Physiology of rooting and establishment of cashew air layers
12. Standardization of planting medium and containers in the nursery
13. Role of growth regulators in promoting rooting and establishment of air layers in cashew
14. *In situ* grafting in cashew

II. Crop management

1. Fertilizer trial in cashew
2. Method of fertilizer application in cashew (Observational trial)
3. Nutritional studies in tree crops- uptake pattern and deficiency symptoms in cashew
4. Hormone application to increase fruit set in cashew
5. Pruning trial in cashew
6. Soil test based and productivity linked approach for cashew nutrition (ICAR adhoc project)

III. Crop improvement

1. Comparative yield trial of Anakkayam selections and hybrid progenies (air layers)
2. Comparative yield trial of existing high yielders of cashew (seedlings)
3. Variability in the F1 population of cashew
4. Pollination studies in cashew
5. Multilocational trial of 18 cashew types and hybrids

IV. Crop protection

1. Survey of insect pests of cashew
2. Study on varietal resistance and control of die back disease using newer fungicides

3. Trial on foliar application of urea along with insecticides (Observational trial)
4. Pest complex infesting cashew inflorescence
5. Chemical control of pest complex in cashew
6. Evaluation of Lamdacyhalothrin against cashew pests
7. Developing integrated production package for enhancing productivity of cashew

V. Processing technology

1. Studies on optimum maturity and chemical composition of cashew apple for the preparation of different unfermented products
2. Clarification of cashew apple juice by different methods
3. Enrichment of organic wastes from cashew garden (observational trial)

VI. Projects under Kerala Agricultural Development Project (KADP)

1. Multilocational trials on orchard management practices- intercropping
2. Spacing trial
3. Cultural trial
4. Standardization of vegetative propagation in cashew
5. Nutritional studies in cashew
6. Multi locational fertilzer trial in farmers' fields
7. Studies on root activity of cashew using radio isotopes
8. Survey and collection of superior genotypes in cashew
9. Genetic improvement by hybridization and selection
10. Relative susceptibility of cashew types to infestation by *Helopeltis antonii*
11. Exploration of the feasibility of biological control of the tea mosquito bug
12. Studies on controlling stem borer

VII. Projects under National Agricultural Research Project (NARP)

1. Nutritional studies in cashew using clonal planting material
2. Spacing trial in cashew using clonal planting material
3. Pruning and training studies in cashew

VIII. Projects under multi state cashew research project (MSCRP)

1. Standardization of vegetative propagation in cashew
   a. Testing of different propagation techniques in large scale
   b. Establishment of progeny gardens and clonal multiplication units
2. Establishment of trial cum demonstration cum multiplication plots with recommended types of cashew adopting efficient propagation techniques
   a. Trials in Institutions (RARS, Ambalavayal & Integrated Tribal Development Area Farm, Attapady)
   b. Trials in cultivators' fields
3. Demonstrations of Package of Practices including chemical and sanitational control of cashew pests and diseases
   a. In cultivator's plots
   b. Trials on the control of cashew pests- relative efficiency of ULV sprays of insecticides applied aerially for the control of tea mosquito and other pests
4. Training of field staff (Agrl demonstrators and Malis) in cashew propagation and cultivation

C. Ongoing research projects

1. AICRP on Cashew

Fourteen research projects are being undertaken under the All India Co-ordinated Research Project on Cashew.

1. Germplasam collection, conservation, evaluation, characterization and cataloguing of cashew
2. Hybridization and selection of cashew
3. Multilocational trial II (1992)
4. Multilocational trial III (2002)
5. Multilocational trial V (MLT 2006)
6. NPK fertilizer experiment in cashew
7. Intercropping trial in cashew
8. On farm fertilizer trial in cashew in farmers' fields
9. Fertiliser application in high density plantations
10. Organic farming in cashew
11. Evaluation of insecticides for control of tea mosquito bug (TMB) and others insect pests.
12. Control of cashew stem and root borers: prophylactic and curative trials
13. Bio-ecology of pests of regional importance and survey of pest complex and natural enemies
14. Screening of germplasm to locate tolerant/resistant types for major pests of the region

2. Plan projects

1. Evaluation of promising Madakkathara accessions

2. Growth and yield of cashew as influenced by chemical retardants

3. Collaborative projects

1. Forewarning of TMB in cashew (in collaboration with College of Horticulture, Vellanikkara)
2. Cataloguing of cashew germplasm of Kerala with molecular markers and digitizing the morphological data (in collaboration with College of Agriculture, Vellayani)
3. Development of an Agricultural Expert System Software, AGRI EXPERT (in collaboration with College of Agriculture, Vellayani)
4. Development of INM package for commercially important plantation crops (in collaboration with College of Agriculture, Vellayani)

2. CASHEW RESEARCH STATION, ANAKKAYAM

The station was established in 1963.

1. Research highlights

1. This station has released four high yielding varieties of cashew so far;

   i. **Anakkayam-1**: It is the first cashew variety released by the Kerala Agricultural University. The high yielding seedling type BLA-139-1 was released as *Anakkayam-1* in 1982.
   ii. **Dharasree:** a middle season flowering hybrid, which was released in 1996, has average yield of 15 kg per tree.
   iii. **Akshaya:** This hybrid with large nuts was released in 1998. The flowering occurs during the middle of the season. The average yield per tree is 11.8 kg. The export grade is high (W180)
   iv. **Anagha:** This variety, with an annual yield of 13.7 kg/tree/annum, was released in 1998. This is a mid season flowering variety

2. A new variety of cashew, Selection 990, is in the pipeline for release. It is a clonal variant of the released variety Anakkayam1. Unlike Anakkayam 1, nuts of this clone are bold and bigger with high kernel content. The clone is quite early and harvest can be completed before April. The clone shows field resistance to tea mosquito attack. Average yield is 18.5 kg per tree per year. Average weight of nuts is 10.4 gm and that of kernel is 3.3 gm.

2. Ongoing research projects

1. Collection, maintenance and evaluation of cashew germplasm
2. Breeding improved varieties of cashew by hybridization
3. Evaluation of 96 series hybrids
4. Establishment of a polyclonal progeny orchard of cashew

3. REGIONAL AGRICULTURAL STATION, PILICODE

A sub centre of the AICRP on Cashew was started in February 1993 at this station to take up research on cashew considering the importance of cashew cultivation in the northern districts of Kerala. The centre undertakes the following research programmes.

1. Germplasm collection, evaluation, characterization and cataloguing of cashew types.

This experiment was started in 1994. 87 diverse types were identified under the project, of which 64 types have been assigned IC numbers. PLD-4 was found to be superior in yield. PLD -57 (TPB 1), a dwarf type, was used for hybridization with Anakkayam 1 and Madakkathara 1. PLD 57 is having very short internodes, very small leaves, very compact canopy and panicles. It is a very early flowering type in October but yield in 2 kg/tree only.

2. Evaluation of precocious dwarf KGN 1

The experiment was started in 2002 to evaluate the performance of KGN 1.

3. Fertilizer application and spacing trial in high density plantation

The experiment was started in 2000 to formulate fertilizer schedule for high density cashew plantations.

4. Multilocational trial V (MCT 2006)

Started in 2008, with 25 promising types/released varieties.

***

INDIAN CASHEW IN GLOBAL ARENA

P.P. Balasubramanian
Directorate of Cashewnut and Cocoa Development, Cochin - 682 011, Kerala

Introduction

Cashew is grown in India as a commodity of commerce. The versatile property of this crop, though was identified in Brazil in the middle of 15th century AD, India was the first to exploit its economic and commercial aspects. Such exploitation with deep scientific exploration was started in India only from the later part of 19th century, until then, practically little was the efforts for its adoption in any part of the world. Even in India, its entry was in the 2nd half of the 16th century made by the Portuguese sailors who later colonized western part of India. Here again over a period of five centuries a systematized economic exploitation did not take place, for, the introducers conserved it only for prevention of soil erosion and manufacture of alcoholic beverage from its apple called feni. The other colonizers who subsequently came to India, did not envince any interest on cashew, as their commencing from 2nd half of the 19th century started witnessing a moderate interest for the development of cashew in India.

Almost simultaneous to the introduction of this crop to India, many of the other Asiatic, African, and Latin American countries started developing this crop from the fag end of 19th century. At present there are 27 other countries remaining in the fold of cashew cultivation.

Global situation

Including India, cashew is grown in 28 countries in the world. Its adoption mainly was for the economic sustainability of the nations concerned and their participation in the international commerce has been simultaneous to the initiation of the developmental efforts in India.

Cashew in an evergreen species. Tropical humid region with a latitudinal range of 27°N and 28°S of equator experiencing a summer temperature of 32 to 36°C and winter (cooler) temperature not falling below 20°C, and such areas in central and South American Zone generally known as Latin American Zone, Asian Zone and African Zones enjoying this preferential climatic situation are the major areas of the cultivation in the world. These cashew growing regions specifically fall almost equidistantly far of the equator and are spread almost equally in the Northern and Southern Hemisphere. As far as cashew production is concerned, the rawnut is available through out the year except for the month of July. Rawnut production becomes available in almost half of the period prior to July, ie February to June in the parts of Asian and West African Zone in the northern hemisphere and after July ie August to February again in some parts of Asian Zone and South African Zone and Latin American Zone in southern hemisphere.

The global area under cashew is around 3.1 million ha with a production of 1.9 million MT (2004-05). The global productivity level is 690 kg/ha. The trend in productivity has a phenomenal bearing to the distance from equator. While the productivity is substantially high in areas near to the extremity of specified latitudinal ranges, it narrows down according to the nearing distance to the equator. This may be due to the effect of day length as the sun traverses towards the tropic of cancer or towards the tropic of capricorn.

Indian situation

Efforts for the development of cashew was started in India from the later part of 19th century in the post independent era. The overall development of agriculture in India has been the part of five year plan activities commencing from 1950 and cashew came to its fold from the 2nd five year plan starting from 1955 onwards. Research on cashew was also initiated almost simultaneous to developmental efforts.

The initial attempt for the development of cashew in India was from the pioneering effort of the forest departments as a part of their afforestation activity. Though the

economic value and its importance in international commerce was realized as early as in 1920's, until the beginning of the five year plan activities since independence, the developmental efforts remained confined to afforestation activities and with very little activities for its promotion in private sector. Since 1960's several state development agencies initiated promotional activities in small and marginal holdings limiting their role to the distribution of seeds and seedlings. Since the formation of Directorate of Cashew Development in 1966, co-ordinated activity for the promotion of this crop with a national outlook came into effect. Since then multifarious activities like fresh planting with distribution of better seedlings, nutritional management and programmes for combating pests and diseases were included for the integrated development of this crop.

Research as mentioned above was progressing in several regional stations simultaneous to such developmental efforts, which was later brought into the umbrella of All India Co-ordinated Cashew Research Project of ICAR. This happened in 1972, when from the complementary effect of research outputs and supplementary role of development agencies in a combined way moved towards a unilateral direction of increasing the production and productivity of cashew in the country. The period commencing from 1980's thus witnessed evolution of high yielding varieties, easy multiplication technique for generation of clones of these H.Y.V., regionalised and localized nutritional management and measures for effective control of pests and diseases. These research output were transalated into the field of activities through regional nurseries for propagation of the identified high yielding clones, area expansion with such materials and transfer of technology through training, campaigns, and several other publicity measures.

The impact of the above developmental measures commencing from 2nd plan to the present 10th FYP is in the Table 1.

Until the beginning of 8th plan, the area coverage was with indiscript seedlings of inferior genetic stock. Because of the conventional notion that cashew needs no attention, such plantations were left to the nature high and dry. The little care to such plantations resulted in high amount of natural variation in their growth and fruiting habit. Areas earmarked were also literally infertile. Such attitude has limited the productive ability of these plantations. From

Table 1. Impact of five year plans

Plan	Area (000ha)	Production (000 MT)	Productivity (kg/ha)
I	109	-	-
II	185	40	400
III	265	100	400
IV	351	135	400
V	447	180	524
VI	510	221	305
VII	534	305	635
VIII	659	430	720
IX	750	470	710
X	820	544	810

8th plan onwards the Government policy for promotion of cashew, literally eliminated the use of seedlings for plantation development in the light of evolution of several high yielding varieties with regional specification. All the areas developed from 8th plan are of clones of such high yielding varieties. Nearly 2.5 lakh ha have been covered with such good varieties. The situation of cashew plantation after 8th plan therefore improved due to the horticultural outlook attached to it. Inspite of such efforts, the productivity did not get altered much due to the ageing of the seedling plantations raised in the early five year plan periods. The senility so set in, has exerted its influence in decreasing the productivity of such plantations. Though there are around 8.6 lakh ha as on this day, these plantations are equally divided into three categories viz. seedling plantations of below 30 years of age providing a consistent productivity of more than 700 kg/ha, plantations of above 30 years of age which are literally senile, hardly giving only 25 -30% productivity of the normal seedling plantations and clonal plantations which are giving more than a ton per hectare. The distribution of such plantations as on 2004-05 are given in Table 2.

From the table, it can be seen that the Indian productivity of cashew is more or less of the average productivity of global situation. Some of the regions like Vietnam, Tanzania, and Mozambique which are a little far of the

Table 2. Status of cashew plantations in India (2004-05)

Category		Area ('000 ha)	Production ('000 t)	Productivity (kg/ha)
<30 years	Seedlings	280	214	700
>30 years	Seedlings	290	62	300
Normal	Clonal plants	250	268	1000

equator have a productivity of greater than one tonne per hectare. In India, the similarly placed states are West Bengal, Chattisgarh and Maharashtra, where the productivity is 50% more than the national average ie within the range of 1-1.5 t/ha.

Global trade on cashew

The global trade on cashew mostly takes place from India, Vietnam & Indonesia of the Asian Zone, Tanzania and Mozambique of the African Zone, Brazil of the Latin American Zone. Few other countries like Benin, Guinea Bissau, Ivory Coast, Ghana, Senegal, Madagaskar & Nigeria from African Zone also take part in the global trade mainly exporting the rawnuts as such.

From Asiatic zone, 68% of the production goes for kernel export and 6% is traded as rawnut as such for exporting to other needed countries. Rawnut transaction within the Asiatic Zone takes place from Indonesia and Philippines to India and Vietnam. The Indonesian production estimated is 90,000 MT out of which nearly 55,000 MT on an average is getting exported to India. Of the remaining, substantial part is believed to get exported to Vietnam.

In the African Zone, the total estimated production is 6.73 lakh MT. Out of which 18000 MT (3%) alone take part for cashew kernel export and 76% get traded as rawnut as such. All the African countries export rawnut to India, while a part of the production from Mozambique, Tanzanaia and Guinea Bissau get exported to Vietnam.

In the Latin American Zone, Brazil is the major country taking part in cashew kernel export. Out of a total production of 2.24 lakh MT, 1.70 (76%) gets exported as cashew kernel. The other countries in this zone are minor ones without any role in international trade. Of the total world production of 18.89 lakh MT, 8.59 lakh MT (30%) gets traded as rawnut as such in unprocessed form. The remaining 24% of world production is believed to be consumed within the producing zone themselves. The Asiatic and African Zone put together has a total production of 16.58 lakh MT of which 6.89 (42%) is traded in the form of processed kernels while 5.70 lakh MT (34%) is traded as unprocessed rawnut. The interesting phenomena here is that the trade from Brazil alone is equal to the total trade in the form of kernels and rawnut taking place from Asiatic and African Zone. Thus Brazil has to be considered as one of the major exporter of cashew kernel harmonizing from her own production while the other countries like India and Vietnam depends for such trade on import of rawnut from African Zone.

Cashew consumption by kernel importing countries

The cashew kernel importing countries are in fact non producers of cashew. They constitute entirely into a separate group under American, European, South East and Far East Asian and Oceanic Zones besides some Asian countries.

India continuously holds a major share of 45 to 54% in the global trade over the years, while Brazil has been maintaining its position in a uniform manner, contributing 16-20%. In the case of Vietnam, an aggressive and competitive trend is seen in the trade increasing her share to the global market year after year. Though India is the major supplier in the global market, her position is seen declining@ 4-5% per annum while Vietnam increases its trade at the same rate. Thus, it can be seen that Vietnam is the one restricting the performance of India in the global trade.

Indian cashew in global commerce

India exports cashew kernels to America, Europe, South East & Far East Asia, Asian and Oceanic Zones. The major market for India is the American Zone consuming 50-56% of the total exports of cashew kernels from India. The next major consumers are European Zone consuming 24-20% of the total exports. The rest of the regions hardly take 20% of the total exports.

Indian commerce in relation to indigenous production and import

The international trade of cashew kernels was started in the 1st quarter of the 20th century. Cashew industry in India was primarily built up in the early stages depending upon the import of rawnut from American Zone. A concerted effort for the development of this crop started in the 2nd half of the 20th century, gradually supported increase in production of rawnut from indigenous sources. In the beginning the production of rawnut in India was below 1 lakh MT. Only from the early 80's Indian production reached the level of 2 lakh MT. Till this period, the export was gradually increasing and the annual average import was around 1.3 lakh MT. This trend of import

declined to the level of 38,000 MT per annum on an average and the Indian production reached to the level of 3 lakh MT till the beginning of 90's. The trend in import increased to 2 lakh MT per annum inspite of the increase in Indian production to 4.5 to 5 lakh MT at the beginning of 21st century. Thus the Indian industry has been growing simultaneously with the increase in indigenous production as well as with import. Though the Indian production was increasing, not more than 50 to 60% was taking part in export with the phenomenal increase for indigenous consumption. Even in the current millennium of the 21st century, this trend is noticed from the Table 3.

While the export has been increasing 6% p.a. the import also has been increasing @ 15% p.a. The indigenous production recorded an increase of 10% p.a. from 5.00 lakh MT of 2002-03 to 5.44 lakh MT of rawnut. At the same time the participation of indigenous production for export was practically nil or negligible during this period. In other words, Indian export has maintained with 100% import leaving almost the entire production from indigenous sources for indigenous consumption.

Indian cashew in the global arena

During 1995-96 to 2004-05, cashew kernel trade in the global arena has been of the order of 1.6 million tones of which India shared 0.9 million tones (53%). Brazil provided 0.3 million tonnes (19%) and Vietnam provided nearly 0.4 million tonne (25%). The remaining countries have taken a share of 3% only.

Brazil has been there in the field sharing almost 50% of India's exports till 1998-99, while share of Vietnam was negligible. Both the Indian and Brazilian share to the global market correspondingly decreased when Vietnam started an aggressive intrusion from 2001 onwards. 60-62% share of India in the 1st half of the decade ending 2004-05 decreased to 44-55% in the subsequent part of the corresponding decade. Though there has been a slight reduction in the share of Brazil in the 2nd part of the decade in consideration, the aggressive trend of Vietnam became conspicuous. The kernel consuming countries are more or less constant without much expansion to any newer areas. The traditional market of India alone is getting shared by these two countries. Thus, for India to maintain its share in the global market, she will have to exploit newer areas. Even within the present market, the consumption has been increasing only @ 6% p.a. and such increase is mostly getting captured by Vietnam. Vietnam is improving her trend because she is able to sell the kernels at lower rates. The lowering of market price to India can therefore be a positive step to maintain and increase her position in the global market.

Problems faced by India

The global trade situation gives an indication that Vietnam almost consumes all her production for export with a little level of import for cushioning the local demand, whereas in the case of India, as already mentioned earlier, the trend in import is magnificently high.

From Table 4, it can be seen that import has been steadily increasing except for 1 or 2 years in the past decade. During the last five years there has been a tremendous increase in import to meet the export to the extend of 90-100% and the participation of Indian production has been remaining very low. This is an indication that India is the largest single consumer of cashew kernel in the world consuming nearly 70-100% of her production. The level of imports has not affected the rawnut price within India. Without affecting the Indian farmers, import has played a positive role in the economic advantage of our nation at large, though more than 50% of export earnings gets drained for import. This phenomena though is unique among the commercial horticultural sector of India it is not a desirable aspect in the trading system of our commerce.

The Indian cashew industry, from the processing and trade

Table 3. Export and import details from India

Period	Export (CK)	Rawnut equivalency	Import	Total Production (000 MT)		
	(000MT)	(000MT)	(000MT)	Indian export	Indian consumption	Total
2002-03	104	473	401	72 (14)	428 (86)	500
2003-04	101	459	452	7 (1)	528 (99)	535
2004-05	127	577	579	-	544 (100)	544

Table 4. Trend in cashew import

Year	Export (CK)	Rawnut Equivalency	Indian	Import Production	Share of Import in Export	Share of indegenous in import
1995-96	70	318	418	223	70	30
1996-97	69	314	430	192	61	39
1997-98	77	350	360	225	64	36
1998-99	75	341	460	181	53	47
1999-2000	92	418	520	201	48	52
2000-01	89	405	450	249	61	39
2001-02	98	445	470	357	80	20
2002-03	104	473	500	400	85	15
2003-04	101	459	535	452	98	2
2004-05	127	577	544	579	104	Nil

performance, is in a stable ground to consume nearly a million tonnes of rawnut. The import and the indigenous sources sustains nearly 0.4 million labour families, besides nearly a million of farming families. In economical terms, considering the Indian agricultural resources, cashew thus plays a pivotal role towards the national GDP.

Prospects of Indian cashew

India, among the other 27 cashew growing countries, is the largest area holder, producer, exporter and importer. The industrial set up is a labour oriented good performer. Had India been able to produce one million tones of rawnuts, the quantum she is at present annually processing, there won't have been the huge drain though imports. But in the global trade contracts cashew is one of the items supporting the multilateral trade policy and imports as such cannot be considered for elimination. Even if she can produce a million MT and continue to import the half a million MT, which she is doing at present, she will be able to manage the present trend of exports. Contrary to it, Indian production is meeting only 50% of the industrial capacity. Any effort to increase her production will not therefore be in vain in the context of expanding consumer preference and market absorbability.

Can India produce 1 million MT?

Indian export earning from cashew is annually, a little over 500 million US$. Indeed an effort to double the production of rawnut to reach 1 million MT will be an up hill task. Development of this crop was started with indiscript and genetically inferior seedling stocks to cover huge hectarage. Scientific refinement became available only in the recent past. Most of the best areas have gone under bad materials while most of the best materials now available are going to the bad areas. Most of best areas covered under bad materials have at present become senile. From Table 2, it is clear that of the 8.2 lakh ha now available under cashew, 2.9 lakh ha are above 30 years of age giving the least production and productivity. These areas, though are under inferior seedling stock, because of the continued vegetation would have become ameliorated well for the best materials to perform better. Therefore the immediate task India should take shall be to replant these areas with the best performing varieties. Hunting for new areas in non traditional tracts, where the performance of cashew is yet to be proved beyond doubt, should be curtailed without draining financial resources. Such resources should be entirely ploughed back for replanting purposes. Clonal materials of HYV are proving better and if such materials can go for replanting the senile areas mounting up year after year the Indian production can very well touch one million tonnes within a period of 15 years.

MORPHOLOGY OF CASHEW

P.B. Pushpalatha
Dept. of Processing Technology, College of Horticulture
Kerala Agricultural University, Thrissur - 680 656, Kerala

Growth and development

Cashew is a polygamous and andromonoecious evergreen perennial tree. The growth of cashew tree is not continuous. It occurs as intermittent short lasting flushes of shoots from apical or lateral buds of resting stems before returning to a quiescent state. Periods of extended dormancy are generally short in young plants but usually last several months between flushing episodes in mature trees.

There are two types of growth in cashew, which can be termed as intensive and extensive. The intensive shoots grow to a length of about 25 to 30 cm and terminate in a panicle. Simultaneously three to eight laterals arise within 10 to 15 cm of the apex. Some of these lateral shoots may also terminate in panicle 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 to 30 cm and rests. A bud sprouting 5 to 8 cm below the apex leads to further growth. The 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, where as low yielders have less than 20%. Seventy five percentage of the shoots of the intensive types produce flowers as against 12% in the extensive types.

Cashew putforth flushes twice in a year. One is pre-bloom flushing; occurring September to October and the other is post- bloom flushing occurring in May to July. A percentage of the flushes that originate in September to December slowly convert to panicles during October to November season. Time and intensity of flushing and flowering is a varietal character (Pushpalatha, 2000). Early varieties exhibit flushing during September to October, mid season varieties during October to November and late season varieties during November to December. Reproductive flushes are generally short statured with small rosette of leaves at the tip. Those that remain as vegetative are long with comparatively bigger leaves (Plate 1).

Period of flushing is shorter in the early flushing types (20 to 25 days) while it is higher in the case of mid (30 to 35 days) and late season varieties (40 to 45 days). The flushes originating in May to July are designated as vegetative flushes as they do not put forth panicles and contribute to the vegetative framework of the tree. They grow for next one to two months and enter in to dormancy. Pushpalatha (2000) reported great variability in flushing characters of different cashew types (Table 1).

The correlation coefficients worked out with respect to flush characters and yield has shown a negative correlation especially that with flush length. This emphasis that shorter flush length and higher yield are correlated and a direct selection can be done on this basis. Excess vegetative growth and development is not desirable, as it will negatively affect yield.

Root system

The cashew seed germinate giving rise to radicle. It grows downward and rapidly develops into taproot, which produces laterals within a week. By this time the plumule emerges and put forth shoot system. The young plant (1 to 1 ½ year old) develops a strong and extensive

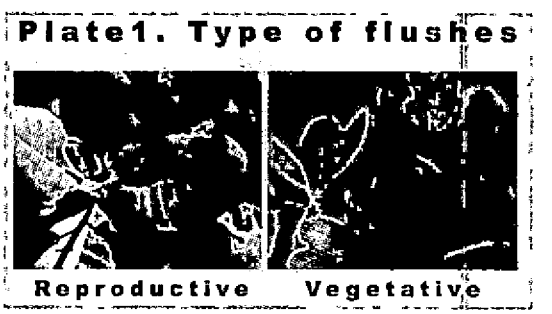


Table 1. Variability in flushing characters of 27 selected cashew varieties

	Sl. No.	Variety	No. of flushes (m^{-2})	Flush length (cm)	No. of leaves $flush^{-1}$	Shoot girth (cm)
1	2	3	7	8	9	10
EH	1	Madakkathara-1	13.75^{cde}	9.82^{efg}	4.45^{defghij}	1.96^{bcdefghi}
	2	Anakkayam-1	15.95^{ab}	9.62^{efg}	4.43^{defghij}	2.07^{bcde}
	3	BRZ-248(s)	16.38^{a}	8.48^{fghij}	4.62^{cdefghi}	1.78^{hi}
MH	4	H-1596	13.5cde	8.70^{fghi}	6.23^{b}	1.85^{efghi}
	5	H-1593	14.55^{bcd}	9.00^{efghi}	4.75^{cdefghi}	1.87^{efghi}
	6	Dharasree	13.35^{cde}	8.45^{fghij}	4.75^{cdefghi}	1.98^{bcdefghi}
LH	7	Priyanka	15.10^{abc}	9.07^{efghi}	4.32^{efghij}	1.97^{bcdefghi}
	8	Anagha	13.75^{cde}	8.98^{efghi}	5.88^{abc}	1.93^{bcdefghi}
	9	Madakkathara-2	13.65^{cde}	7.82^{ghij}	4.28^{fghij}	2.05^{bcdef}
EM	10	BRZ-120	12.65^{def}	6.42^{j}	3.15^{j}	2.13^{abcd}
	11	H-1589	13.15^{cde}	9.50^{efgh}	4.35^{efghij}	2.15^{abc}
	12	H-1588	12.05^{efg}	9.73^{efg}	5.43^{bcdefg}	1.91^{defghi}
MM	13	H-1610	14.50^{bcd}	8.38^{fghij}	4.20^{ghi}	2.03^{bcdefg}
	14	Amrutha	13.85^{cde}	8.25^{fghij}	5.48^{bcdef}	1.99^{bcdefgh}
	15	H-1600	12.90^{def}	7.35^{hij}	3.95^{hij}	1.76^{i}
LM	16	K19-1	12.60^{def}	8.15^{ghij}	4.38^{defghij}	1.85^{efghi}
	17	H-856	13.80^{cde}	8.90^{efghij}	4.85^{cdefghi}	2.02^{bcdef}
	18	KTR-27	12.25^{efg}	7.20^{ij}	3.63^{ij}	1.88^{efghi}
EL	19	BRZ-2	9.75^{hi}	12.90^{bc}	5.60^{bcdef}	2.32^{a}
	20	BRZ-3	12.10^{efg}	13.68^{abc}	6.50^{b}	1.54^{i}
	21	Pu-8	9.70^{hi}	15.25^{a}	9.08^{a}	1.83^{fghi}
ML	22	A-6-1	11.00^{fgh}	10.90^{de}	4.88^{cdefghi}	1.92^{cdefghi}
	23	A-26-2	10.65^{gh}	10.38^{def}	4.45^{cdefghi}	1.84^{efghi}
	24	Pu-1	8.00^{i}	10.92^{de}	5.75^{bcd}	1.81^{ghi}
LL	25	H-719	9.40^{hi}	13.27^{bc}	5.70^{bcde}	1.98^{bcdefghi}
	27	H-718	10.05^{b}	12.15^{cd}	5.27^{bcdefgh}	2.15^{ab}
	27	K-30-1	10.50^{gh}	14.63^{ab}	8.13^{a}	1.95^{bcdefghi}

Values having any common superscript are not significantly different from one another

EH – Early season high yielders EM – Early season medium yielders EL – Early season low yielders
MH – Mid season high yielders MM – Mid season medium yielders, ML – Mid season low yielders
LH – Late season high yielders LM – Late season medium yielders LL – Late season low yielders

root system both side ways and down wards over an area of double the size of the tree canopy. The tap root of a full-grown cashew tree penetrates deeply into the soil and extends its laterals extensively with a network of both primary and secondary roots, which ensure the plant enough nutrition and water. The root distribution studies in cashew have shown that 70% of the active roots are located up to 60 cm depth and 2m radius.

The root system of seedlings, layers and grafts are different. The layers are devoid of a tap root, which penetrate deeply into soil like in seedlings and grafts. They possess fibrous root system formed with lateral roots. The tap root system possessed by seedlings is very vigorous and extensive compared to the grafts. By virtue of their more spreaded and vigorous growth, the requirement of water and nutrients will be more for seedlings, which force them to put out extensive root system. Because of this, seedlings require larger spacing compared to grafts and layers. Salam *et al.* (1995) studied the root distribution pattern in seedling-raised cashew trees of 20 years old. Cashew tree was found to have an extensive root system spreaded over an area of 400 cm laterally around the tree and 200 cm vertically from the soil surface. An adult cashew tree possesses 176 kg of roots. Ninety five percent of cashew roots occur within 300 cm laterally around the plant. The rhizosphere area of 2 m around the plant contained 77.9% of the total

roots. The longest root of cashew tree had a length of 6.4 m and was running laterally. Ninety four percent of roots occur within a depth of 100 cm from the soil surface and only 5.7% grew beyond this depth. The finer roots were seen concentrating at the surface layer and their occurrence decrease with depth.

Canopy Characteristics

The germinating seeds give rise to plumule, which develop into shoot system. It takes 5 to 6 years for the seedlings and 3 to 4 years for the grafts and layers to develop the canopy. There exists wide variability with respect to canopy characteristics (shape, height, spread, surface area and yield) of seedlings, grafts and layers. Evaluation of cashew germplasm accessions at NRRC, Puttur has revealed great variability with respect to canopy spread (Swamy *et al.*, 1990). Out of 161 accessions, eleven accessions were found to posses bushy to medium plant habit and compact to medium canopy spread. Based on study, which involve 56 cashew hybrids and 16 parents, high degree of variation with respect to canopy spread was reported by Manoj (1992). A study conducted at Cashew Research Station, Madakkathara have shown that the canopy spread of cashew varieties range from 7.97 and 10.35 m.

Nalini (1998) studied the branching and subsequent canopy development pattern in seedlings, grafts and layers. In seedlings, six classes of branches could be identified. These six classes are the main trunks, that have got an orthotropic rhythmically active terminal meristem which produce an intermediate trunk bearing tiers of branches. These main trunk is designated as n_0 and from the n_0 main trunk, n_1 order of branches are produced in acropetal succession. These n_1 order of branches, even though are orthotrops in nature, in the course of development of the canopy, grow almost parallel to the surface of the soil. From the n_1, which again show rhythmic growth n_2, n_3, n_4 and n_5 branches develop in the same sequence.

From the n_1, n_2 branches are produced. Initially three or four or up to five branches are produced in one season but in the final development only one or two will be remaining. The rest of the branches are aborted by self-thinning (pruning). The resultant canopy in the case of a seedling after a few years of growth will be like a hemisphere placed above a solid cylinder.

Branching pattern of graft was also examined critically. It was found that n_0 main trunk followed rhythmic growth like that of seedling. The n_1 order of branches unlike the ones in seedling was acute in orientation. In the case of subsequent order of branches, the pattern was intensive i.e. out of the total branches produced during each season, more number persisted and formed part of the canopy. The canopy that resulted due to this intensive branching was like a cone, placed above a small cylinder.

In most of the layers it was observed that n_0 main trunk was very short and the n_1 order of branches three to four in number became predominant. They got oriented more or less parallel to the ground surface and subsequent development of the remaining orders of branches was intensive which resulted in a canopy that was compact and hemi spherical.

The trees that are of seedling origin showed a higher trunk length compared to graft and layers but because of branching pattern and subsequent hemispherical development of canopy, the canopy get closed and availability of reflected light get reduced.

Nalini (1998) studied the angle of order of different branches. It was seen that the first order of branches of seedlings and layers were at an angle of about 85°. Subsequently, in the case of layers, the angle become more acute compared to seedlings. The resultant canopy in both cases was hemi spherical in nature. In grafts, the initial branching was at an angle of about 65° from the main stem, which was little more acute than seedlings and layers. Subsequent branches followed similar pattern, as was seen in layers and seedling, which finally resulted in a spear shaped canopy.

Pushpalatha (2000) recorded great variability with respect to canopy spread among different graft-raised cashew varieties planted at Madakkathara. The high and medium yielding varieties were found to extend their canopy more, compared to low yielding varieties. They also differed with respect to height at which canopy started to spread and trunk girth (Table 2).

Leaf characters

The leaves are glabrous, thick and leathery, oblong to obovate, smooth on both sides and alternatively arranged

Table 2. Variability in canopy characteristics of 27 different cashew varieties

	Sl.No.	Variety	Height (m)	Trunk girth (cm)	Spread (m)
1	2	3	4	5	6
E.H	1	Madakkathara-1	5.45^{ab}	53.50^{bcdef}	4.75^{cde}
	2	Anakkayam-1	4.80^{efghi}	55.50^{bcdef}	5.25^{bcd}
	3	BRZ-248(s)	5.45^{ab}	43.50^{g}	5.28^{bcd}
M.H	4	H-1596	4.7^{ghi}	52.25^{cdefg}	4.38^{efgh}
	5	H-1593	4.35^{ilk}	45.75^{fg}	3.80^{hij}
	6	Dharasree	5.07^{bcdefg}	47.75^{fg}	4.10^{ghij}
L.H	7	Priyanka	5.28^{abcde}	53.25^{bcdf}	4.43^{efg}
	8	Anagha	5.67^{a}	56.75^{bcde}	5.18^{bc}
	9	Madakkathara-2	5.50^{ab}	54.00^{bcdef}	4.98^{bcd}
E.M	10	BRZ-120	4.68^{ghij}	59.00^{bcd}	6.15^{a}
	11	H-1589	4.55^{hijk}	50.25^{defg}	5.13^{abc}
	12	H-1588	4.20^{jk}	52.75^{cdefg}	5.00^{cdef}
M.M	13	H-1610	5.43^{abc}	56.75^{bcd}	4.50^{defg}
	14	Amrutha	4.88^{defgh}	53.25^{bcdef}	5.10^{bc}
	15	H-1600	4.07^{k}	72.25^{a}	4.20^{efghi}
L.M	16	K19-1	4.50^{hijk}	54.00^{bcdef}	5.15^{bc}
	17	H-856	4.75^{ghi}	46.75^{fg}	4.20^{efghi}
	18	KTR-27	4.57^{hij}	71.00^{a}	5.65^{b}
E.L	19	BRZ-2	5.27^{abcde}	61.00^{bcd}	4.05^{fghij}
	20	BRZ-3	5.30^{abcd}	49.25^{efg}	4.08^{fghij}
	21	Pu-8	4.95^{cdefgh}	58.25^{bcd}	3.63^{ij}
M.L	22	A-6-1	5.72^{a}	58.25^{bcd}	3.88^{ghij}
	23	A-26-2	5.53^{ab}	51.75^{cdefg}	3.75^{ij}
	24	Pu-1	5.40^{abc}	61.25^{bc}	4.08^{fghij}
L.L	25	H-719	4.52^{hijk}	55.25^{bcdef}	3.70^{ij}
	27	H-718	4.78^{fghi}	54.75^{bcdef}	3.85^{ghij}
	27	K-30-1	5.25^{abcdef}	62.75^{b}	4.33^{efghi}

Values having any common superscript are not significantly different from one another

E.H – Early season high yielders E.M – Early season medium yielders E.L – Early season low yielders
M.H – Mid season high yielders M.M – Mid season medium yielders M.L – Mid season low yielders
L.H – Late season high yielders L.M – Late season medium yielders L.L – Late season low yielders

on the twigs. They are blunt at the tip and slightly cone shaped at the base. The leaf length varies from 10 to 20 cm and the width from 5 to 10 cm in the ratio of 1.8:1. The petioles are about 0.5 to 1 cm long. The short, flexible petiole is broadened at the base, which is deep brown in colour.

The leaves are simple and pinnately veined, each leaf having about 20 pairs of veins, slightly standing out on the under leaf. The ventral surface is soft and glabrous while the dorsal surface is leathery in all the varieties.

The young leaves are reddish brown, which gradually turns to dark green when mature, within 20 days. The mature leaves are intense brilliant green on the upper surface and opaque green underneath.

Flowering characters

The timing and intensity of flowering was found to vary greatly among cashew varieties. The early varieties flower between October- November, mid season varieties between November - December and late season varieties after December (Pushpalatha, 2000), under Kerala conditions.

The flowering characters (number of panicles m^{-2}, percentage of hermaphrodite flowers, panicle length (cm), panicle breadth (cm) and number of nuts $panicle^{-1}$ of cashew have a direct bearing on its yield potential and great variability exist among different cashew types with respect to these characters (Table 3). The flowering characters exhibited a strong positive correlation with

yield. Among them the number of panicles m^{-2}, percentage of hermaphrodite flowers and number of nuts per panicles were most prominent. The occurrence of these characters in great intensity in cashew trees can be taken as their ability to yield heavily.

The duration of flowering varies among different cashew types. Parameswaran *et al.* (1984) reported the relationship between yield and duration of different phases of flower opening in cashew. The main duration of flowering in trees above medium yield was 83.7 days and those below minimum yield were 102.7 days.

Inflorescence

The inflorescence is a terminal indeterminate panicle of polygamomonecious type (Damodaran *et al.*, 1965). The hermaphrodite (bisexual) and staminate flowers are produced on the same panicle. The panicle appears as a cluster and each branch of the cluster bears a terminal flower subtended immediately by two or more bracts. From the axial of these bracts, grow further, bracted flower stalk. 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). The ratio of hermaphrodite to staminate flowers varies depending up on the variety, environmental condition and planting material used. There exist three distinct phases of flowering in cashew. The intermediate stages are generally productive one. The first is male phase with staminate flowers, the second is the mixed phase with staminate and hermaphrodite flowers and the third is the male phase again with staminate flowers. Parameswaran *et al.* (1984) reported that the proportion of male phase in the total duration in the flowering was significantly low in trees above medium yield.

Table 3. Variability in flowering characters of 27 selected cashew varieties

	Sl. No.	Variety	No. of panicles m^{-2}	Hermaphrodite flowers (%)	Panicle length (cm)	Panicle breadth (cm)	No. of nuts panicle^{-1}
EH	1	Madakkathara-1	12.02^{abcde}	30.97^{bcd}	19.09^{abc}	17.92^{ef}	14.69^{a}
	2	Anakkayam-1	13.30^{a}	28.60^{d}	14.77^{g}	16.40^{ef}	13.46^{ab}
	3	BRZ-248(s)	12.90^{ab}	34.63^{a}	14.52^{g}	18.08^{fg}	12.44^{bc}
MH	4	H-1596	11.85^{abcdef}	21.83^{h}	18.30^{bcde}	17.02^{ef}	9.30^{fg}
	5	H-1593	12.45^{abcd}	22.35^{gh}	19.30^{abc}	17.95^{fg}	9.25^{fg}
	6	Dharasree	12.40^{abcd}	25.51^{ef}	17.33^{cde}	23.55^{cf}	10.19^{efg}
LH	7	Priyanka	12.85^{abc}	23.53^{fgh}	16.73^{def}	22.45^{ab}	10.81^{def}
	8	Anagha	12.35^{abcd}	25.27^{ef}	19.18^{abc}	24.37^{a}	9.82^{efg}
	9	Madakkathara-2	12.20^{abcd}	30.83^{bcd}	16.20^{efg}	17.33^{ef}	12.06^{bcd}
EM	10	BRZ-120	10.85^{defg}	26.08^{e}	18.58^{abcd}	18.0^{def}	10.19^{efg}
	11	H-1589	9.35^{ghij}	32.56^{ab}	20.1^{ab}	22.95^{abc}	9.44^{fg}
	12	H-1588	11.20^{bcde}	31.77^{bc}	20.50^{a}	24.20^{a}	8.94^{g}
MM	13	H-1610	10.95^{cdefg}	23.78^{efgh}	18.38^{abcd}	18.10^{ef}	9.06^{g}
	14	Amrutha	11.45^{abcdef}	32.46^{ab}	18.40^{abcd}	18.02^{ef}	9.75^{fg}
	15	H-1600	10.05^{fgh}	29.74^{cd}	16.92^{de}	23.03^{ab}	11.44^{cde}
LM	16	K19-1	10.25^{efgh}	26.25^{e}	18.10^{bcde}	17.85^{ef}	12.50^{bc}
	17	H-856	11.85^{abcdef}	24.37^{efg}	17.98^{abcde}	21.10^{bcd}	9.85^{efg}
	18	KTR-27	8.65^{hij}	22.25^{h}	19.38^{abc}	24.57^{a}	13.13^{b}
EL	19	BRZ-2	6.25^{kl}	9.91^{kl}	14.75^{fg}	22.80^{ab}	4.25^{hi}
	20	BRZ-3	8.15^{ij}	9.73^{kl}	12.62^{b}	21.90^{abc}	5.50^{hi}
	21	Pu-8	5.60^{kl}	8.91^{l}	9.65^{ij}	23.08^{ab}	3.69^{i}
ML	22	A-6-1	6.35^{kl}	6.43^{h}	9.85^{ij}	18.15^{ef}	5.69^{hi}
	23	A-26-2	7.15^{ijk}	12.13^{jk}	11.77^{hi}	18.23^{ef}	2.94^{i}
	24	Pu-1	6.25^{kl}	13.30^{ij}	11.12^{hij}	17.85^{ef}	4.31^{hi}
LL	25	H-719	5.50^{kl}	10.12^{kl}	11.01^{hij}	14.48^{g}	5.88^{h}
	27	H-718	5.93^{kl}	16.44^{i}	11.08^{hij}	19.00^{def}	4.50^{hi}
	27	K-30-1	4.90^{l}	12.89^{ij}	12.33^{b}	20.02^{cde}	3.56^{i}

Sex ratio

The ratio of hermaphrodite (bisexual) to staminate flowers varies depending upon the variety, environmental conditions and planting materials. Damodaran *et al.* (1965) after detailed studies on the flowering habit and sex ratio of cashew reported that in most of the panicles studied, the flower that opened in the early stages were generally staminate, while the perfect flowers made their appearance during the middle of the flowering period of the panicle. The proportion of perfect flowers was found to vary considerably even between panicles of same tree. They observed that panicles, which emerged earlier in the season had a higher proportion of staminate flowers than those produced later in the season.

According to Raju (1979), the percentage of hermaphrodite flowers was 22 to 68 under natural condition and growth regulators at different conditions influenced the percentage of hermaphrodite flowers. Damodaran *et al.* (1965) observed a weak positive correlation between the number of hermaphrodite flowers and yield in cashew trees. Contrary to this, studies conducted by Gopikumar (1978) revealed that there was no correlation between sex ratio and the yield of cashew tree. Simple correlation analysis by Parameswaran (1979) indicated a positive correlation between yield and percentage of bisexual flowers.

Under Orissa conditions, the percentage of hermaphrodite flowers was found to vary between 5.94 and 20.69% (Patnaik *et al.*, 1985). Baptla varieties are reported to have hermaphrodite flowers ranging from 8.00 to 15.00 percent (Reddy and Rao, 1985). Elsy (1985) reported that the cashew panicle of the type BLA-139/1 has a mean of 286.1 flowers of which 199.8 are male and 86.3 are hermaphrodite working out to a mean sex ratio of 1:2.83 of hermaphrodite to male flowers. Hence dearth of flowers or sex ratio cannot be considered as a cause for low yield. Wide variation in the number of perfect flowers depending on the climatic conditions was reported by Das and Sahoo (1987).

The selections Ullal-1 and Ullal-2 are reported to have 2.27 to 6.66 percentage hermaphrodite flowers under humid conditions of Ullal (Khan and Kumar, 1988). Krishnappa *et al.* (1991) noted variability to the extent of 231.4 to 835.8 in different varieties with respect to number of flowers per panicle. The number of staminate flowers ranged from 115.4 to 302.0 and number of nuts per panicle from 4.5 to 8.0. Maximum perfect flowers were recorded up to five and six weeks while high sex ratio was observed within the first week of flower opening.

Structure of flower

The flowers are small, white to light green at the time of opening, later turning to pink (Plate 2). 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. The flower is typically pentamerous. Each hermaphrodite flower stands upon an obconic pedicel and a few millimeters 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. 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 to 11 stamens of unequal size. Of these, one or two are large exerted fertile stamens of 6 to 8 mm length and the remaining are small sterile stamens (3 to 5 mm). 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 pollen sacs of each lobe. Compared to the large ones, the small

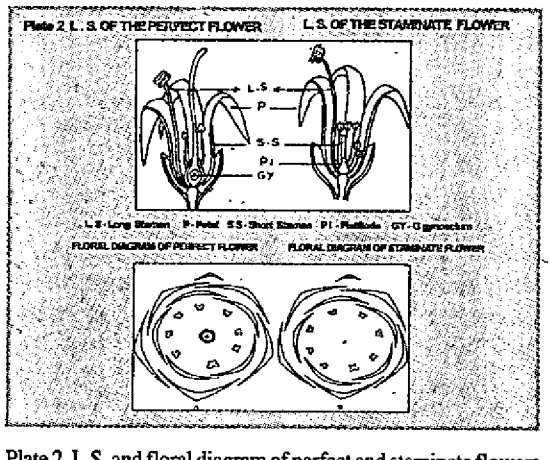


Plate 2. L.S. and floral diagram of perfect and staminate flowers

stamens contain only a few pollen grains. The pollen grains are grooved with the exine between the grooves finally 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 or two mm for staminate and 6 to 12mm for hermaphrodite flowers. 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.

Pollination, fertilization and fruit setting

Anthesis and dehiscence

Flowers start opening early in the morning (6 am) and complete anthesis generally in the forenoon (by 10 am). The staminate flowers open earlier than the hermaphrodite flowers. The greatest number of bisexual flowers (80%) open between 9.00 and 10.00 hours and continue till 4 pm. The hermaphrodite flowers start opening from 9 am to 10 am and continue till 1 pm. Damodaran *et al.* (1966) found that under Kottarakkara conditions, nearly half of the staminate flowers opened before 7 am and the opening of over 95% was completed before 11am. There was practically no anthesis of staminate flowers after 2 pm. In the case of perfect flowers the peak period of anthesis was between 10 am and 12 noon.

According to Raju (1979) male flowers commenced opening before 6 am both in the periphery as well as in the inner position of the canopy of foliage and it continued till 1 pm. The peak period of anthesis of male flowers was between 7 and 8 am and that of hermaphrodite flowers was between 9 am and 11 am. He found that the time span of anthesis of hermaphrodite flowers lasted only for shorter period as compared to male flowers. In general, hermaphrodite flowers started opening after 7 am and continued upto 1 pm. Damodaran *et al.* (1966), while conducting the studies on morphology and biology of cashew flowers, found that the opening of perfect flowers on the shady side of the tree was a little later than that on the sunny side. Veeraraghava and Vasavan (1977) studied the influence of rainfall on the productivity of cashew and found that high rainfall adversily affected flower opening. According to Raju (1979) environmental factors seemed to have some influence in the time of flower opening. The slightly delayed anthesis of flowers situated within the canopy of foliage indicated the influence of humidity and temperature on anthesis.

Dehiscence invariably takes place after the flowers have opened. The anther dehiscence commences after 3.5 hours of anthesis with a peak at 9.30 am. Sporadic dehiscence of anthers is observed. The rate of dehiscence is slightly higher on the sunny side till about 10.30 am as compared to that of shady side. The anther dehiscence take place by means of longitudinal splits of the two anther lobes exposing the bluish gray coloured pollen grains, which turn brown when dry.

Receptivity of stigma

The stigma is found receptive throughout the day after the opening of flowers, but become non receptive from the second day. It is most receptive about six hours after anthesis, the optimum period seems to be 12 noon on the day of anthesis.

Pollination

Cashew is an entomophilous and highly cross-pollinated crop. The flower structure is conducive for cross-pollination, since the developed stamen of the hermaphrodite flower has only a short filament, which is only half the length of the style.

Being a cross-pollinated crop, pollination has to be effected through agents like water, wind, insects etc. Damodaran *et al.* (1966) observed on cashew panicles insects like black and red ants, the hoverfly and the common bee. However he did not recognize them as cashew pollinators, as the insect visitors were found to be very few and rare.

The fruit set is only 48% in natural open pollination. Insects such as ants and flies visit the flowers and transfer the sticky pollen to the stigmatic surface. Naturally no other insects except black and red ants are seen to visit the flowers frequently. However, the heavy scent of flowers indicates that insects play an important role in pollination. Wind seems to be the predominant agency for pollination. The high proportion of male to perfect

flowers suggests that the tree may be basically wind pollinated.

Parameswaran (1979) clearly indicated that a large proportion of bisexual flowers remained unpollinated. He suggested that even in trees producing a fairly high proportion of bisexual flowers would not exhibit fruit setting. Vidyadharan (1983) had the opinion that under natural conditions, pollination in cashew was not very efficient. Failure of pollination was one of the reasons for poor fruit set in cashew in India.

Pollen viability and germination

The viability of pollen grains is found to be around 94 per cent. However in artificial medium, the highest germination obtained was only 36.2% in 30% sucrose solution at 29°C at room temperature (Damodaran, 1977).

Fruit Setting

Fruit set in cashew become evident after about seven days of pollination as indicated by the swollen ovary being visible above the corolla cup (Damodaran *et al.*, 1966). According to them, the final recovery was only 4 to 6 percent of the hermaphrodite flowers.

In cashew there seems to be considerable variation in the percentage of fruit set year after year. The cashew flower once fertilized undergoes radical transformations, the zygote remains dormant for some time and later on produces an embryo. 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. 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 ovule consists largely of the extension and curving upward of the chalazal end. The nut reached maximum size in 30 days, hardened in the ensuing 10 days and declined in size by 10% at harvest. 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 only in 60 days. Fruit drop is a common phenomenon in cashew. Elsy (1985) observed that in the peanut stage 7.29 and 28.04 per cent of hermaphrodite flowers, in the naturally pollinated and hand pollinated panicles respectively are retained. These figures are reduced to 5.19 and 19.98 per cent respectively towards maturity stage.

Apple and nut development

The apple and nut development pattern in cashew with respect to nut and pedicel growth, change in circumference, volume, and colour of apple, change in nut length, width and thickness kernel formation and change in colour of nuts have been extensively studied by Narayanankutty (2000).

The development and maturation process of cashew fruit took 52 to 60 days for completion (Plate 3). In early season variety Anakkayam-1 fruit development was completed in 52 days while in mid and late season varieties, the duration ranged from 55-60 days. After fertilization the developing nut became visible by 5th or 6th day (pea stage). At 'pea' stage the pedicel length in early season varieties Anakkayam-1 and Madakkathatra – 1 ranged between 0.69 cm and 0.8 cm. In mid season varieties it ranged between 0.78 cm and 0.98 cm and in late season varieties the range was between 0.83 and 0.92 cm. Apple length was significantly different between varieties at all stages of growth. The pedicel length increased 6 to 10 times as it reached the ripe stage. Absolute growth rate was not significantly different between varieties. In mid and late season varieties, a lag phase was observed in the cumulative growth curve. Average daily growth in length ranged from 0.083 cm to 0.127 cm among the varieties.

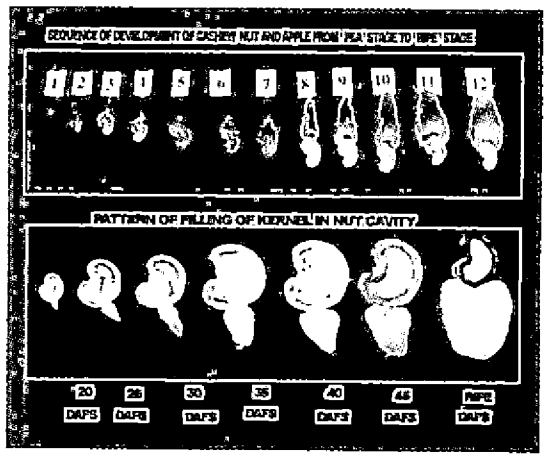


Plate 3. Sequence of development of nut and apple and filling pattern of kernals

The apple circumference increased 12-243 times during the growth period. The rate of growth was slow up to 40 DAFS stage. Maximum growth was observed between 40 and 60 DAFS stage. Apple volume increased 59 to 112 times through the course of development. Increase in apple volume was marked from 35 to 40 DAFS stage in mid and late season varieties. Apple specific gravity ranged between 1.04 to 1.15 in young apples. In ripe apples specific gravity was less than one.

In early stages of development the pedicel colour was purple that turned to green or light green by 40 DAFS stage. Typical colour of apple appeared at the fully ripe stage. Increase in fresh weight of apple from pea stage ranged between 650-1500 times. There was an exponential increase in fresh weight from 40-45 DAFS stage. Rate of fresh mass accumulation ranged from 0.819g per day in variety Anakkayam -1 to 1.563g per day in variety Madakkathra – 2. The absolute growth rate (AGR) in between stages of growth was not significantly different. Apples accumulated a major part of the dry weight from 40 DAFS stage. The relative growth rate (RGR) was maximum between the periods from pea stage to 20 DAFS stage. A second peak was observed between 41 and 50 DAFS. The firmness of apple flesh ranged between 5.17 to 7.10 kg cm^{-2} at 40DAFS stage. There was a sharp decline in flesh firmness when the apples ripened. Removal of nut from the growing fruit resulted in early abscission. Up to the stage of 25 DAFS, removal of nut resulted in termination of apple growth within one week. Removal of nut beyond 35 DAFS stage resulted in an increased rate of growth for the apple. Critical dependence of apple on nut was observed till 45 DAFS stage.

The nut length, width and thickness increased up to 40 DAFS stage and declined later. In early varieties maximum length was recorded at 30-35 DAFS stage while in mid and late season varieties, maximum length was recorded at 40-45 DAFS stage. Shrinkage was recorded from 40 DAFS stage onwards with 7 to 23 percent reduction in thickness. Absolute growth rate in terms of length of nut was maximum during the early stages of growth.

Maximum fresh weight of nuts was observed at 30-40 DAFS stage. Rate of growth was maximum between 35 and 40 DAFS. A decline in fruit weight was observed from 40 DAFS stage. Major part of dry matter accumulation in nut was completed by 45 DAFS stage. Relative growth rate was maximum during the first 15 days after 'pea' stage. A second peak in RGR of nut was observed between 31 to 40 DAFS stage.

Kernel formation started from 20 DAFS stage. A jelly like endosperm was visible in nut cavity by 30 DAFS stage. In mature nut, kernel accounted for 29.3% of nut weight. Colour of nut changed from light green to gray by 50 DAFS stage. Filling of nut cavity was complete at this stage. Weight gain of kernel continued 52-54 DAFS stage. Colour change in apple was visible by 50 DAFS stage and typical colour of variety developed when the apple was fully ripe. The firmness of apple flesh dropped from 5.1- 6.0 kg cm^{-2} at 40 DAFS stage to 1.33- 2.07 kg cm^{-2} at 55 DAFS stage. Harvest of fruits for utilization of both cashew nut and apple should be done at the fully ripe stage of the apple.

References

Damodaran, V.K., Abraham, J. and Alexander, K.M. 1965. The morphology and biology of the cashew flower. *Agric. Res. J. Kerala* 3 (1&2): 23-28

Damodaran, V.K., Abraham, J. and Alexander, K.M. 1966. The morphology and biology of the cashew flower (*Anarcadium Occidentale*.L.). *Agric. Res. J. Kerala* 3 (2): 23-8

Damodaran, V.K. 1977. F_1 Population variability in cashew. *J.Plant. Crops* 5(2): 89-91

Das, R.C. and Sahoo, A.K.1987. Studies on floral biology of cashew under Bhuvaneswar environmental conditions. *Orissa J Hort.* 15(1): 12-16

Elsy, C.R.1985. Pollination studies in cashew (*Anarcadium Occidentale*.L.). MSc (Ag) Thesis submitted to Kerala Agricultural University, College of Horticulture, Vellanikkara, Thrissur, Kerala.

Gopikumar, K. 1978. Variations in seedling progenies of open pollinated cashew (*Anarcadium Occidentale*.L.). MSc Thesis submitted to Kerala Agricultural University, College of Horticulture, Vellanikkara, Thrissur, Kerala.

Khan, M.M. and Kumar, D.P. 1988. Ullal Cashew-1 and Cashew-2 varieties of cashew for Karanataka. *The cashew* 2(1): 17 –18

Krishnappa, K.S., Gowda, T.N.Y., Raju, G.T.T. and Gowda M.C. 1991. Studies on floral characters of certain varieties of cashew under eastern dry tract of Karnataka. *Cashew Bull.* 28 (10): 11-13

Narayanan Kutty, M.C. 2000. Development pattern, storage bahaviour and variability in processing characters of cashew apple. Ph D Thesis submitted to Kerala Agricultural University, College of Horticulture, Vellanikkara, Thrissur, Kerala.

Manoj, P.S. 1992. Biometrical studies in cashew (*Anarcadium Occidentale.L.*). MSc (Hort.) Thesis submitted to Kerala Agricultural University, College of Horticulture, Vellanikkara, Thrissur, Kerala.

Nalini, P.V. 1997. Productivity in relation to branching pattern and pruning in cashew *(Anarcadium Occidentale.L.*). Ph D Thesis submitted to Kerala Agricultural University, College of Horticulture, Vellanikkara, Thrissur, Kerala.

Parameswaran, N.K. 1979. Factors affecting yield in cashew (*Anarcadium Occidentale.L.*). MSc Thesis submitted to Kerala Agricultural University, College of Horticulture, Vellanikkara, Thrissur, Kerala.

Parameswaran, N.K., Damodaran, V.K. and Prabhakaran, P.V. 1984. Factors influencing yield in cashew (*Anarcadium Occidentale.L.*). *Indian cashew J.*16(3):9-15

Patnaik, H.P., Das, M.S. and Panda, J.M. 1985. Studies on fruit set and fruit drop in Cashew under Orissa condition. *Cashew Causerie* 7(4): 7-8

Pushpalatha, P.B. 2000. Morphophysiological analysis of growth and yield in cashew (*Anarcadium Occidentale.L.*). Ph D Thesis submitted to Kerala Agricultural University, College of Horticulture, Vellanikkara, Thrissur, Kerala.

Raju, V.K. 1979. Studies on fruit set and fruit drop in cashew (*Anarcadium Occidentale.L.*). MSc Thesis submitted to Kerala Agricultural University, College of Horticulture, Vellanikkara, Thrissur, Kerala.

Reddy, S.K. and Rao, R.R. 1985. Cultivation of Cashew in Andra Pradesh. *Cashew Causerie* 7:9-11

Salam, M.A., Pushpalatha, P.B. and Suma, A. 1995. Root distribution pattern of seedling raised cashew tree. J. of Plantation crops 23(1): 59-61

Swamy K.R.M. , Thimmappaiah and Kumaran, P.M. 1990. Evaluation of cashew germplasm accessions. The cashew 4(4): 12-13

Veeraraghavan, P.G. and Vasavan, M.G. 1977. Influence of rainfall on the productivity of cashew. *Indian cashew J.* 13(2): 23-24

Vidhyadharan, K.K.1983. Breeding and vegetative propagation of cashew nut. In: Lecture notes of training for officers of Special Agricultural Development Unit, Kerala Agricultural University, Thrissur, 143 p.

AGROCLIMATOLOGY OF CASHEW

G.S.L.H.V. Prasada Rao and C.S. Gopakumar
College of Horticulture, Kerala Agricultural University
Vellanikkara 680 656, Thrissur, Kerala

Cashew (*Anacardium occidentale L*) grows along the West and East Coasts of India from South to North, lying between 09° N and 23° N latitudes. Though it grows beyond 23° N latitude, its production is relatively low as the reproductive phase coincides with cold injury/low temperature during winter (December-February). Being a tropical coastal tree, it cannot thrive under low winter temperature. There is significant yield variation in cashew among the different agroclimatic zones of the country. Year-to-year yield variation is also significant, as the crop is weather sensitive. Therefore, an attempt has been made to highlight the influence of weather on cashew production. It is useful to choose the better cashew growing environments to enhance the area under cashew so as to enhance the cashew productivity vertically and horizontally.

1. Cashew yield in different environments

The cashew yield at Vengurla is the highest (18.5 kg/tree), where the crop is under moderate to severe soil moisture stress for five to seven months during its reproductive phase. The cashew yield of the superior varieties is 10.5 kg/tree at Madakkathara, where a prolonged dry spell of three to five months is seen during the reproductive phase of cashew (Fig. 1). Bhubaneswar and Vridhachalam recorded 12.8 kg/tree and 8.9 kg/tree, respectively where the maximum temperature during the nut setting and development phase (March to May) is high and considered to be a constraint occasionally under severe soil moisture stress. At Bapatla, the cashew yield is similar to that of Bhubaneswar. At Chintamani, the cashew yield is 8.1 kg/tree where crop is under soil moisture stress for a prolonged period unlike at other cashew growing locations. It is evident that cashew productivity was relatively low where the crop is under soil moisture stress for eight to ten months as the case at Vridhachalam and Chintamani. However, the yield is much better at cashew research stations where cashew is grown under rainfed conditions in better crop management situations when compared to that of country's average (less than 4 kg). Also, the cashew production is relatively high in Kannur and Kasaragod districts in Kerala, where prolonged dry spell is noticed from November to March, coinciding with the reproductive phase of cashew. At the same time, the yield is low whenever intermittent rain spells received from November to May across the west and east coasts of India due to immature nut fall. It appears that cashew is enamoured with dry spell/ drought during its reproductive phase and provides relatively better yield if the cashew plantations are cultivated scientifically.

2. Rainfall

Rainfall distribution across the cashew tract of the west coast of India is uni-model. Heavy rainfall during monsoon (June-September), followed by dry spell from

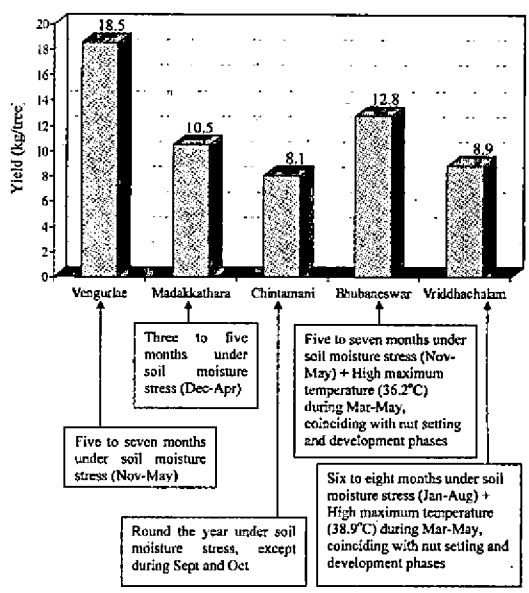


Fig. 1. Mean cashew yield (kg/tree) of superior varieties at selected locations under different agroclimatic conditions

November to May if pre-monsoon showers fail, is the characteristic rainfall feature along the west coast where cashew is predominantly grown. The above situation is more prevalent in the northern districts of Kerala and beyond (up to Vengurla in Maharashtra). The dry spell from November to March coincides with reproductive phase of cashew across the cashew tract along the west coast, experiencing moderate to severe soil moisture stress. The cashew tract across Maharashtra experiences prolonged dry spell of 5 to 7 months as rain ceases by the end of October and experiences more soil moisture stress. However, dormant phase (June-September) of cashew is under prolonged wet spell. In spite of the fact that the reproductive phase of cashew at all locations along the west coast (Kottarakkara, Madakkathara, Anakkayam, Pilicode, Puttur and Vengurla) is under soil moisture stress, the cashew plantations are healthy under rainfed conditions if the cashew is cultivated scientifically.

The annual rainfall is relatively less over the cashew tract of Orissa and West Bengal and the distribution of rainfall is alike to some extent as in the case of west coast (Fig.2a) due to the influence of south west monsoon. Across the cashew tract of Andhra Pradesh (Bapatla), rainfall is relatively better from July/August onwards and sometimes, rains extend up to November due to cyclones, which are not uncommon. In contrast, Tamil Nadu receives more rains from September to November due to influence of north-east monsoon and it may extend up to December where cashew is grown (Fig. 2b&c). Quite interestingly, cashew at Chintamani (Karnataka) is always under soil moisture stress throughout the year as rainfall is less than evapotranspiration round-the-year. The ground water table is also very low at Chintamani. Despite the above fact, cashew plantations are comparable at Chintamani (Karnataka). Across the East Coast also, healthy plantations are seen where the reproductive phase of cashew experiences soil moisture stress from February to May. The monthly rainfall distribution over the East Coast (Vriddhachalam, Chintamani and Bapatla) is different to other cashew growing states as they are influenced by rain received during the late southwest monsoon and northeast monsoon (October-December). It is the reason, why, the dry spell commences from November across the West Coast while February along the East Coast (Tamil Nadu).

From the above, it is evident that cashew experiences moderate to severe soil moisture stress across the West Coast under rainfed conditions and prolonged further

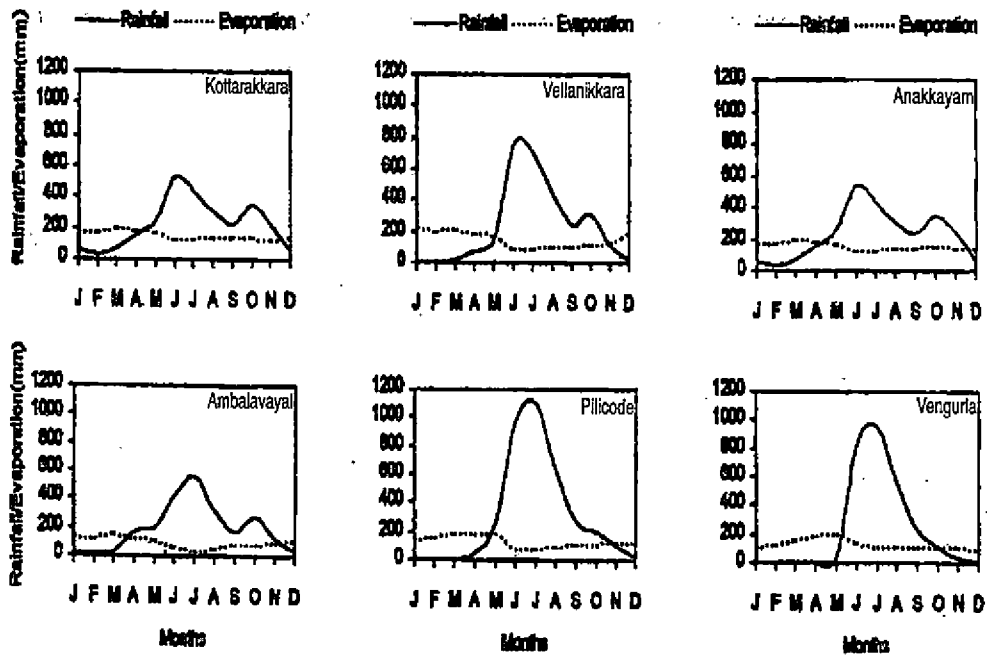


Fig. 2a. Rainfall and pan evaporation (mm) at different locations across the west coast of India

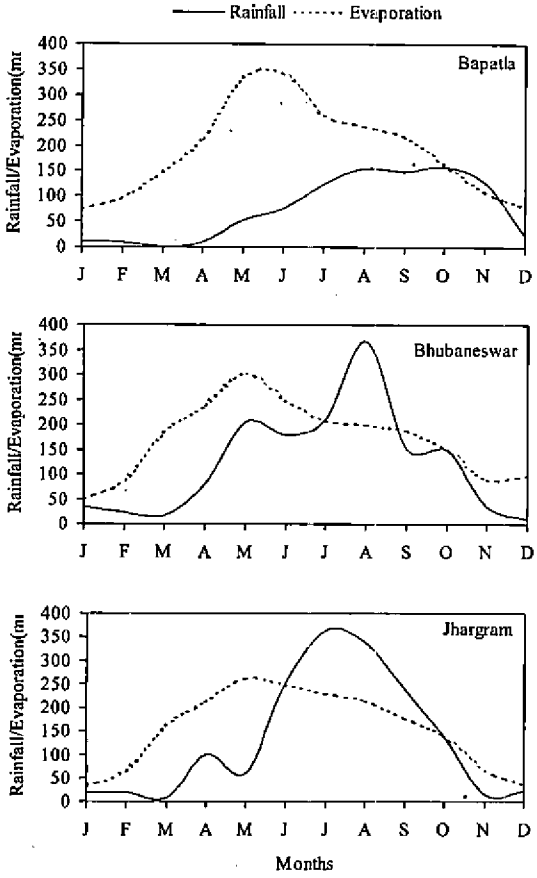


Fig. 2b. Rainfall and pan evaporation (mm) at different locations across the east coast of India

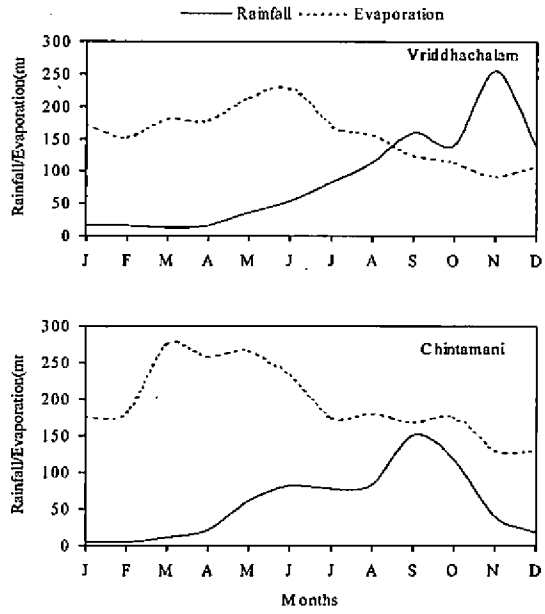


Fig. 2c. Rainfall and pan evaporation (mm) at Vriddhachalam and Chintamani

across the East Coast as it experiences late rains with less number of rainy days and rainfall is below crop water need. It is also understood that the better availability of soil moisture during flowering period (December and January) may not influence the time of flowering in cashew. The unusual rains during November and December may lead to inordinate delay in reproductive phase of late season types/non-descript planting material across the West Coast. The delay in the time of flowering may be detrimental for cashew production as the number of bisexual flowers produced might be less since the flowering phase misses the mild winter.

3. Temperature

Cashew may require relatively dry atmosphere with mild winter for better flowering. The mild winter may be defined as "low minimum surface air temperature ranging between 15 and 20°C coupled with more dew nights having moderate dew" in humid climates. The cashew yield and its quality are affected due to prevalence of high maximum temperature (35° C and beyond) during the reproductive phase of cashew (flowering/nut setting to harvest) in a situation where prolonged abnormal drought is noticed. The above situation is noticed across the East Coast at Vriddhachalam, Bapatla, Bhubaneswar and Jhargram. Sometimes, the maximum temperature shoots up to 42°C during the nut development period across the east coast. However, it is not the case across the West Coast. The moderate (30-33°C) maximum temperature that persists across the West Coast during the reproductive phase may be ideal for better nut development and its quality. However, at Madakkathara in Kerala along the west coast, high wind speed during November and December and maximum surface air temperature beyond 35°C during summer (February-April) may be limiting factors for obtaining better yields in cashew. It needs further examination. Also, the physiology of crop is to be totally understood to find out the mechanisms, which are working internally in favour of drought tolerance in cashew.

3.1 Effect of latitude and altitude on flowering

Hopkins (1938) attempted to express the importance of latitude, longitude and altitude in the distribution and

rate of development of plants by means of a "bioclimatic law". It may be stated as "A biotic event in north America will, in general, show a lag of four days for each degree of latitude, five degree of longitude and 400 feet of altitude, northwards, eastward and upward in spring and early summer". In mango, the India Meteorological Department also established that there was a delay in flowering from south to North of India, which generally followed Hopkins bio-climatic law.

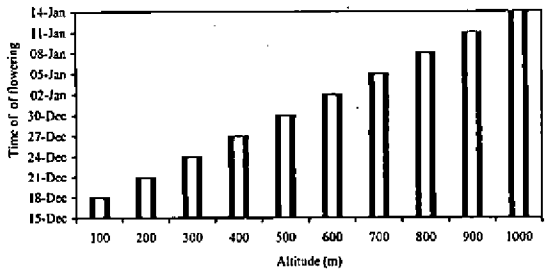


Fig. 3. Influence of altitude on cashew flowering

The law stated by Hopkins is also applicable in case of biotic events of cashew in tropical monsoon climates under better crop management in rainfed situations, provided the genotype and rainfall distribution are uniform. However, there is a difference in number of days delayed in cashew flowering at each degree of North latitude while the effect of altitude on time of cashew flowering is similar as stated by Hopkins (1938). In tropical monsoon climates, there appeared to be a delay of 6 days in cashew flowering at every 1^0 of North latitude and for every 100 m of altitude, the delay in cashew flowering was three days (Fig. 3). The variation in duration of reproductive phase of cashew with latitude and altitude could be explained due to variations in surface air temperature viz., day maximum and night minimum temperatures. More and more studies are to be taken up in this direction to understand the effect or geographic co-ordinance on horticultural crops.

3.2 Heat units and cashew yield

A significant variation in heat unit requirement of cashew is noticed depending upon genotype. Early variety like Anakkayam (ANK - 1) requires only 1953 day^{0}C for reproductive phase (25% bud break to 75% harvest) while 2483 day^{0}C in case of late season types like Madakkathara (MDK - 2). The heat unit requirement of mid season type like MDK-1 is 2245 day^{0}C. It reveals that early season types require less heat units while late season types require more heat units and the heat unit requirement of the mid season types is intermediary (Table 1). The heat units versus cashew yields of test varieties showed that there is no definite relationship exists between them as negative relationship is seen in 50% of the cases and positive in other 50% of cases. However, the mean nut yield follow the number of heat units except in MDK-2. It is mainly attributed to incidence of the pest complex, which is not uncommon during the flowering season of cashew across the West Coast. Interestingly, the kernel weight of all the test varieties followed the heat units (Fig. 4). It can be inferred that the cashew yield and kernel weight may follow the availability of heat units if other environmental conditions are homogenous. It reveals that the biotic events and cashew yield attributes not only respond to rainfall regimes but also thermal regimes too.

4. Phototropism in cashew

Cashew shows a tendency to grow more towards South in response to sunlight in the Northern Hemisphere. It is more evident in higher latitudes towards north in search of sunlight. The direction-wise occurence of abiotic events indicated that there is a clear-cut difference in the number of flushes produced, number of panicles and number of fruits set/m^2 within the canopy of a tree.

The branches of cashew in south produced maximum

Table 1. Heat units (day^{0}C) and cashew yield (kg/tree) of test varieties at RARS, Pilicode

Year	ANK-1 (Early)		MDK-1 (Mid)		MDK-2 (Late)		Mean	
	No. of heat units	Yield	No. of heat units	Yield	No. of heat units	Yield	No. of heat units	Yield
1995-96	2302	2.3	2122	2.8	3091	1.1	2505	2.1
1996-97	1850	3.1	2219	2.9	2287	1.0	2119	2.3
1997-98	1983	0.8	2837	4.0	2419	8.2	2413	4.3
1998-99	1675	7.1	1803	7.1	2135	4.3	1871	6.2
Mean	1953	3.3	2245	4.2	2483	3.6	2227	3.7

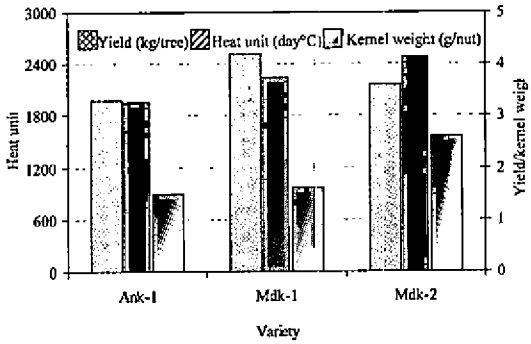


Fig. 4. Heat units (day°C), cashew yield (kg/tree) and kernel weight (g/nut) at RARS, Pilicode

number of fruits, followed by West and East while the lowest towards north. Cashew responds well to sunlight, indicating that it has a predominant phototropism character. Interestingly, harvest is estimated to be more in south (60-80%) compared to that of north (20-40%) of cashew trees (Fig. 5a). A delay of one week to 10 days in appearance of all the biotic events of cashew towards north within the cashew tree can also be noticed (Fig. 5b). It also appears to be photosensitive as the reproductive phase is confined to season bound, varying between March and May across the west and east coasts of India. However, harvesting falls in June/July at higher altitudes (Ambalavayal and Chintamani). Of course, de-colourisation of nuts happens and their weight and quality are very poor as regular rains start by that time. Though delay in budbreak and flowering is seen towards north (Bapatla, Bhubaneswar and Jhargram), the crop matures early and completes by April-end or first week of May. This could be attributed to high maximum temperature (35-40°C) that prevails during summer (March-May). It appears that the cashew is not only photosensitive but also thermosensitive as the biotic events respond to low minimum and high maximum temperatures. It seems that a temperature range between 13 and 35°C may be optimum for better growth and production of cashewnuts. However, the optimum temperature range for cashew is yet to be worked out since it is only observational.

5. Yield forecasting models for cashew

It is evident that the reproductive phase of cashew is very sensitive to weather aberrations and final crop output depends upon weather conditions if no pest incidence is noticed. The variations in crop output could be known only after the crop is over or in due course of reproductive phase of cashew. It may not be much useful for the cashew industry since information on cashew production is not known before the crop season commences. It means, a sort of crop forecasting mechanism is to be developed well ahead of crop season commences. Such a mechanism is evolved for crop output of cashew for the State of Kerala based on rainfall from September to December (Fig. 6). Similar attempt can be made for the country as a whole so that the information can be used in EXIM policy. In view of drastic decline in cashew area across Kerala in recent years the model needs to be re-validated for forecasting cashew production.

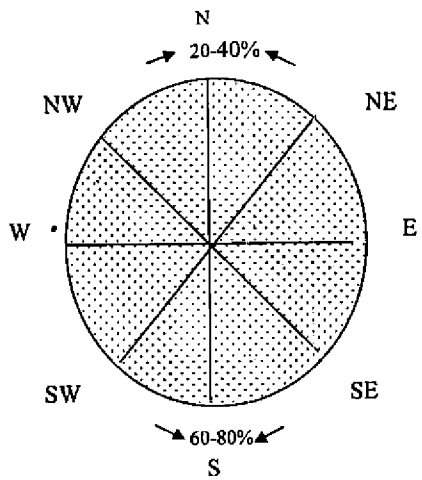


Fig. 5a. Direction-wise yield pattern in a cashew tree

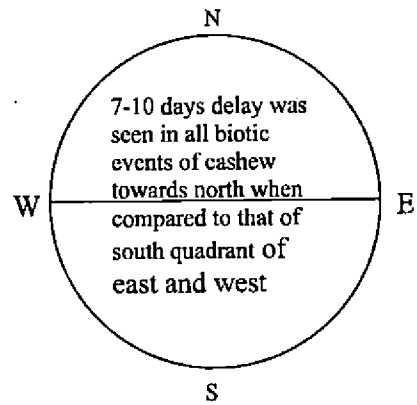


Fig. 5b. Occurence of biotic events between northern & southern parts of a cashew tree

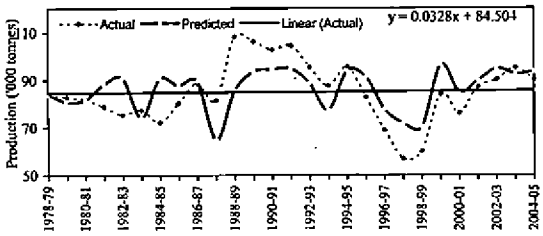


Fig. 6. Actual and estimated production of cashew over Kerala from 1978- 79 to 2004-2005

6. Agroclimatic zones of cashew

Bhaskara Rao *et al.* (2002) made an attempt to indicate agroecological sub-regions and climatic conditions of cashew-growing areas in different states. Taking into consideration the variations in fruiting phase, temperature variations along the west and east coasts, rainfall behaviour including summer showers, different agro-ecological zones are demarcated and suggested suitable varieties. The length of crop growing period for cashew varies from 90 to 270 days depending on agroclimatic / ecological regions and varieties. Kerala is the major

Agro ecological Zone No.	Description	Areas	Varieties recommended
19.2	**Kerala:** Central and south Sahayadris, hot moist sub-humid transitional ESR with deep, loamy to clayey red and lateritic soils, low to minimum AWC and LGP 210-270 days	Area with medium AWC and LGP	VRI 3, Kanaka, Dhana, VRI 2, NDR-2-1, Amrita, Ullal 1,3,4
19.3	**Konkan, Karanataka and Kerala:** Coastal plain, hot humid to per humid transitional KSR with deep, clayey to loamy, acidic, coastal alluvium-derived soils, low AWC and LGP 240-270 days.	Coastal areas of Kozhikode, Kannur, Kasaragod, Malappuram, part of Thrissur, part of Trivandrum, fall in this humid transitional zone. Coastal areas of Maharashtra	V1, V3, V6, V7, Dhana, Kanaka, Goa1, NDR-2-1, Ulla1, 3, 4, VRI 3, 2 and BPP 8
12.1	**Orissa State**: Garjat hills, Dandakaranya and Eastern Chats, hot moist sub humid ESR with deep loamy red and lateritic soils, low to medium AWC and LGP 180-210 days	Kalahandi, Phulbani, Balangir, Sambalpur, Sundargarh and Koraput fall in this zone	Early flowering varieties which benefit from precipitation during NE monsoon
12.2	Eastern Ghats, hot moist sub humid ESR with medium to deep loamy red and lateritic soils, medium AWC and LGP 180-210 days	Interior parts of region 18.4 below also falls in this zone. Coastal areas of West Godawari	In the coastal areas of Orissa, varieties which flower some time during January and February will be suitable
7.3	**Andhara Pradesh:** Eastern Ghats (south), hot moist semi-arid/dry humid ESR with medium to deep loamy too clayey mixed red and black soils, medium AWC and LGP 150-180 days	West Godawari, Krishna, part of Nellore, Guntur, Prakasam	BPP4, BPP6, VRI 1 and VRI 3
18.4	Utkal plain and east Godawari delta, hot dry sub humid ESR with deep, loamy to clayey coastal and deltaic-derived soils, medium AWC and LGP 180-210 days	Srikakulam, part of Vizianagaram, part of Visakhpatnam, part of East Godawari	Varieties which flower in February-March viz., BPP6 and BPP 8
8.1	**Tamil Nadu:** Uplands and leeward flanks of south sahayadris, hot dry semi-arid eco sub region with moderately deep to deep, loamy to clayey, mixed red and black soils, medium AWC and AGP 90-120 days	Thirunelveli	Varieties which flower very early with supplementary irrigation
8.3	Tamil Nadu uplands and plains, hot moist semi-arid ESR with deep red loamy soils, low WC and LGP 120-150 days	Dharmapuri, North Arcot, Chengalpettu, Villupurram, South Arcot, Thiruchirappilli, Thanjavur and Pudukkottai	VRI 2 and VRI 3

12.3	**West Bengal:** Chotanagpur plateau and Garjat hills, hot dry sub humid ESR with moderately deep to deep loamy clayey red and lateritic soils, medium AWC and LGP of 150-180 days	Major parts of Midnapore and Bankura	BLA-39-4, Tree No.6, Jhargram-1 and BPP-8
15.1	Bengal basin and north Bihar plain, hot moist sub humid ESR with deep loamy to claycy alluvium-derived soils, medium t high AWC and LGP 210-240 days	Part of Midnapore	BLA-39-4, Tree No.6, Jhargram-1 and BPP-8

(After Bhaskara Rao *et al.*, 2002)

cashew growing area in the country, falling under the two agro-ecological sub regions of 19.2 and 19.3 and they are as follows:

Based on the information available on various aspects of cashew production in relation to weather, soil and yield potential, an attempt has been made to demarcate "Agroclimatic zones for cashew" across the west and east coasts of India by Prasada Rao(2002). Cashew productivity can be improved towards north across both the coasts of west and east while it may decline towards inland plateau of Peninsular India (Fig. 7). The north-east region may also be not conducive due to occurence of frequent cold waves during fruiting season.

7. Weather, insect pests and diseases

Tea mosquito bug (*Helopeltis antonii* Signoret (Heteroptera: Miridae)), is the most important pest of cashew. It sucks the sap of tender parts of cashew including inflorescence, panicles and young cashew nuts. The insect injects its saliva into the plant during its feeding which causes drying of the affected parts. It is a severe menace across the cashew tract of west and east coasts, to some extent. The pest menace is also seen in "Maidan areas" of Karnataka located at high ranges where cashew is predominantly grown. The pest infestation commences in October and November depending upon the location and synchronizes with flushing and flowering stages and reaches its peak during the blossom period (Fig.8). The bumper crop expected in 1998-99 across the west coast was devastated due to pest complex (Tea mosquito bug and the fungus *Colletotrichum* sp.) and the crop yield harvested was only half of the expected or even less. The incidence of pests alone causes a loss of up to 50 per cent or more in yield of cashew.

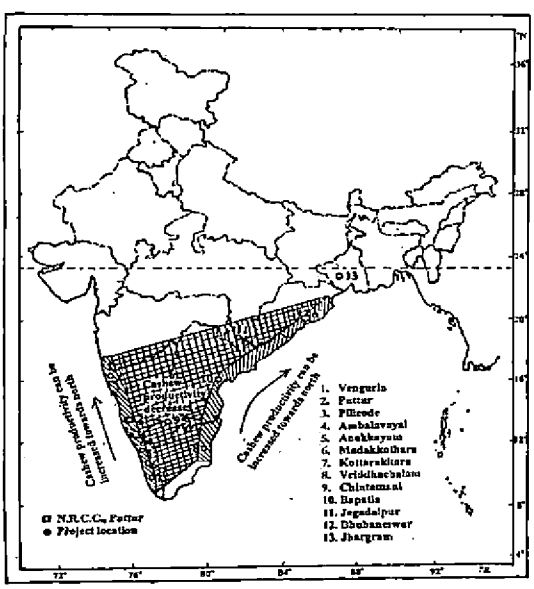


Fig. 7. Agroclimatic zones for cashew

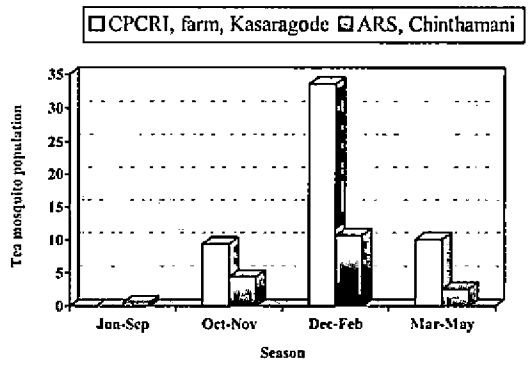


Fig. 8. Season-wise tea mosquito population in cashew

7.1 Hot spot areas of tea mosquito bug

The hot spot areas of tea mosquito bug across the cashew tract of the whole country have been demarcated taking into account the optimum night temperature during the flushing and flowering stages. The criteria adopted for intensity of pest based on night temperature is as follows:

Night surface air temperature	Intensity of tea mosquito bug
15 and 20° C	Moderate to Severe
12 and 15° C	Low to Moderate
10 and 12° C	Low
< 10° C	Free from pest incidence

The pest population may be moderate to severe across the west coast, commences from northern districts of Kerala to southern districts of Maharastra, where cashew is predominantly grown. The pest population may be low to moderate across the east coast and high ranges (Ambalavayal in Kerala and Chintamani in Karnataka) and relatively free from pest population across the cashew tracts that are grown in West Bengal and North-eastern States (Fig. 9) as the pest population may not survive in cold, hot and wet weather.

As the above criteria was based on two data points, it was tested and modified the upper limit of night temperature under the category "Moderate to Severe" as pest population is noticed in endemic areas of southern districts of Kerala, where the night temperature during flushing and flowering stages is noticed between 20 and 23° C (Kottarakkara and Madakkathara). Of course, the night temperature at the above places falls below 20° C

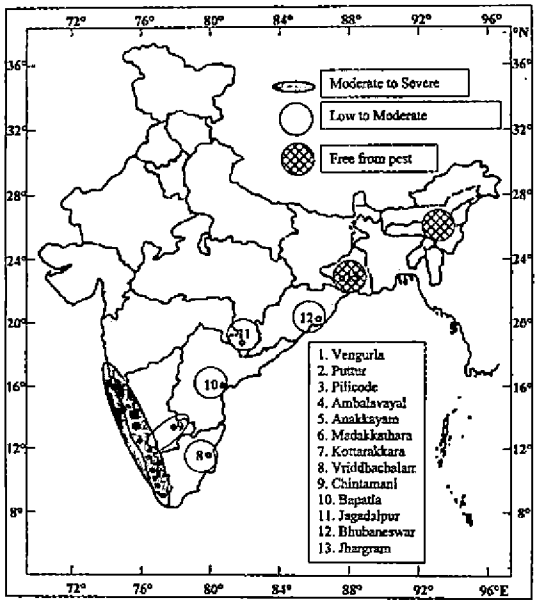


Fig. 9. Hotspot areas of tea mosquito bug in cashew across India

Table 2. Minimum temperature versus intensity of tea mosquito bug

Minimum temperature (°C)	TMB population (No/q/tree)	Intensity of TMB
>24	<4	Low
22 and 24	4 to 8	Low to Moderate
15 and 22	8 to 20	Moderate to Severe
12 and 15	4 to 8	Low to Moderate
10 and 12	<4	Low
<10	0	Nil

occasionally during winter, which coincides with flowering phase of cashew. Sundararaju (2005) also revealed that only minimum temperature has consistent negative relationship with the pest outbreak. The revised criteria is given in Table 2.

The hot spot areas of tea mosquito bug population will throw a bird's eye view for integrated pest management as well, for expansion of cashew cultivation across India. However, the study needs further investigations with more number of data points on pest surveillance. As such, to my surprise, no institute is involved in pest surveillance of tea mosquito bug at national/state level.

7.2 Is pest forewarning operational?

It is obvious that weather plays a major role in initiating outbreaks of tea mosquito bug. The endemic areas could be very well identified by systematic collection of data on incidence of tea mosquito bug through surveillance along with the threshold weather variables. As the pest incidence builds upon host plants under the favourable physical environment, it is difficult to understand the system and to forewarn the further build up of pest unless concerted efforts are made to build up sound databank. Since last three decades, several models namely, linear and non-linear regression equations, logistic models and computer based simulation models have been used for predicting or forewarning of the pest and diseases. Most of the above models are seen in literature from outside the country where these are put in operation. In India, the forewarning and early warning systems against major pests and diseases are still not operational, despite availability of some models. It is true in case of tea mosquito bug too. Databank and pest population trends in time and space in relation to meteorological parameters are to be developed in case of cashew. The predictability of tea mosquito bug incidence

with reasonable degree of accuracy has to be explored and appropriate models developed under field conditions.

8. Crop Growing environments

The climatic requirements during the reproductive phase of cashew are relatively favourable across the west coast except at few pockets where the maximum surface air temperature goes beyond 35° C. As a whole, the major threat to cashew production across the west coast is the incidence of tea mosquito bug complex. It is, again, triggered by favourable weather. Suitable genotypes and crop management under various field conditions along with scientific control measures against the pest complex will go a long way to sustain cashew production across the cashew tract of west coast (Table 3).

The meteorological factors like night temperature (<10° C) and day maximum temperature (>35° C) during the reproductive phase of cashew may not be conducive for better flowering along the east coast. In addition, the occurrence of cyclones is not uncommon. It is a major threat to cashew plantations across the east coast. Unless the cashew plantation is well protected with wind breaks/ shelter belts, it will not be a viable economic proposition to grow cashew across the east coast. Farmers grow cashew only under irrigated conditions along the East Coast.

8.1 Environmental constraints over Kerala

The benevolent and malevolent effects of cashew environment across Kerala are highlighted separately in Table 4, as it plays a major role in cashew industry. As a whole, the incidence of pest complex is the threat to cashew production over Kerala. In few pockets like Palghat and Thrissur, the adverse effects of high wind speed and the maximum surface air temperature beyond 35 ° C during the reproductive phase on nut yield and its characteristics are yet to be understood. Similarly, lack of mild winter and occasional wet spells towards south of Kerala may also hinder cashew production. However,

Table 3. Cashew and its environment across the west and east coast of India

Environment	West coast	East cost
PLANT		
1. Planting Material	Pedigree & Senile	Relatively new plantations
2. Crop management including crop Protection measures	poor	Relatively better
3. Dormant phase	No moisture stress	Soil moisture stress
4. Reproductive phase	Soil moisture stress	Soil moisture stress
5. Flowering	December/January	February/March
SOIL		
1. Soil	Laterite	Littoral sand and sandy loam
2. Topography	Hill Slopes	Plains
CLIMATE		
Coastal climate	Same	Same (except Chinthamani & Jagadalpur)
Annual rainfall	2000 to 3600 mm	600 to 2000 mm
Max. Temperature	< 35°C (30-35°C) –may be optimum	> 35°C (occasionally shoots up to 40°C) - may not be conducive
Min. Temperature	>15°C (15-20°C) –may be optimum	<15°C (occasionally goes below 10°C in north) - may not be conducive
Soil temperature	Moderate	High
Sunshine	2700 to 3000	2700 to 3000
Relative humidity	70 to 90%	50 to 70 %
Cyclones	Rare	Not uncommon
IRRIGATION	No summer irrigation	Farmers practice irrigation
PEST & DISEASES	Incidence is common	Incidence is not common
1. Tea mosquito	Moderate to severe	Low

Table 4. Cashew and its environment over Kerala

	Environment	Effect
PLANT		
1. Planting Material	Pedigree & Senile	Malevolent
2. Crop management including crop Protection measures	Very poor	Malevolent
3. Dormant phase	No soil moisture stress, Exposed to low solar radiation due to heavy rainfall	Benevolent/ Malevolent
4. Reproductive phase	Soil moisture stress	Malevolent
5. Flowering	December/January pest complex-Benevolent	Early season type may escape
SOIL		
1. Soil	Very deep and well drained laterites (OC-marginal N-low to medium K_2O-low)	
2. Topography	Slopes	
CLIMATE		
Coastal climate		
Annual rainfall	2000 to 3600 mm	Malevolent
Max. Temperature	< 35°C (30-35°C opt.)	Benevolent
Min. Temperature	>15°C (15-20°C opt.)	Benevolent
Soil temperature	Moderate	Benevolent
Sunshine	Around 2700	Benevolent
Relative humidity	70 to 90%	Malevolent
Wind speed	Low to moderate except over Palghat and Thrissur	Benevolent- It is doubtful in case of Palghat and Thrissur districts where wind speed is high
IRRIGATION	No summer irrigation	Malevolent
PEST & DISEASES		
1. Tea mosquito	Moderate to severe production	Malevolent-threat to cashew

detailed studies are to be undertaken on optimum cashew growing environments to exploit better yields in cashew with multi-disciplinary approach.

References

Bhaskara Rao, E.V.V., Yadukumar, N. and Bhat, N.G. 2002. Agroecological regions and varietal classification of cashew in developmental strategies. Proc. of the 5th National Seminar on Indian cashew in the New Millennium, Vishakhapatnam, 12-13 April 2002, pp.43-51

Prasada Rao, G.S.L.H.V. and Gopakumar, C.S. 1995. Climate and Cashew. *The cashew* 8(4):3-9

Prasada Rao, G.S.L.H.V. and Gopakumar, C.S. 1999. Latitudinal and altitudinal influence on cashew flowering over Kerala. Proc. of XI Kerala Science Congress, CPCRI, Kasaragod, 27th February-1 March, 1999, pp.242-46

Prasada Rao, G.S.L.H.V., Krishnakumar, K.N. and Xavier Tony 2001. Agroclimatic zones for cashew across India. Proc. of TROPMET 2000, Cochin, 1-4 February 2000, pp. 556-559

Prasada Rao, G.S.L.H.V., Giridharan, M.P., Jayaprakash Naik, B., Gopakumar, C.S., Krishnakumar, K.N. and Xavier Tony. 2001. Influence of weather factors on bud break, flowering and nut quality of cashew (*Anacardium occidentale L.*). *Indian Journal of Agricultural Sciences* 71 (6): 399-402.

Prasada Rao, G.S.L.H.V., Thirumala Raju, G.T., Puttaswamy, Krishnakumar, K.N. and Xavier Tony. 2002. Forecasting tea mosquito bug (*Helopeltis antonii.*) of cashew (*Anacardium occidentale L.*). *Journal of Agrometeorology* 4(1) : 45-52.

Prasada Rao, G.S.L.H.V., Krishnakumar, K.N. and Xavier Tony. 2000 Crop weather diagrams of cashew- an agroclimatic tool for crop forecasting. Proc. of Twelfth Kerala Science Congress, January 2000, Kumily, pp.520-26

Prasada Rao, G.S.L.H.V., Krishnakumar, K.N. and Xavier Tony. 2000. Agroclimatic zones of cashew across India. Proc. of the TROPMET-2000, Cochin, 1-4 February, 2002, pp. 556-559

Prasada Rao, G.S.L.H.V. and Krishnakumar, K.N. 2004. Crop yield forecasting of cashew. www. commodityIndia.com. April 2004, 4(4): pp.51-52

Prasada Rao, G.S.L.H.V., 2002. Climate and Cashew. 2002. Kerala Agricultural University, Thrissur, 100 p.

Sreekanth, P.D. and Bhaskara Rao, E.V.V. 2003. Model for forecasting yield in cashew. *The cashew* pp.23-31

Sreekanth, P.D., Yadukumar, N. and Gangdhara Nayak, M. 2004. Cashew yield forecasting under different planting densities. Journal of Plantation Crops 32(3):58-63

Sundararaju, D. 2005. Seasonal abundance and extent of damage of tea mosquito bug on cashew. Journal of Plantation Crops 33(1):53-58

CASHEW GERMPLASM - COLLECTION, CATALOGUING AND EVALUATION

V.G. Jayalekshmy
Dept. of Plant Breeding and Genetics,
College of Agriculture, Vellayani - 695 522, Thiruvananthapuram, Kerala

Introduction

Cashew is a perennial fruit tree tropical in habitat and yielding the well known delicious nut mostly preferred in the new world. Portuguese first introduced cashew in the Malabar Coast during the 16th centuary and from this local point it is presumed to have dispersed to other parts of the country and also to South East Asia (De-Costa, 1578). Even though Brazil is the center of origin of cashew, due to more than four centuries of growing, cashew has well acclimatized to Kerala conditions. Due to intensive out crossing in seed-raised plantations, wide genetic variability exist in this crop. Kerala can be considered as a secondary centre of origin with respect to genetic divergence in cashew prevailing in this area. Though the original introductions were from very few trees, cross pollination and seed propagation have resulted in natural segregation.

As cashew is a highly cross-pollinated heterozygous polyploid, there is great variability in vigor, productivity, sex ratio and also fruiting behaviour (Ascenco, 1986). Hence an in depth study of germplasm collection is almost essential. The term germplasm is used in its widest sense to include all genotypes to be found in local population and collection of introduced material.

The main objective of germplasm collection is to preserve and document the genetic variation in representative samples of primitive varieties /land races of cultivated as well as wild relatives. Those, which are endangered by genetic erosion, are also to be conserved because of the basic variation in the crop. Hence, though variability in cashew is enormous, collection, conservation, cataloguing and evaluation are the basic needs for evolving varieties by selection and hybridization. In this chapter an attempt is made to report the present status of cashew germplasm collection with special reference to Kerala.

1. Germplasm Collection

The germplasm collection serves as the initial population out of which parents are to be selected. It is much easier to collect seeds than the collection of vegetative parts of the plant from various parts of the country or from abroad. Seed nuts are fairly abundant and can easily be packed for transportation; whereas great care is required to keep vegetative collection alive, during transmission to the introduction station (Gene Bank). The cuttings will easily dry out or rot, if they are not properly wrapped in waterproof material. Since seed nuts incorporated a wide range of genetic diversity, the genetic integrity of a particular genotype can be preserved through vegetative propagules only.

The efforts to collect and conserve germplasm of cashew in India started with the establishment of pioneering centers in the early fifties. There had been considerable exchange of materials between these centers. Since the exchanges of materials were through seedling progenies in most parts, the heterozygosity of the parent trees and the out crossing behaviour render the materials so disseminated as a constantly evolving dynamic system. Even though most of the collections available are of indigenous sources, they are not strictly so, since the nucleus material that spread widely and naturalized in India's habitat, have come entirely through introductions only. However,the variability with respect to several trials in cashew has been too large for a material originated from a limited gene pool. Hence there is good scope for introductions from far and near. The exotic types are from Brazil, Malaysia, Sri Lanka, Tanzania, Nigeria, Mozambique, Kenya, Singapore and Panama Republic.

1.1. History of germplasm collection in cashew

The early attempts for germplasm collection were made during the early fifties with the sanctioning of ad-hoc schemes in the states of the then composite Madras viz., Travancore, Cochin and Bombay. The research stations started in the above schemes in Kerala (Kottarakkara), Karnataka (Ullal), Tamil Nadu (Vridhachalam), Andhra Pradesh (Bapatla) and Maharashtra (Vengurla) took up the programme of collection of locally available elite plants for evaluation and further selection.

In these attempts, the emphasis was on high yielding types and the collections were made on individual tree basis and not as population samples. Therefore in all the research stations individual trees were considered as an accession and even when more than one tree is available in the progeny of a single tree, they were given individual tree numbers. Further in these collections only open pollinated seeds were collected which led to considerable variability within the individual accessions in all the centers.

Many of the other research centers which were established subsequently have collected the seeds of the germplasm from the centers *viz.*, Bapatla, Kottarakkara, Ullal, Vridhachalam and Vengurla.

Due to inherent heterozygous nature, the sub samples from original collection do not very often exhibit the characters in original collection. While making the initial collection of germplasm, these states have confined their survey to the respective states and hence they represent the local germplasm available in that state. Since the inception of All India Co-ordinated Spices and Cashew Improvement Project in 1971, Central Plantation Crops Research Institute (CPCRI) also took up the programme of cashew germplasm collection under the co-ordinated project programme and established a germplasm collection of 292 accessions at CPCRI, Regional Station at Santhigodu in Karnataka. This consists mainly of seedling progenies of collections which are available at Bapatla, Vengurla, Anakkayam and Vridhachalam and a few collections made locally from Karnataka.

Subsequent to the establishment of NRC-Cashew, Puttur, the germplasm collection through seeds has been discontinued and only the vegetative propagated material is being collected with an objective of establishing a National Gene Bank. A co-ordinated approach was brought in the cashew germplasm collection by organizing joint survey teams consisting of scientists of NRC-Cashew and the all India co-ordinated Cashew Improvement Project (AICCIP) centers of the respective states. In the cropping season, the source population is surveyed and trees for collection are identified. Later from the same identified trees the scion sticks are collected for making the softwood grafts in the respective centers and at NRC-Cashew. This procedure currently adopted ensures collection of representative samples of the source trees identified and also ensures that duplicate sample is maintained at respective co-coordinating center in the state, which aids in proper conservation of collection. Efforts are underway to identify the important and diverse genotypes in the collections already available based on available evaluation data and multiply them clonally and plant them in the conservation blocks at a closer spacing(Rao and Swamy, 1994).

1.2. Size of germplasm holdings in India

More than one thousand accessions of seedling origin and more than 500 clonal accessions are being maintained in different cashew research stations in the country. Among the seedling accessions, 23 are exotic collections of which nine were collected from Brazil, Nairobi, Mtwara, Lindi, Nacala, Mozambique, Extanganyka, Singapore and Australia (Rai and Vidhyachandra,1982) and 14 were collected from republic of panama (Rao 1991). These exotic collections are being maintained at Ullal and Madakathara. Rai and Vidhyachandra(1981) reported that none of the exotic collections were comparable to the indigenous collections in yield performance.

A total of 1167 accessions have been conserved in the National Cashew Gene Bank (NCGB) at National Research Center for Cashew (NRCC), Puttur and Regional Cashew Gene Bank (RCGBs) at AICRP on cashew centers, namely, Agricultural Research Station (ARS), Chinthamani, Regional Fruit Research Station (RFRS), Vengurla, Regional Agricultural Station (RARS) Pilicode, Cashew Research Station (CRS) Madakathara, Regional Research Station (RRS) Vridhachalam, Cashew Research Station (CRS) Bapatla, CRS Bhubaneswar and Regional Research Station (RRS) Jhargram (Table-1).

1.3. Status of cashew germplasm in Kerala

Cashew research in Kerala started with the initiation of a

Table 1. Cashew germplasm holding in India

Sl.No	State	Research station	No. of accessions conserved
1	Karnataka	NRCC, Puttur	451
		ARS, Chinthamani	75
2	Maharashtra	RFRS,Vengurla	157
3	Kerala	RARS Pilicode	64
		CRS, Madakathara	93
4	Tamil Nadu	RRS,Vridhachalam	177
5	Andhra Pradesh	CRS, Bapatla	179
6	Orissa	CRS, Bubaneswar	47
7	West Bengal	RRs Jhargram	81
	Total		1324

regional research station at Kottarakkara under ICAR. This scheme continued till 1962. When ICAR terminated financial support to the scheme, the state government decided to have a cashew research station at Anakkayam at Malappuram District. Subsequently, when the All India Coordinated spices and cashew nut improvement project was started from 1970, the Anakkayam station was treated as a sub center under the project. Following the formation of Kerala Agricultural University, Cashew Research Station was started at Madakathara which became the subcentre of AICRP on Cashew (Damodaran, 1980).

Survey and collection of novel types to enrich the germplasm was the initial research programme in Kottarakkara. These accessions were later transferred to research stations at Anakkayam and Madakkathara. At Cashew Research Station Anakkayam, 84 accessions (few seedling progenies and other air layers of germplasm from Kottarakkara) and at Madakathara, 93 seedling accessions and 68 clonal accessions are being maintained (Anon., 1989). In addition seeds of 18 accessions from the republic of Panama were introduced and sown during July 1988 and seedlings of 14 accessions were planted during September 1988 for evaluation (Anon., 1989). Ramdas and Thatham (1981) have studied 38 accessions for different characters and they observed variability for yield (0.525-23.025 kg/ tree), 100 nut weight (252-567g), shelling percentage (21.2-31.6 percent) and 100 kernel weight (68-200g).

At present cashew germplasm in Kerala Agricultural University is maintained at three research stations, Anakkayam with 85, CRS Madakathara with 167 and RARS Pilicode with 64 accessions (John *et al.*, 2003). This germplasm includes indigenous collections, collections from other states and exotic collections from Brazil, Indonesia, Tanzania and Republic of Panama.

This germplasm is enriched with many novel varieties like the precocious dwarf accessions from Brazil (Anon, 2001), cashewnut shell liquid free accession Pattannur 1-1 (Nalini *et al.*, 1994) which can be used raw for culinary purposes, purple cashew (ornamental) from NRCC, Thaliparamba dwarf suitable for high density planting from Pilicode (TPB-1) etc.

2. Cataloguing

Characterization of cashew cultivars is a prerequisite to identify cashew genotypes. This will enable the researchers to incorporate desirable characters into new varieties. Germplasm description includes two steps

- To compile passport data.
- To characterize the material for easily recognized traits

2.1. Registration of cashew germplasm

In order to safeguard our national interest in the field of plant genetic resources and to protect our indigenous accessions, national/indigenous collection numbers (IC Nos) are being assigned to crop germplasm by the National Bureau of Plant Genetic Resources (NBPGR), New Delhi. To obtain IC Nos, the passport information on all the cashew accessions, which have been conserved in NCGB and RCGBs in the country has been collected in the proforma supplied by NBPGR. ICNos have been assigned to 1149 accessions.

The International Board of Plant Genetic Resources has suggested descriptor lists for collection, characterization and evaluation of cashew germplasm (IBPGR,1986). This list is exhaustive and some characters may not be effectively used for characterization of the source population. Based on this Swamy *et al* (2001) have published a catalogue of minimum descriptors of cashew based on which cataloguing of cashew germplasm can be effectively done. This contains 68 data fields based on which the cashew trees are characterized.

2.2. Molecular markers for germplasm cataloguing

As the desired phenotypic characters are often highly influenced by environmental conditions, conclusions based on mere morphological data have lead to erroneous

Table 2. Data fields on which catalogue of minimum descriptors is prepared

Data number	Data field
1-6	Accessionnumber,donor name, type of maintenance etc.
7-17	Tree characteristics
18-27	Leaf characteristics
28-30	Flowering
31-35	General characters of apple and nut
36-41	Floral traits
42-50	Apple character
51-59	Nut characters
60-61	Flowering habit
60-67	Kernel characters
68	Cumulative yield

conclusions. The data obtained from such evaluation are not always based on assessment at the genetic level, often resulting in the maintenance of duplicate accessions. In this regard Random Amplified Polymorphic DNA (RAPD) (Williams and Calland, 1990) provides an excellent tool to study the genetic diversity and genetic relations and helps in identifying duplicates in a population. RAPDs were used to study the diversity in the Tanzanian cashew accessions (Mneney *et al.*, 1998). Neto *et al.* (1995) were also able to differentiate dwarfed cashew accessions using RAPD markers. Dhanraj *et al.* (2002) estimated genetic diversity among 90 cashew accessions in the National Cashew Gene Bank and found the diversity in Indian cashew as moderately to high. This could be the first step towards more efficient germplasm management of cashew in India.

2.3. Storage protein as markers to characterize cashew accessions

Proteins can be used to provide varietal profiles. These markers are ubiquitous and the variation can be understood in genetic terms. Hence, they are used and widely accepted as a source of reliable data in evolution, taxonomy and genetics. They are, thus, reflective of the genotype. Samanta *et al.* (1990) did electrophoresis (SDS-PAGE) of cotyledon storage proteins for 17 cashew varieties for varietal identification. The band patterns were compared with each other and distinct differences were observed in the presence or absence of some bands of different molecular weights. Ushavani (2002) studied electrophoretic pattern of kernel protein in 12 cashew genotypes and found that storage protein profile can be utilized for characterizing the cashew germplasm.

2.4. Status of cashew germplasm cataloguing in KAU

All the accessions of cashew germplasm maintained at CRS Madakathara have been characterized based on minimum descriptors for vegetative characters (Anon., 2002). In a study conducted at Cashew Research Station, Madakathara, 33 cashew accessions were screened with different primers and have identified 17 primers which could identify the cashew cultivars.(Anon., 2002). Ushavani (2002) studied RAPD markers as potential tool to characterize cashew germplasm.

A project on "Cataloguing of cashew germplasm of Kerala with molecular markers and digitizing the morphological data' is being undertaken at KAU with financial assistance from Kerala State Council for Science Technology and Environment. In this project, 100 germplasm accessions (50 from CRS Madakkathara, 25 from CRS Anakkayam and 25 from RARS Pilicode) were characterised with 2 RAPD markers. Twenty oligomcleopide primers were used for the RAPD study. Sixty accessions (30 from CRS Madakkathara, 15 from CRS Anakkayam and 15 from RARS Pilicode) were characterised with AFLP markers. Six primer combinations were used for the AFLP analysis. Genetic divergenic studies with AFLP and RAPD markers showed that the germplasms maintained in the three locations have unique indigenous collections.

A software named "DOCGERM" was developed for storing and utilising the morphological data of the germplasm accessions (Jayalekshmy *et al.*, 2008). This software has provision for adding new data and for selecting the accessions based on breeders' requirements. This will function as a national data base of cashew germplasm covering all the gene banks under ICAR.

This project also envisages digitizing the details of all the cashew cultivars in the germplasm available in Kerala. This can be made possible by developing software using suitable programmes to catalogue the data. This programme can make available the details of any cultivar maintained in any of the cashew germplasm.

3. Evaluation

Germplasm evaluation is an important part of variety development programme designed to utilize germplasm sources. Of the 44 cashew varieties released in the country, 25 are selections made from the germplasm

materials. These 25 varieties were identified and released based on the germplasm evaluation carried out at different centers (Table 3).

3.1. Germplasm evaluation at KAU

Germplasm evaluation has resulted in the release of five promising varieties suited to Kerala. Details are presented in Table 4.

Many of the promising accessions in the germplasm had been used for hybridization to evolve superior hybrids. These accessions are T-30, Brazil-18,T-20,K 30-1,ALGD-1,H 3-13,H-4-7and BLA 139-1. Of these accession K30-1 requires special mention, as it parented five released hybrids. This accession has very bold nut size of more than 12g (Jayalekshmy and John, 2004).

Nandini and James (1985) analyzed the yield potential of promising accessions at Anakkayam and identified seven promising accessions with good yield potential. Nalini and Santhakumary (1991) studied the performance of selected genotypes of cashew at CRS Anakkayam and identified 10 promising accessions.

Manoj *et al.* (1994) had stated variability in cashew as influenced by hybridization and found that high degree of variability existed with respect to growth parameters, floral traits and yield attributes. In studies done on growth and quality analysis of different genotypes of cashew in Northern Kerala, Naik *et al.* (1997) reported wide genetic variation among the genotypes. Variability in 18 morphological characters among 27 genotypes of cashew were studied by Pushpalatha (2000) and found high genetic variation among the genotypes.

Table 3. Germplasm selections released as cashew varieties (Rao *et al.*,1998)

State	Centres	Varieties
Andhra Pradesh	Bapatla	BPP-3, BPP-4, BPP-5, BPP-6
Karnataka	NRCC, Puttur	NRCC Sel-1, NRCC Sel-2
	Chinthamani	Chinthamani-1
	Ullal	Ullal-1, Ullal-2, Ullal-3, Ullal-4, UN-50
Kerala	Anakkayam	Anakkayam-1
	Madakkathara	Madakkathara-1, Madakkathara-2, Sulabha, K22-1
Maharashtra	Vengurla	Vengurla-1, Vengurla-2
Orissa	Bubaneswar	Bubaneswar-1
Tamil Nadu	Vridhachalam	VRI-1, VRI-2, VRI-3
West Bengal	Jhargram	Jhargram-1
Goa	ICAR R.C	Goa-1

Table 4. Characteristics of cashew varieties evolved through selection (Salam and Rao, 2001)

Variety	Parentage	Institution	Year	Yield (kg)	Nut wt. (g)	Kernel wt. (g)	Shelling %	Export grade
Anakkayam-1	T.No.139 of Bapatla	KAU Anakkayam	1982	12.00	5.95	1.67	27.99	W280
Madakkathara-1	T.No.39 of Bapatla	KAU Madakkathara	1990	13.80	6.20	1.64	26.80	W280
Sulabha(K 10-2)	Selection Kottarakkara	KAU Madakkathara	1996	21.90	9.80	2.88	29.40	W210
Madakkathara-2	Neduvellur	KAU Madakkathara	1990	17.00	7.25	1.88	26.20	W210
K 22-1	Kottarakkara Selection	KAU Madakkathara	1987	13.20	6.20	1.60	26.50	W280

4. Future Strategies

The immediate priority should be to enhance the genetic variability in the germplasm of the country. For this extensive survey has to be done periodically. Each single survey should be for single specific objective like bold nut, apple and kernel qualities, dwarfness with compact canopy, resistance or field tolerance to major pests (Tea mosquito and stem borer), earliness, yield etc. It is also suggested that introductions from Central America and Brazil should be continued which is the original home of cashew. The accessions like *A.gigantium* from Surinam which has reported to have the biggest apple (Tirimanna, 1984) and dwarf clones from Brazil (Ascenso, 1986) have to be included in the germplasm.

With regard to documentation special emphasis should be given in characterizing all the accessions with molecular markers and the existing data should be digitized and stored so that all the informations regarding the germplasm will be readily available.

For conservation of germplasm, cryopreservation and storage of excised embryos should be under taken so that the germplasm can be conserved and protected from the natural calamities.

References

Anonymous.1989.AICCIP Summary report(1987-89). Natl. Res. Centre for cashew, Puttur.

Anonymous.2001.Annual report of CRS Madakkathara, KAU.

Anonymous.2002.Annual report of CRS Madakkathara, KAU.

Ascenso, J.C. 1986. Potential of the cashew crop-1. *Agric. Intl.* 38:324-327.

Damodaran, V.K.1980. Cashewnut Research Station Anakkayam. *Cashew causerie* 20-21

De-Costa, C. 1578. *Tratodo das progase Medicinas Indias Orientais*.1964 edn. Junta de investigacoes do uttramar, Lisbon.pp.356.

Dhanraj, A.L., Rao, E.V.V.B., Swamy, K.R.M. and Bhat, M.G., Prasad, D.T. and Suresh, N.S. 2002. Using RAPDs to assess the diversity in Indian cashew germplasm. *J. Hort. Sci. Biotech.* 77(1) : 41-47

IBPGR.1986. *Cashew descriptors*. International Board of Plant Genetic Resources.

Jayalekshmy, V.G. and John, P.S. 2004. Nut component analysis in cashew. *Indian J. Plantn Crops* 32(3)

Jayalekshmy, V.G., Lawrence, P., Gopinatha, A. 2008 DOCGERM - A database of cashew germplasm - Information at the fingertip. *J. Pln Crops* 36:3:197-200.

John, P.S., Susannamma Kurien, Jayalekshmy, V.G.and Mini, C. 2003. Research and development of cashew in Kerala. Golden jubilee (1953-2003) Souvenir. UAS Bangalore, Agricultural Research Station, Ullal

Manoj, P.S., George, T.E. and Krishnan, S. 1994. Variability in cashew (*Anacardium occidentale* L.) as influenced by hybridization. *The Cashew* 8 (4): 10-13.

Mneney, E.E, Mantell, S.H., Tsokutouridis, G., Amin, S., Bena, A.M.S and Thangavelu, M. 1998. Trees for life – the key to development. Proc. of the International cashew and coconut conference held at Dar es Salam, Tanzania, February 17-21, 1997. College, University of London, Lye, Kert.pp. 108-115.

Nalini, P.V., Pushpalatha, P.B., Chandy, K.C. 1994. A special type of cashewnut sans shell liquid . *The Cashew* 8(1):15-16

Nalini, P.V. and Santhakumari, S. 1991. Study on performance of selected types of cashew at CRS Anakkayam, Kerala. *The Cashew* 5(3):3-6

Nandini, K. and James, K.I. 1985. Performance of promising types in an yield trial at CRS Anakkayam. *Cashew Causerie* 7(4):12-13

Naik, B.J., Muraleedharan, P., Latha. P. and Sujatha, K. 1997. Growth and quality analysis of different genotypes of cashew in Northern Kerala. *The Cashew* 1114: 31-36.

Neto, S.P.S., Marota, I., Taliaiwa F., Dono, K., Mastumoto, K. and Gonees, J.A.1995. Identification of cashew (*Anacardium occidenale* L.) seedlings with RAPD workers. *Acta Hort.* 370:21-26.

Puspalatha, P.B. 2000. Morphophysiological analysis of growth and yield in cashew (*Anacardium occidentale* L.). PhD. (Hort) thesis. College of Horticulture, Vellanikkara.

Rai, P.S. and Vidhyachandra, B.1981.Review of work done in cashew. UAS Res. Rev. Series No.6.pp.36

Ramdas, S. and Thatham, D.V. 1981. Variability and correlation of certain characteristics in cashew nut. *PLACROSYM* 4:229-235

Rao, E.V.V.B. 1991. AICCIP Annu. Rept.1990-91. National Research Center for Cashew, Puttur (Karnataka)

Rao, E.V.V.B. and Swamy, K.R.M.1994. Genetic Resources of Cashew. *Advances in Horticulture* Vol.9 –Plantation and Spice Crops--part 1 (eds. Chadha, K L and Rethinam, P.). Malhotra Publishing House, New Delhi. pp. 19-917

Rao, E.V.V.B., Swamy, K.R.M. and Bhat, M.G.1998. Status of cashew breeding and future priorities. *J. Plantn Crops* 26 (2): 103-114.

Swamy, K.R.M., Rao, E.V.V.B. and Bhat, M.G. 2001. Status of cashew germplasm in India. Proceedings of the XV Biennial workshop 18-20 october2001, NRCC, Puttur.

Swamy, K.R.M., Rao, E.V.V.B. and Bhat, M.G. 2001. *Catalogue of minimum descriptors of cashew*, NRCC, Puttur.

Salam, M.A. and Rao, E.V.V.B. 2001. *Cashew varietal wealth of India*. KAU.

Samantha, S.K., Das, A. and Basu, A.K. 1990. Identification of cashew cultivars by electrophoresis of cotyledon storage proteins. *Seed Res.*. 1 :.419-425

Trimana, A.S.L.1984. Prospects of cashew cultivation in Surinam. *Cashew research and development* (eds. Rao, E.V.V.B. and Khan, H.H.) Indian society for plantation crops,CPCRI, Kasargod, Kerala. pp. 249-252.

Ushavani, D. 2002 Morphological, Biochemical and molecular markers in genetic analysis of cashew. M.Sc. (Ag). thesis. Horticultural College, Vellanikkara.

Williams, J. and Calland, M.C. 1990. Fingerprinting genomes using PCR with arbitrary markers. *Nucl .Acids. Res.*18: 7213-7218

CASHEW VARIETIES

B. Jayaprakash Naik
Regional Agricultural Research Station, Pilicode - 671 353, Kerala

Introduction

The concept of the varieties in cashew is of recent origin. Cashew was primarily propagated for soil conservation and afforestation in the earlier years. Due to research efforts in different cashew growing states of India, 44 varieties have been released so far. Of these, 25 varieties are the outcome of the selection in the germplasm and 19 varieties are produced by hybridization and selection with the yield potential ranging from 1.44 to 3.80 tonnes per hectare. Early bearing and higher yield were the primary criteria for releasing a variety for cultivation in earlier days. However, in view of the demand for better kernel size and higher shelling percentage, later efforts were intensified to release high yielding varieties with bold nut size. Accordingly several high yielding varieties were released in India which contributed substantially for the productivity improvement.

1. Characteristics of high yielding varieties

A high yielding tree should have: compact canopy, intensive branching, high lateral to leader ratio, short to medium duration of flowering (45-60 days), high sex ratio, early and cluster bearing (4-6 nuts per panicle) with medium to big size nut (6-10 g), high shelling percentage (30-35%), resistance/ tolerance to Tea Mosquito Bug and high nutritive value. NRCC has standardized certain nutritive value for cashew kernels and fixed a quality index (A1-A5) which has been developed to grade the varieties. So the future strategy should include breeding varieties which have quality index of 'A' *ie.*, > 35 gm protein, lysine >50 micrograms/ mg protein and >42 gm of sugar (Rao and Bhat,1996; Nagaraja, 1987).

2. Selection

Direct selection of superior elite trees from the existing population is the first step in the improvement of cashew. Amenability to vegetative propagation is highly advantageous in the genetic improvement of cashew. The desirable plant type/ hybrid can be vegetatively multiplied for commercial cultivation. 25 varieties were released all over India by selecting the superior type from the germplasm evaluation and selection started during 1963 from different research stations. The list of these varieties with their nut yield and related characters are given in Table 1.

3. Hybridisation and selection

Even though wide variability exists in cashew, it is difficult to obtain a single tree possessing all the desirable characters. Northwood (1966) reported that even though the yields of the best tree were more than twice that of the mean, the percentage of such trees were very low and it is also necessary to consider quality. A tree which produces large number of nuts often has small nuts which are not suitable for the cashew trade. The hybridization programme can break this linkage of undesirable characters. For hybridization, the parents selected should be of proven performance and able to combine easily with other varieties and the selection should be made in the progeny which have combined the characters of desirable parents. Crosses are made among the selected plants of the best cashew progenies in order to combine specific characters with that of yield. Crosses can be made between plants of similar yields but differing in other economic attributes such as resistance to disease or to the attack of insects. The parents used in hybridization are selected on the basis of various parameters such as tree canopy, size of nut, yield, flowering phase, number of nuts/ panicle, percentage of bisexual flowers. Few germplasm accessions with certain distinct characteristics are given below:-

TPB-1 (Dwarf)

It is a natural dwarf selected from Kurumathur near Taliparamba in Kannur Dist. during 1995 (Fig. 1 and 2). It grows very short (2m height) with very short

Table.1. Details of cashew varieties released through selection

Name of the variety	Parentage	Institution	Year	Yield (kg)	Nut wt. (g)	Kernel wt.(g)	Shelling (%)	Exp. Grade
ANK-1	T No. 139 Bapatla	KAU	1982	12.00	5.95	1.67	27.99	W280
MDK-1	T No. 39 Bapatla	KAU	1990	13.80	6.20	1.64	26.80	W280
Sulabha	K 10-2 Selection	KAU	1996	21.90	9.80	2.88	29.40	W210
MDK-2	Neduvellur	KAU	1990	17.00	7.25	1.88	26.00	W210
K 22-1	K 22-1	KAU	1987	13.20	6.20	1.60	26.50	W280
Vengurla -1	Ansur-1	KKV	1974	19.00	6.20	1.39	31.00	W240
Vengurla -2	WBDC-VI (V 37/3)	KKV	1979	24.00	4.30	1.00	32.00	W320
BPP3	3/3 Simhachalam	ANGRAU	1980	11.00	4.80	1.34	28.10	W400
BPP4	9/8 Epurupalam	ANGRAU	1980	10.50	6.00	1.15	23.00	W400
BPP5	TNo. 1	ANGRAU	1980	11.00	5.20	1.25	24.00	W400
BPP6	TNo. 56	ANGRAU	1980	10.50	5.20	1.44	24.00	W400
VRI-1	Vazhisodanipalayam material	TNAU	1981	7.20	5.00	1.40	28.00	W320
VRI-2(M 44/3)	T1668 of Kattarpalli	TNAU	1985	7.40	5.10	1.45	28.30	W320
VRI-3(M 26/20	Edayanchavadi	TNAU	1991	11.68	7.18	2.16	29.10	W210
Ullal 1	Taliparamba	UAS	1984	16.00	6.70	2.05	30.70	W210
Ullal 2	3/67 Guntur	UAS	1984	9.00	6.00	1.83	30.50	W320
Ullal 3	5/37 Manchery	UAS	1993	14.70	7.00	2.10	30.00	W210
Ullal 4	2/77 Tuni-AP	UAS	1994	9.50	7.20	2.15	31.00	W210
Chintamani-1	8/46 Taliparamba	UAS	1993	7.20	6.90	2.10	31.00	W210
UN 50	2/27 Nileshwar-T No. 25	UAS	1995	10.50	9.00	2.24	32.80	W180
NRCC-1	3/28 Simhachalam-AP	NRCC	1989	10.00	7.60	2.10	28.80	W210
NRCC-2	2/9 Dicherla	NRCC	1989	9.00	9.20	2.15	28.60	W210
Jhargram-1	T 16 Bapatla	BCKVV	1989	8.50	5.00	1.50	30.00	W320
Bhubhaneshwar 1	WBDC-5 (V 36/3)	OUAT	1989	10.50	4.60	1.47	32.00	W320
Goa-1	Balli-2	ICAR.RC	1999	7.00	7.60	2.20	30.00	W210

Fig.1. The dwarf type, TPB-1

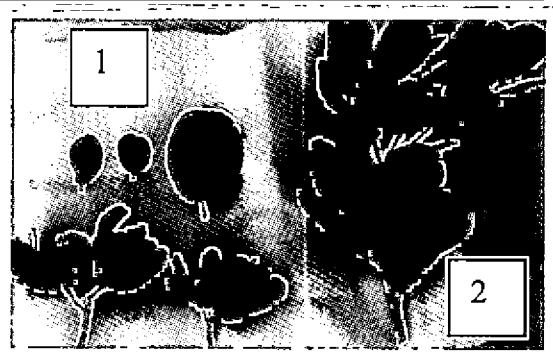


Fig. 2. Comparison of internodal length and leaf size of the dwarf TPB-1 and a normally tall plant

internodes, small leaves, dense foliage, and short and dense inflorescences.The bisexual flowers 7.8 per cent. It starts flowering very early in Ocotber and continues upto January. Fruit setting is very low (4.5 per cent) and single nut per panicle. The nut weight is 3 g and apple is small and red in colour. This dwarf is being used for hybridization with the semi dwarf, ANK 1 and the local popular variety MDK1 at RARS, Pilicode with the objective of obtaining dwarf high yielding hybrids suitable for high density planting.

KGN 1

A precocious type started bearing at seven months of age of seedlings at CRS Madakkathara in 1998. It was introduced from Brazil and bearing bold nuts. It gives

very good yield from the first year onwards and the kernel is also bold and of export quality. The accession is being evaluated with the local popular and semi dwarf types in all the AICRP centres.

Mridula (PTR 1)

The variety, a selection from the Pattannur area in Kannur district is a late season and the shell sans shell liquid. The nuts are very small (3.55g) and kernel weight is 1.38g only. Annual nut yield is only 3.31 kg per tree and hence not recommended for commercial cultivation. The apple is round and dark red in colour.

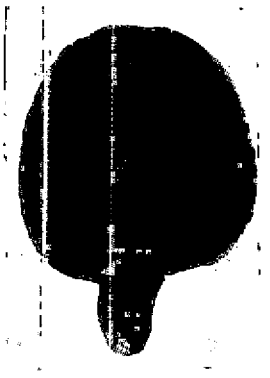


Fig. 3. Mridula

The hybridization programmes are in progress in various research stations since 1963 and different cross combinations were obtained. The released hybrids from India are listed in Table 2.

4. Varieties recommended to Kerala

Of the 15 varieties released by the Kerala Agricultural University, five were selections and ten were hybrids. Most of the varieties released are suitable for cultivation in coastal and midlands below 700m MSL.

The varietal description of the released varieties has been made. The released varieties can be grouped mainly into three groups viz., early, mid and late season types based on their time of flowering. The early types flower during October – November, the mid season in December – January and the late types during the February – March. They may again be classified into three types based on the nut size viz., Small nut types (nuts of weight below 6g), medium nut types (nut weight ranging from 6 -8g) and bold nut types (nut weight above 8g).

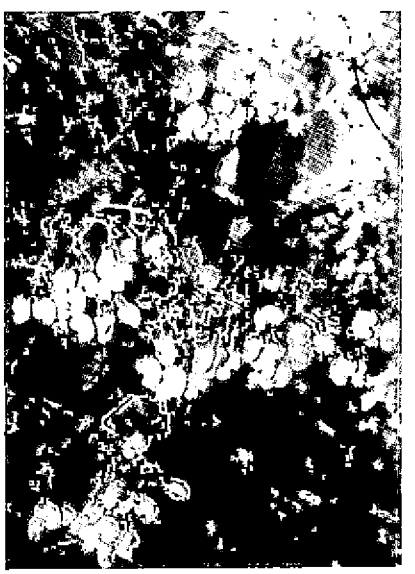
4. 1 Selections

4.1.1. Anakkayam 1

It is a selection of the tree number 139 from the Cashew Research station, Bapatla and released from the Cashew Research Station, Anakkayam in 1982. The plant is semi-tall with dense and compact canopy. A very early type starting flowering in October and nuts can be harvested during December. The flowering phase is short. The apple is small and yellowish pink in colour. The average nut weight is 5.95g and kernel weight 1.67g with the shelling percentage of 27.99. It requires 168-170 nuts to weigh 1kg and the export grade is W280. The average yield per tree is 12kg.

4.1.2. Madakkathara 1

It is a selection of the tree no. 39/A from CRS, Bapatla and released from the Cashew Research Station, Madakkathara in 1990. It is tall with dense and compact canopy. An early type, flowering in November and fruiting period extends from January to March. The apple is yellow in rind colour, juicy, sweet and excellent for processing.



Apple juice content was estimated to be 72 per cent. The average annual yield is 13.8kg per tree. It bears medium size nuts with the average nut weight of 6.2g and the kernel weight is 1.62g with the shelling percentage of 26.4. The Export grade is W280. It is a popular variety in Kerala.

4.1.3. K22-1 (Kottarakkara 22-1)

The variety was released as a selection of Tree no. 22

Table 2. Details of cashew varieties released through hybridization

Name of the hybrid	Parentage	Institution	Year of release	Nut Yield (kg)	Nut wt. (g)	Kernel wt. (g)	Shelling (%)	Exp. Grade
Dharasree (H 3-17)	T-30 x Brazil-18	KAU	1996	15.02	7.80	2.40	30.50	W240
Anagha (H-8-1)	T-20 x K-30-1	KAU	1998	13.73	10.00	2.90	29.00	W180
Priyanka (H-1591)	BLA-139-1 x K-30-1	KAU	1995	17.03	10.80	2.87	26.57	W180
Vengurla 3	Ansur-1 x Vettore 56	KKV, Vengurla	1981	14.40	9.10	2.09	27.00	W210
Vengurla 4	Midnapur red x Vettore 56	KKV, Vengurla	1981	17.20	7.70	1.91	31.00	W210
Vengurla 5	Ansur early x Mysore Kotekar 1/61	KKV, Vengurla	1984	16.60	4.50	1.00	30.00	W400
Vengurla 6	Vettore 56 x Ansur 1	KKV, Vengurla	1991	13.80	8.00	1.91	28.00	W210
Vengurla 7	Vengurla 3 x M 10/4 (Vri-1)	KKV, Vengurla	1997	18.50	10.00	2.90	30.50	W180
BPP-1	T 1xT 273	ANGRAU	1980	10.00	5.00	1.75	27.50	W400
BPP-2	T 1xT 273	ANGRAU	1980	11.00	4.00	1.04	25.70	W450
BPP-8	T1xT39	ANGRAU	1993	14.50	8.20	1.89	29.00	W210
Kanaka (H 1598)	BLA139-1 x H3-13	KAU	1993	12.80	6.80	2.08	30.58	W280
Dhana (H 1608)	ALGD-1 x K 30-1	KAU	1993	10.66	8.20	2.44	29.80	W210
Amrutha (H1597)	BLA 139-1 x H 3-13	KAU	1998	18.35	7.18	2.24	31.58	W210
Akshaya (H 7-6)	H-4-7 x K 30-1	KAU	1998	11.78	11.00	3.12	28.36	W180
Raghav (H1610)	ALGD-1 x K 30-1	KAU	2002	14.65	9.20	2.27	26.60	W210
Damodar (H 1600)	BLA 139-1 x H3-13	KAU	2002	13.65	8.20	2.00	27.27	W240
Poornima	BLA 139-1 x K-30-1	KAU	2006	14.08	7.8	2.6	31.00	W210
Bhaskara	Selection from Goa	NRCC	2006	10.70	7.38	2.2	30.60	W240

from the erstwhile Cashew Research Station, Kottarakkara by the Kerala Agricultural University in 1987. It is a tall type with dense and compact canopy. A mid-season type, flowering in December – February and fruiting during February –March. Annual yield is 13.2kg per tree and the average nut weight is 6.2g. Kernel weight is 1.6g. The shelling percentage is 26.5 with the export grade of W280.

4.1.4. Madakkathara 2

A selection from the tree no 2 in the Neduvallur estate of Kannur district, Kerala. The variety was released by Kerala Agricultural university in 1990 from the CRS, Madakkathara. It is a late season variety, flowering in January-March and comes to fruiting in February to May. It is a high yielder with 17 kg per tree and nut size is medium (7.2g per nut). The kernel weight is 1.88g with shelling percentage of 26 and export grade of W240. Apple is medium sized and pink in colour.

4.1.5. Sulabha (K 10-2)

A bold nut variety with an average yield of 21.9 kg per tree and released in 1996 by Kerala Agricultural University. It is a selection from tree no. 10 Kottarakara, Kerala. Plant is tall with compact and dense canopy. A late season variety, flowering in January – February and fruiting extends from February to April. Apple is large, elongated, juicy and pinkish yellow in colour. The average nut weight and kernel weight are 9.8g and 2.88 g respectively. The export grade is W210 and shelling percentage is 29.4. It is highly suitable to the coastal and midlands of the west coast.

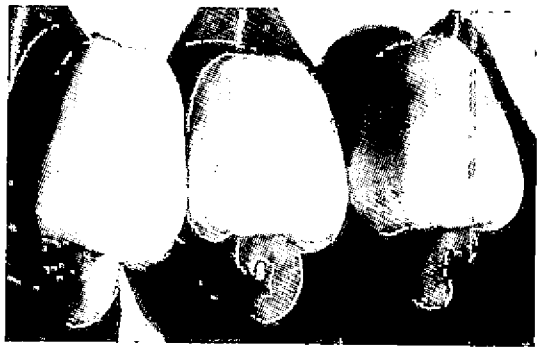
4.1.6. Vridhachalam 3 (VRI 3)

A selection released from the Tamil Nadu Agricultural University in 1991 and performing comparatively well in agro-climatic situations of Kerala. Hence it is recommended for cultivation in Kerala. It is early flowering in January and yields 11.68kg nuts annually per tree. The nut size is 7.18g and kernel weight is 2.16g with a shelling percentage of 29.1 and export grade W 210. The apple is reddish pink in colour. Tree shape is compact with dense branches.

4.2. Hybrids

4.2.1. Kanaka (H 1598)

It is a hybrid between BLA 139-1 and the hybrid H3-13



and was released by the CRS, Madakkathara in 1993. The tree is tall with open canopy and intensive branching. The hybrid is early flowering in November-December. The fruiting season is December to March. Annual yield is 12.8 kg per tree. The nut size is medium (6.8gm per nut) with high shelling percentage. The kernel weight is 2.08 with the export grade of W280. The apple is round and yellow in colour.

4.2.2. Dhana (H 1608)

The hybrid was released for cultivation in 1993 by the KAU. It is a hybrid between the high setting exotic type from Brazil and a bold nut type (ALGD -1 x K 30-1). The tree is tall with dense canopy and flowers in December–January as a midseason type. Apples are yellow in colour and highly juicy (72%). Nut yield per tree is 10.66 kg and the nuts are bold with 8.2 gm. The shelling percentage is 29.8% and kernel weight is 2.44g with export grade W210. It was released for cultivation in national level as it performed well in all the AICRP cashew centres.

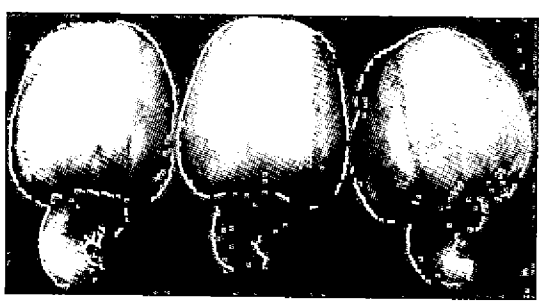
4.2.3. Priyanka (H 1591)

It is a hybrid between BLA 139-1, a high yielding and high setting type and K 30-1, a very bold nut type. The hybrid was released in 1995 from CRS, Madakkathara and recommended for cultivation in all the cashew growing tracts in India. It is a mid-season type, flowering in December-February with an average yield of 17.03 kg per tree per annum. The nuts and kernel are very bold, 10.8g and 2.87g respectively. Usually ninety-three nuts could weigh one kg. The shelling percentage is 26.57 and export grade is W180. The tree is having open canopy and dense branching habit. A very popular variety in Kerala.

4.2.4. Dharashree (H 3-17)

The hybrid was released in 1996 from CRS, Anakkayam. It was developed as hybrid between the tree no. T 30 and Brazil 18, a bold nut type from Brazil. The tree is having sprawling branching habit and compact canopy. Flowering is in mid-season (December-January) and fruiting in January–March. Apple is yellowish pink in colour. Annual nut yield is 15.02 kg. The nut size is medium (7.8g) and kernel weight is 2.4g. Export grade is W240 and shelling percentage is 30.5.

4.2.5. Amrutha (H 1597)

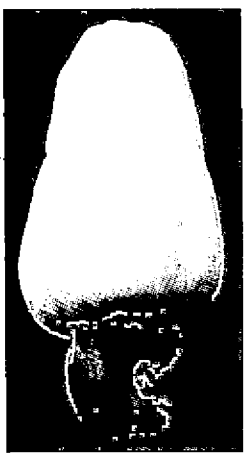


It is a mid-season hybrid released in 1998 from CRS, Madakkathara. Parents of this hybrid are BLA 139-1 and H 3-13. The tree shape is sprawling type with low branches and starts flowering during December – January. The average annual nut yield is 18.35 kg per tree. Nuts are medium sized (7.18g) and kernel weight is 2.24g with the shelling percentage of 31.58 and export grade W210. The apple is juicy (72.2%) and yellow in colour.

4.2.6. Anagha (H 8-1)

A hybrid with very bold nut and kernel, released from the CRS, Anakkayam in 1998. The parents are tree no. 20 and K 30-1. The tree is with compact canopy and dense branches and flowering is in January-February. The apple is reddish orange in colour. Annual nut yield is 13.73kg per tree and nut weight is 10g. The kernel is bold (2.9g) with a shelling percentage of 29 and export grade W180. The hybrid is recommended for coastal and midlands of Kerala.

4.2.7. Akshaya (H 7-6)



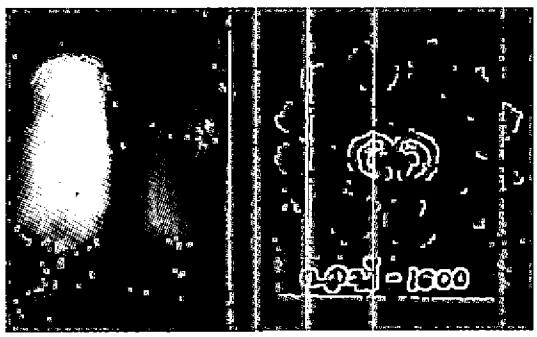
This is a hybrid between H 4-7 and the bold nut type, K 30-1. The tree has compact canopy with dense branching. The hybrid is mid-season and starts flowering in December – January. Apple is yellow in colour. Average nut yield is 11.78 kg per tree per annum. The nuts are very bold (11g) and the kernel weight is 3.12g. The shelling percentage is 28.36 and export grade W180.

4.2.8. Raghav (H 1610)

It is a hybrid between ALGD -1-1 and K 30 -1 released from CRS, Madakkathara in 2002. The tree is tall with compact canopy and flowering is in January to February. Nuts are harvested in March –April. Annual nut yield is

14.7 kg per tree. Nut weight is 9.2g and kernel weight is 2.27g per nut with export grade of W 210. Shelling percentage is 26.6. The apple is yellow in colour with 68 per cent juice.

4.2.9. Damodar (H 1600)



The hybrid was released in 2002 from CRS, Madakkathara. It is a cross between Anakkayam and H 3-13 and midseason flowering (December to January). The nuts can be harvested during February to March. The tree is tall with profuse branching and dense canopy. The tree trunk is smooth and slightly tolerant to stem borer. The average annual yield is 13.4 kg per tree with nut weight 8.2g and kernel weight 2g (export grade 210). The shelling percentage is 27.3. Apple colour is red with 68 per cent of juice. It is highly suitable to northern Kerala.

4.2.10. Poornima (H 1593)

Poornima (H 1593) was released from CRS, Madakkathara during 2006. It is a cross between BLA 139-1 and K-30-1. This hybrid, with upright and compact tree habit, has intensive branching. It has mid-season (December-January) flowering behaviour. The mean annual yield of the variety is 14.08 kg/tree. It has the desirable nut characters like high nut weight (7.8 g)

high kernel weight (2.6g), high shelling percentage (31%) and good export grade (W 210) suitable for industry. It is moderately susceptible to tea mosquito bug. This hybrid has desirable apple attributes like apple-nut ratio 9.01), juice yield (75.3%), TSS (13.3%), acidity (0.38%), ascorbic acid content (221.7/100g) and phenol (0.61%).

5. Indices of selection

Even though there is a wide range of variation in respect of most of the economic characters in the existing populations, it is rather difficult to find a single tree, possessing all the desirable characters in a high degree. Breeding of perennial crops is laborious, time consuming and present many technical problems. The trees are highly heterozygous and the selection of parent trees for specific economic characters does not ensure that the progeny having the desired character can be obtained in the F1 or F2 with any degree of precision. However since cashew can be propagated by vegetative means selection can be made in the F1 or F2. The strategy in the breeding programme for cashew will be to make crosses involving as many parental combinations as possible, having the desired characters, make a rigorous screening in the F1 or F2 and multiply the selected progenies by vegetative methods. Unlike in many other crops, we have very little information on the stable characters on which we can rely upon for selecting the desired genotype. However, based on the observations made so far, the following characters may serve as effective indices of selection.

1. **High yield with bold nuts :** Cashew being primarily export oriented crop, it is necessary to give utmost priority for developing varieties and hybrids with export grade kernels.

2. **Dwarf and compact canopy:** To facilitate high density planting.
3. **Short flowering phase:** The chances of loosing crop due to pest infestation are based on the phenological events and the cost of collection of nuts will also be reduced.
4. **High sex ratio:** Adequate care should be exercised in selecting the trees with high bisexual flowers. Recent studies have emphasized the importance of staminate flowers to provide more efficient pollens. So the trees with mixed phase and also high sex ratio are to be preferred as parents over types, which have distinct male phase and hermaphrodite phase.
5. **Breeding for tea mosquito resistance:** One of the production constraints in cashew is the severe incidence of tea mosquito bug in some areas. So production of varieties field tolerant to tea mosquito bug needs priority.
6. **High shelling percentage:** As the economic produce of cashew is the cashew kernel, priorities of industries also should be considered. Processing industries look for high recovery of whole kernels, which fetch higher export value. Currently, for release of any variety, the standards fixed stipulate that a minimum of 28% shelling percentage should be recorded.
7. **Nutrient quality index:** In order to have a competitive edge, we need to develop varieties with high nutritive value.

References

Bhaskara Rao, E.V.V. and Bhat, M.G. 1996.Cashew breeding achievements and priorities. Proceedings of the seminar on crop breeding in Kerala. University of Kerala. 47-53

Nagaraja, K.V. 1987. Proteins of high yielding varieties of cashew. Plant food for human nutrition. 37;69-75.

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

PROPAGATION TECHNIQUES AND NURSERY MANAGEMENT

C. Mini
Cashew Research Station,
Kerala Agricultural University, Madakkathara – 680 651, Kerala

Introduction

Trials to standardize an effective method of propagation for cashew have attracted the attention of a number of research workers in the past and studies were initiated from the very beginning of the cashew research programmes in the country. Various methods have been tried with varying degrees of success under different agro- climatic conditions.

I. SEED PROPAGATION

Being a highly cross pollinated crop, seed propagation will result in a widely varying population. Under seed propagation the approved practice is to collect fully ripe medium sized nuts from trees of proven yield potential.

Another practice of seed propagation followed in some cashew growing areas of Kerala has been described by Pillai and Thomas (1977). The unripe green nuts are plucked from the mother trees along with the apple about 2 weeks prior to its expected date of maturity and are dried above fireplace over a period of 3 to 4 weeks, during February- March. Towards the onset of the South- West monsoon, two dried seed nuts are dibbled *insitu* in partly filled up pits and in due course only the healthier seedling is retained. They have reported that the settlers in Malabar from erst- while Travancore used to collect such nuts in large quantities from Kottayam region for establishing cashew plantations in the Calicut and Kannur districts.

Selection of ideal mother tree

The amount of variation exhibited by seedling progenies in a plantation in respect of morphological and economic characters are observed to be very high. Hence much emphasis has to be given for the selection of ideal mother trees wherever seedling propagation is resorted to.

An ideal mother tree should have 15-25 years age, good health, vigorous growth and intensive branching habit with panicles bearing higher percentage of hermaphrodite flowers. Mother tree should bear nuts of medium size and weight (5-8 g/nut) with average yield of 15 kg nuts per annuum.

Performance analysis was made relating to economic characters of about 500 seedling progenies of Tree No. 20 of the Cashew Research Station, Anakkayam, which had an average yield of 30 kg nuts with an average nut size of 3.5g during their first six years of orchard life (Veeraraghavan and George, 1982). There was considerable variation in respect of morphological characters, early yield, nut yield, nut size etc. The study revealed that the performance of trees in the first 5 to 6 years of orchard life in a plantation will give an indication of their future yielding behaviour. They suggested that it is desirable to remove trees which yield below 500 g of nuts in the sixth year of orchard life and those exhibiting alternate bearing nature.

Selection of seed nuts

The fallen nuts are separated from the apple during March- April. Moisture content of harvested cashew nut will be as high as 15-20%. High moisture content causes deterioration of the kernel due to mould, bacteria or enzyme action. Affected nuts may also loose their nutty taste, aroma and also quality. The harvested nuts are dried in sun for two to three days. If the nuts are to be stored, they are dried to attain a moisture level of 8-9%.

A digital moisture meter that can read upto 20% moisture, has been developed by CPCRI, Kasaragode to estimate the moisture content of raw cashew nut. Its salient features are non-destructive testing, direct display in percentage, good repeatability, accuracy and compactness in size and weight (Madhavan, 1998).

Good, mature and medium sized nuts, which sink in water, after drying in sun are selected as seed nuts. The

recommended practice is to soak the seed nuts in water for 18-24 hours to hasten germination. A trial conducted at Cashew Research Station, Kottarakkara with water-sinking and water-floating seednuts to find out the difference in germination and the time taken for the same, revealed that 92% of the heavy nuts germinate within a period of 14 to 17 days while water-floating nuts recorded only 64% germination within a period of 14- 22 days (Anon, 1962).

Veeraraghavan and Pushpalatha (1988) suggested the guidelines for raising and supply of elite seedling material. The seedlings are raised in polythene bags of 20 cm × 15 cm, filled with garden soil leaving a gap of 1-1.5cm above soil during May. The presoaked seed nuts are sown at a depth of 2-3 cm with stalk end up and the seeds germinate in seven to ten days.

Seed viability

Seed viability is an important factor which controls the vigour of the seedlings and their subsequent performance. A study conducted at Kottarakkara (Anon, 1962) to determine the period of viability of seed nut under metallic bin storage revealed that there was progressive decrease in percentage germination as the period of storage increased and the germination was less than 50% after the 6th month.

The study undertaken at the College of Horticulture (Aravindhakshan and Gopi Kumar, 1979), Vellanikkara indicated that the germination percentage was highest during the first month after harvest and the viability will be lost completely after 12 months of storage at room temperature. Different types of cashew behaved differently in the period of retention of viability (Table 1). Mini and Mathew (2008) found that cashew seeds could be effectively stored upto 13 months with more than 70 per cent germination by priming with 5000 ppm thio urea for 24 hours at ambient temperature.

Standardization of seedling selection technique

Height, girth, number of primary branches and internodal length are the most important morphological characters which contribute to seedling vigour in cashew. Two to three months old healthy tall seedlings with good girth and more number of leaves can be selected for planting, rejecting the less vigourous and diseased ones.

A study conducted at Kottarakkara to find the selection index for seedlings in the nursery stage, by correlating the size, weight, volume etc. of nuts to seedling vigour, precocity, yield and other economic attributes revealed that weight, volume, L/B ratio of nuts were positively correlated with seedling vigour. Larger sized heavy nuts produce vigorous healthy seedlings in the nursery. Selection of nuts based on nut characters alone was not dependable for getting uniform seedlings. However the data from the study indicated that the weight of nuts has a positive correlation with height and number of leaves in seedlings and negative correlation with girth and internodal length of seedlings (KAU, 1978).

High variation was recorded in different morphological characters like height, girth and internodal length between different types of cashew in the nursery at Vellanikkara conditions (Gopikumar and Aravindakshan,

Table 1. The germination percentage of different types of cashew at monthly intervals

	Germination percentage at different months of storage												
Types	1	2	3	4	5	6	7	8	9	10	11	12	13
T-20	83	80	80	75	70	56	49	41	31	11	6	2	0
Anakkayam-1	91	92	89	85	83	72	71	62	43	3	0	0	0
BLA-256-1	91	89	76	70	70	66	60	62	21	19	9	0	0
BLA-1	71	70	69	71	69	63	59	56	41	18	0	0	0
Ansur-1	89	80	75	74	70	69	59	32	20	17	0	0	0
K-27-1	71	70	71	70	63	62	60	37	17	10	0	0	0
Sawantwadi	86	80	78	76	76	15	16	10	9	2	0	2	0
M-6-1	94	80	72	63	60	37	30	10	10	8	0	5	0
Vridhachalam-1	97	96	89	69	67	60	54	32	22	21	10	0	0
Vengurla-36-3	94	69	68	43	40	40	38	32	22	20	8	0	0
Mean	86.7	80.6	76.7	69.6	66.8	54	49.6	36.4	23.6	12.9	3.3	1.4	0

1979). Compared to variation between different types, variation within a type was low. Open pollinated seeds from 10 types, T-20, BLA-1, Vridhachalam-1, Anakkayam-1, Vengurla 36-3, K-27-1, Ansur-1, BLA 256-1 Sawantwadi and M-6-1 were used for the study.

A study was conducted to estimate the growth rates in respect of characters like height, girth, primary branches and internodal length of seedling and indicate the relative growth habits of the different types of cashew grown under similar conditions in the nursery (Gopikumar *et al*, 1979). Analysis of the mode of growth of a particular character of a type was based on the mean of the values of that characters measured at each specified age point. As the logistic growth function gave a poor fit to the data, the linear growth model, expressed in the following form was used.

$$Y = a + bt$$

Where Y = Amount of growth of a character under study
a = Positive intercept
b = Constant rate of weekly growth
t = Age of the plant, 0,1.....8

The linear model gave a good fit to the data as coefficient of determination (R_2) were relatively huge in all cases. The prediction equation can be used to find the expected growth of cashew plants of different types at specific age points under ideal conditions.

Precocity in seedling cashew

Early flowering is a desirable character counted upon in tree crops. Vidhyadharan and Aravindakshan (1977) recorded an unusual case of precocity in one seedling of cashew out of 200 seedlings in the nursery maintained at Cashew Research Station, Madakkathara. The seedlings flowered 8 months after sowing, produced one inflorescence and out of the two fruits set, one was carried to maturity. The seedling was 63 cm height and possessed four branches at flowering. It indicates that early flowering is a type character and indicates the possibility of selecting plant types for this character.

II. VEGETATIVE PROPAGATION

Vegetative propagation helps to transfer the desirable characters of the mother trees to their progenies. It has been observed that the progenies clonally propagated are true to type to their mother tree in morphological and economic characters as compared to the seedling progenies of the same tree. Any method of vegetative propagation can be said to be successful only when the planting materials so obtained gets established well in the field after planting. Hence detailed studies were undertaken from 1974 onwards at Cashew Research Station, Madakkathara and also at Kerala Agricultural Development Programme to develop a technique for a quick and large-scale multiplication method for vegetative propagation. In the trials conducted in the early years, budding, side-grafting or propagation by cuttings did not succeed (Anon, 1962).

Though successful results have been reported from Amsterdam, propagation by cutting was not successful in the trials conducted in India.

A. Air layering

Air layering has been found to be the easiest, cheapest and best method of vegetative propagation in cashew at Thaliparamba. But at Kottarakkara only 45 per cent success could be obtained (Anon, 1954). There were reports of the cashew layers excelling seedlings in growth, flowering and fruiting (Nayar and John, 1958; Kurup and Viswanathan, 1970) and having better root and shoot systems, compared with the seedlings of the same age (Damodaran, 1968). Successful air layering was also reported by Abraham (1956) and Damodaran (1970).

Method

Pencil-thick terminal shoots of 9-12 months old are selected and a strip or ring of bark 0.6-1.2 cm thick is removed by using a sharp knife carefully without injuring the underlying wood. Wind a string around the cut area and cover it with moist moss or wood shavings or sand and saw dust mixture or ordinary potting mixture and wrap round with 150-200 guage polythene film of size 23 x 15 cm. Secure loose ends of film with jute fibre. When roots begin to emerge from ringed portion in 40-60 days give a "V" cut at lower end of treated shoot. After about 15 days deepen the cut slightly. Cut and separate rooted shoot about 7 days later. Pot the layers immediately after separation from the tree in containers of size 15 x 15 cm made from coconut husk and keep them in shade. Avoid excessive amount of watering. Plant the layers along with the container in the prepared pits during the onset of SW monsoon. It is advisable to defoliate the layers two weeks before separation from the mother plant (KAU, 2003).

Though this was the simplest, cheapest and successful method of propagation as far as rooting is concerned the main draw back experienced with air- layers was their very poor field establishment. In order to find out whether the rooting of air layers can be improved and thereby the percentage of survival after separation enhanced, different trials were conducted (K AU, 1979)

a. Effect of different rooting media

To ascertain whether any media other than the commonly used saw dust + sand medium could promote higher percentage of rooting of air layer and to ascertain whether the high percentage of post separation mortality can be minimized by changing the potting media and containers, a trial was done at Madakkathara (Veeraraghavan *et al.* 1983). Sand and saw-dust (50 : 60), wood shavings, coarse and fine vermiculite were compared and there was no significant difference between the four media tried.

The suitability of another set of rooting media was evaluated using sand + saw dust in equal proportion, sphagnum moss, wood shavings, sand + rock phosphate + saw dust and wood shavings + saw dust. The containers like coconut husks and paddy straw, made of materials with the property of natural disintegration were compared with ordinary polybags. The use of decomposable containers particularly coconut husk pot was proved to be a promising nursery technique for minimizing mortality and obtaining maximum survival of layers in the main field. Different potting mixtures like coconut pith and wood shavings along with common potting mixture were evaluated. Wood shavings with 42.5 percent success and sphagnum moss with 40 percent success rate were significantly superior to the other treatments (KAU, 1978). Ordinary potting mixture in polythene bag is the cheapest and was recommended for large scale production of air layers on economic basis.

b. Effect of plant growth regulator on the rooting and subsequent establishment

Three commonly used root inducing growth substances, viz. Indole-3-acetic acid (IAA), Indole-3-butyric acid (IBA) and L-Naphthalene acetic acid (NAA) each in concentrations of 1000, 500 and 250 ppm were applied in the form of lanolin paste over a width of about 1/2 inch just above the ringed portion.

IAA in concentration of 250 ppm had favourable effects on rooting of air layers, gave the highest percentage of rooting (94) and subsequent sprouting of the layers (74), eventhough the differences were not significant. However, there were significantly larger number of roots per layer (9.74) and the average length of roots was higher (3.62) under the above treatment as compared to the rest. Besides, the number of days from layering to root emergence (16) was also less (Aravindakshan *et al,* 1986).

In another experiment, treatment with IBA 250 ppm and NAA 500 ppm produced the maximum number of rooted air-layers. Treatment with IBA 250 ppm was the best treatment in respect of the mean length of roots while IBA 500 ppm produced the maximum number of roots per layer. The highest percentage of establishment was recorded by layers treated with IBA 500 ppm (Valsalakumari, 1978).

c. Effects of age of parent tree and the type and thickness of shoot

Age of the parent tree has apparently no effect on the extent of rooting of cashew air layers. However, non-flowered shoots gave a significantly higher percentage of rooting than flowered shoots.

The effect of thick-shoots having a girth of 4 cm and over, medium shoots having a girth of 3-4 cm and thin shoots having a girth of below 3 cm was studied. Thick shoots produced a larger number of roots per layer and the layers produced from thick shoots were found to be more vigorous in the first year of its growth in the field (Anon, 1962).

d. Effect of different grades of polythene film

Effect of polythene films of 200, 150 and 100 gauge thickness on layering was studied. Besides collecting data on the extent and intensity of rooting, observations were made on the damage to film from birds, insects etc. and also on the penetration of roots through the film. The results revealed that 200 gauge film was superior to others in respect of the average length of roots per layer. Films of 150 gauge and 100 gauge were easily damaged by birds, insects etc and a minimum thickness of 200 gauge seems to be necessary for layering purposes (Veeraraghavan *et al,* 1983).

Trials on the use of alkathene film for layering instead of gunny piece showed that the film considerably reduced

the time needed for rooting, besides avoiding the daily moistening of the layered shoots in the case of gunny wrappers. The layers were ready for separation in about 3 months time from the date of layering.

e. Effect of defoliation

A trial was conducted to find out whether defoliation of air-layers before separation from the mother plant had any effect on the survival of the layers after separation. Defoliation of air-layers, two weeks prior to separation, had a beneficial effect on survival and successful establishment after separation (Anon, 1962).

f. Effeet of season

November to April was considered as the best season for air-layering in cashew, giving 80 to 100 percent success (Anon, 1962).

The best period for air-layering in cashew was from February to April under Kerala conditions, which coincided with the period of maximum number of shoots in flush on the trees. These months of layering had the added advantage that the layers will be ready for planting out in the field in June and July which are the most suitable months for planting. The lowest percentage of rooting was obtained in July. Percentage of rooting was significantly and positively correlated with the number of shoots in flush on the tree at the time of layering (Valsalakumari, 1978).

g. Correlation of air layering with weather parameters

Rooting was positively correlated with mean maximum temperature and negatively correlated with total rainfall. The establishment of layers was higher in the case of layers planted directly in the field during the high rainfall months of June and July. A significant positive correlation existed between the percentage of establishment of air–layers and the rainfall (Valsalakumari, 1978).

h. Comparative study of the root system of layers and seedlings

Layers and seedlings of four different age groups viz., 6 months, one, two and three years were compared in respect of their shoot and root-growths. The layers had a better root system than the seedling plants of same age. The shoot growth also is better in the case of layers than the seedling plants except in respect of height (Anon, 1962).

i. Transport of layers

Transport of layers is an important aspect to get success in establishment in main field. Layers transported directly, immediately after separation established better than pre- potted layers used after long transport and planted. To avoid transport shock, it is advisable to pack the layers tightly in boxes, filled to half height with moistered sawdust. In this way, large number of layers could also be transported (KAU, 1983).

B. Patch budding, veneer grafting and approach grafting

Month-war trials on *inarching or approach grafting* tried at the Kottarakkara station using four months old seedlings as rootstock indicated that July to October is the best period for this method. Considering the fact that June-July is the best season for planting, it was reported that the grafting can be done in January- February (Anon, 1962).

Veneer grafting and budding trials conducted at monthly intervals resulted in maximum success during June to September, the percentage being 56 in veneer grafting and 84 in patch budding in June (Valsalakumari, 1978). The advantage claimed for budding is the economy in scion material as compared to the other methods. This is true only to a limited extent, as the buds in the terminal portions of the twigs are too close to separate them while taking out. For veneer grafting, rootstocks of below six months old would be successfully employed. Studies at Mannuthy showed 60-80 per cent success by side grafting in July-August under nursery conditions (Anon, 1978). The monsoon season commencing from June to September was identified as the best season for side grafting at Anakkayam in Kerala (KAU, 1978). The result of success of veneer and side grafting reported were based on nursery conditions which were congenial.

Wedge grafting on eight month old cashew seedlings gave 70-75 per cent success in February-March under humid chamber conditions. Valsalakumari (1978) opined that the method needed further modification for adoption on large-scale multiplication.

C. Epicotyl grafting or stone grafting

Preliminary studies revealed that epicotyl grafting is a successful method of propagation as compared to other methods like patch budding, side grafting and veneer

grafting. In epicotyl grafting 8-10 day old tender seedlings are used as rootstock.

The highest percentage of success was during the month of August (30.66 per cent) followed by September (22 per cent), May (21 per cent) and March (18.66 per cent). The period October to December was most unsuitable for stone grafting condition under Vellanikkara (Shylaja, 1984).

When the success of graft union was correlated with weather parameters such as quantity of rainfall, number of rainy days, maximum and minimum temperatures and relative humidity, it was found that there was no correlation between the various weather parameters tested and the percentage of success.

Among the grafting methods tried, cleft method recorded significantly higher percentage of success (15.97 per cent) compared to splice method (12.12 per cent). In cleft method, root stocks were decapilated four cm above the cotyledons and perpendicular cut was made in the centre of the stocks about three cm long. The precured scion shoots were given slanting sharp cuts on either side and inserted into the cleft of stocks. In splice method, scion was given a slanting cut of four to six cm on one side and a similar cut on the top of the stock seedling.

Defoliation of scion shoots ten days before the grafting operation recorded significantly higher percentage of success of 20 per cent than five days precuring and control, where the percentages of success were only 14.13 and 8.25 respectively. The percentage success of grafting under open condition was significantly higher than that under mist. It was found that ten days and five days old rootstocks were equally good and 15 days old rootstocks were least suitable. Stock and scions of the girth 2.1 cm to 2.4 cm was better than those of above 2.4 cm. Scions of length 8.6 cm to 10.5 cm was better than those with a length of 4.5 cm to 6.5 cm, 6.6 cm to 8.5 cm and above 10.5 cm (Shylaja, 1984).

Detailed studies on epicotyl grafting were undertaken under Multi State Cashew Research Project to find out the best season, possible varietal response and stock-scion compatibility (KAU, 1983).

The scion shoots of 4 months old were pre-cured 10 days prior to grafting to ten days root stocks. Epicotyl grafts were prepared at monthly intervals to find out the appropriate time for grafting under Kerala conditions. The varietal behaviour was determined using the scion wood selected from six cashew types viz. Anakkayam-1. Madakkathara-1, H-3-17. H-3-13, K-22-1 and Madakkathara-2.

The method was successful in all the six types tried and an overall average success of 69.3 percent could be obtained. Among the types tried, the types BLA-39-4, BLA-139-1 and K-22-1 recorded maximum percentages of success, amounting to 81.17%, 77.16% and 71.61% respectively. Stock-scion compatibility studies revealed that no varietal difference exists. The type Anakkayam-1 is found to be a better root-stock and scion compared to other types, as it gave maximum percentage of success (75-77%). Anakkayam-1 and Madakkathara-1 when grafted on their own rootstock gave maximum percentage of success, indicating that even the mixed seeds can be used for raising the rootstocks. There is scope for large scale multiplication of BLA-139-1 type adopting this method considering the poor performance of this shy rooting type when air- layered. The summer months from March to May were considered conducive for epicotyl grafting under Kerala conditions.

Though a grafting success of 80% could be obtained initially, epicotyl grafts were more vulnerable to collar rot disease in the later stages after sprouting, resulting in higher percentage of mortality.

D. Soft wood grafting

Among the different grafting techniques tried, softwood grafting has been found to be the most ideal under Kerala conditions considering its high percentage of success and the easier methodology involved.

Raising rootstocks : To obtain maximum success in softwood grafting, more emphasis is to be given in selection of ideal seedlings as rootstock. An ideal rootstock variety is the one which will give maximum number of uniform seedlings based on seedling vigour, growth and other characters required for grafting.

Seed nuts are selected during the peak period of harvest (February-March) and sun dried for 2-3 days. Fresh good quality nuts are selected by immersing in water or 10%

saline solution. Medium sized (7-9g) nuts, which sink in water may be selected to get vigorous seedlings.

Polythene bags of size 25 cm x 15 cm and 300 guage thickness are taken and about 16-20 holes are punched on the bag to ensure good drainage. Potting mixture (1:1:1 red soil: river sand and compost) mixed with rock phosphate @ 5g per 2kg potting mixture is filled in the bag and the pre soaked nuts are sown with stalk end up, at a depth of 2-2.5 cm. Nuts usually germinate within 15-20 days after sowing during monsoon months and within 8-10 days during summer months. Select healthy seedlings having single main stem as the rootstock.

Studies were conducted at Madakkathara to identify suitable varieties/types that will serve as the best rootstocks. When the seedlings were 25 to 30 days old, softwood grafting was done using Anakkayam-I as the common scion. Observations on the sprouting of the grafts recorded at an interval of 15, 21 and 30 days after grafting revealed that under Madakkathara conditions, Anakkayam-1 and BLA 273-1 are the ideal rootstock varieties followed by Madakkathara-1 and H-3-17 was inferior as a rootstock. The added advantage of Anakkayam-1 and BLA 273-1 are their early harvest during February- March. It was concluded that if large scale production of grafts are attempted on these two cashew types during March- April, sufficient number of grafts could be made available to the farmers during June-July which are the ideal months for planting under Kerala conditions (Pushpalatha *et al.*, 1991).

The nursery experiment conducted by Joseph *et al* (2002) to study the effect of biological or chemical agents and soil solarization techniques on growth and vigour of rootstocks revealed that sowing of cashew seeds in solarised potting mixture or in potting mixture prepared with solarised soil or in solarised soil added with farmyard manure containing *Trichoderma harzianum* can result in the production of healthy and vigourous rootstock.

Dwarfing rootstock

Evolution of dwarf cashew types is becoming necessity of the day. Attempts were made (Usha *et al*, 1996) to correlate different parameters like bark percentage, phenolic content, number of stomata with growth and vigour of seedlings and thus to screen the dwarf types. The study revealed that nut weight, height, girth and inter nodal length of seedlings are less in less vigorous types. The number of stomata is more in vigorous types. Phenolic content in leaves and bark percent in stem and root were higher in less vigorous types than that of vigorous types. The approach of using seedlings for root stock after morphological and anatomical screening will considerably reduce the time in searching for the dwarfing rootstocks.

An experiment conducted to study the effect of gamma irradiation on producing dwarfing root stock revealed that irradiation of nuts at 10 KR stimulated the growth of seedlings (Salam *et al.* 1992) where as radiation dozes above 20 KR suppressed the seedling growth, but encouraged branching. Dwarfism was observed in seedlings produced from nuts irradiated at dozes of 40 to 60 KR. The LD 50 value for cashew nuts is found between 40 and 50 KR and beyond 60 KR cashew seeds will not germinate.

Selection of scions

A high yielding variety of cashew is selected as mother plant to collect adequate number of 3-5 months old non flowering lateral shoots of current season's growth as scion. For successful grafting operation in softwood, the rootstock and scion should be in the proper physiological stage.

Five commercial varieties viz. Anakkayam-1, Madakkathara-1, K-22-1, H-3-17 and NDR-1 were compared to assess their performance as scion material using four different lengths viz 10, 12.5, 15 and 20 cm. Healthy and vigorous seedlings of the variety Anakkayam-1 were used as rootstock. Anakkayam-1, Madakkathara-1 and H-3-17, which recorded high percentage of sprouting and survival were identified as the most suitable scions and the ideal length of scion was between 10 and 12.5 cm.

Effect of rootstocks of 21, 28, 35 and 42 days old and precuring scion for a period of seven and 14 days were tried on the success of grafting. 100% sprouting and 100% survival were obtained when 28 days old rootstock and 7 days precured scions were used for grafting (Pushpalatha *et al.*, 1991).

Studies on the effect of scion storage on softwood grafting carried out at Madakkathara during 2003 and 2004 revealed that high success of grafting (81.3%) could

be achieved, even after storing the scion for a period of ten days, by keeping a wet cotton at the cut end and wrapping in newspaper. This method of scion storage facilitates easy and economic storage and transport of scions to distant places (Mini *et al.*, 2006).

Grafting

Two pairs of bottom leaves are retained on rootstock after removing the other leaves. A transverse cut is given on the main stem 15 cm above ground level, a cleft of 4-5 cm deep is made in the middle of the decapitated stem of rootstock. The cut end of the matching scion stick is shaped to a wedge, and inserted into the cleft of the rootstock. After grafting, the grafts are to be covered with a wet polythene cap of 15 x 12.5 cm and tied at the bottom to maintain humidity inside. 20-25 x 3 cm size wet sip-up covers can also be used, but it should be wetted once in three days to maintain humidity.

A study conducted to find out the effect of humidity and temperature, through a mist chamber, with 87-90% RH and temperature 23- 27 °C revealed that keeping grafts in a mist chamber has positive influence to increase the graft take by reducing the time taken for sprouting and enhancing the success percentage of grafts (Pushpalatha *et al.*, 1993).

Nursery management

The grafted plants are to be watered regularly using a rose can or micro sprinkler. New sprouts emerging from rootstock and panicles, if produced are to be removed at frequent intervals. The grafts are to be frequently shifted from one place to another to prevent them from striking roots into the ground. Proper control measures should be done against pest and diseases (KAU, 2003).

Graft production under polyhouse

Softwood grafts can be prepared almost throughout the year with a mean graft success of about 60-70%. Higher success is achieved during the monsoon season. Low cost polyhouses can be prepared from casuarinas/ bamboo poles/ areca reapers/ GI pipes/ PVC pipes and covered with high density polythene sheet of convenient dimensions, preferably 20m long and 6m wide. The height of the polyhouse should be 2.5m in the middle and 1.0 m on both sides. The plants may be watered using hose. Misting units can also be fitted at appropriate points and switched on for about 5-10 minutes at an interval of two hours from 10 a.m to 6 p.m during summer season to reduce the temperature build up inside the polyhouse. Raising of rootstock seedlings, grafting of rootstocks and maintenance of grafts can be done inside the polyhouses. These polyhouses give protection to the seedlings and grafts during heavy rains and reduce the mortality. During summer months the seedlings/ grafts can be maintained in these polyhouses by covering with HDPE shade nets of 35- 50% shade.

Economic analysis of graft production

The quantum of resources required for a cashew nursery with a target of production of one lakh cashew grafts per year wais worked out (Joseph and Jayalekshmy, 2002). An amount of Rs. 14.3 lakhs is required for the production of one lakh cashew grafts. The major share of the production goes to labour (54%) followed by input cost (26%). Interest on NRE amounts to 10 per cent and depreciation on infrastructure amount to 10 percent of the total cost (Fig. 1.). At a sale price of Rs. 20/- per graft, a net profit of Rs. 5.7/- per graft is expected. However, it may be noted that the production cost and the profit may vary depending on the cost of inputs, labour and sale price of grafts.

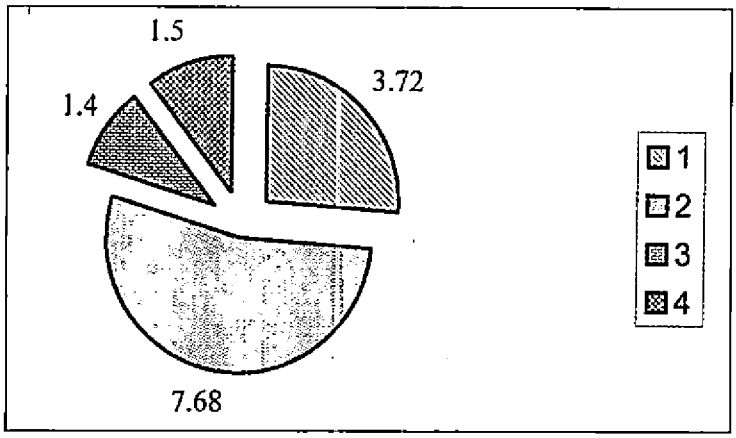
Cashew nurseries offer tremendous scope for income generation and employment generation as well. It also offers considerable scope to enhance raw nut production and to sustain cashew industry in the country.

The project on graft production @ 1 lakh per year can absorb 4360 man days in a year. One lakh cashew grafts are sufficient to plant in 500 ha of land, at a planting density of 200 plants per ha. On yield stabilization, about 1000 tones of raw nuts can be harvested annually which may fetch about Rs. 3 crores per year (@ Rs. 30/- per kg of raw nut).

E. Flush grafting

A new method of softwood grafting was standardized in 1986 at Madakkathara which can be adopted for overcoming the limitations of softwood grafting by enabling large scale multiplication of elite types.

Rootstocks of five age groups viz. 14, 21,28 , 35 and 42 days and 21,28,35 and 42 days old scions were tried in varieties Anakkayam-1, Madakkathara-1, K-22-1, H-3-



Input	-	3.72 (26%)
Labour	-	7.68 (54%)
Interest on NRE	-	1.40 (10%)
Depreciation on infrastructure	-	1.50 (10%)
Total	-	**14.30 (100%)**

Fig. 1. Components of cost of production of a cashew graft

17 and Madakkathara-2. Wedge grafting was done and evaluated under ordinary (75-80% humidity under partial shade) and mist condition (90% humidity in a mist chamber made of polythene sheet). The study revealed that flush grafting can be done with high percentage of success on 21 days old rootstock using 21 days old flushes and the success percentage can be enhanced using a mist chamber. When 72.2% of the total grafts kept under mist condition sprouted and 61.55% survived, the corresponding success figures under ordinary conditions were 65.8% and 33.6% (Pushpalatha *et al* 1990). Among the types compared, BLA-39-4 showed higher sprouting survival under ordinary condition. Mist condition (90% humidity) had a beneficial effect on sprouting, but not on survival. The best season for flush grafting was identified as April-May, though it can be done in all the months except in October, November and December, with an average success of 80-82%.

When induced flushes are used as scion, flushes after 14 days could not be used due to their length and girth (KAU, 1990).

Advantages of flush grafting over softwood grafting

- Younger seedlings can be used
- Grafting can be done whenever the flushes are available and there is no need to wait for the shoots to become 3-4 months old
- More number of progenies of a good mother tree can be produced in a short time
- Precuring of scion can be avoided

This technique facilitates commercial production of cashew grafts in short time. The field establishment of flush graft was 80% as against 90% of softwood grafting, one year after planting (KAU, 1990).

F. Top working

The possibility of top working to rejuvenate unproductive trees was studied (KAU, 1990) by beheading the healthy trees at 0.5 m and 1 m height during the month of March. After retaining 15-20 numbers of healthy sprouts, the rest were removed and softwood grafting was done one month after sprouting.

The highest success of 80% was obtained during April in the age group of 10-15 years, followed by June grafting (77.08%). In the age group of 5-10 years, grafting during June was found to be better (70%) followed by May grafting (55.3%). The rate of growth recorded was more when grafted during April, in the age group of 5-10 years, one year after grafting and in the age group of 10-15 years, it was with May grafting. In general, growth parameters like height, girth, number of primary branches and spread, flowering characters like number of panicles per sq. m and number of nuts per panicle were high with grafts developed on stumps of 1m height.

It was reported that a maximum of 4.7 kg nuts were obtained from an unproductive cashew tree by top working with high yielding clones in the fourth year of top working (Anon, 1993).

G. In situ grafting

The possibility of grafting on seedlings established in the field itself was explored (KAU, 1990). Cashew was sown in field with a spacing of 2ft and softwood grafting was done on 30 days old seedlings. Percentage of success in terms of graft take was recorded as 83.7 and these grafts were more vigorous than poly bag grafts.

Comparison of different vegetative propagation methods

Nayar and John (1958) has reported the performance of vegetatively propagated progenies as compared to seedling progenies at Kottarakkara. Inarched plants were most vigorous in growth as compared to layers and seedlings.

With a view to compare the merits and demerits of using seeds, layers and inarched grafts as planting material, a trial was done at Anakkayam (Veeraraghavan and Vasavan, 1977). Grafts generally failed to establish under field conditions that prevailed at the station. Layers started early flowering as compared to seedlings. Observation revealed the superiority of air layer over seedlings in respect of economic characters like earliness in flowering and higher nut yield.

Detailed studies were conducted at Madakkathara from 1980 onwards on different methods of vegetative propagation other than air-layering (Pushpalatha *et al.* 1990), such as patch budding, side grafting, veneer grafting, epicotyl grafting and softwood grafting. Though all the above methods were found feasible in cashew, the success obtained was 20% in side grafting, 38% in veneer grafting and 28% in patch budding. Such a low percentage of success was not encouraging to recommend the above methods for large scale production of clonal planting materials. In the case of "epicotyl" grafting where a success of about 80% could be obtained initially, the grafts were more vulnerable to "collar rot" disease in the later stages after sprouting resulting in high percentage of mortality. In soft wood grafting the success observed was up to 89%, and the grafts raised by this technique were generally found free from "collar rot" disease, thus ensuring maximum final recovery.

A trial was conducted at RARS, Ambalavayal during 1983-84 with three types of planting materials (epicotyl grafts, layers and seedlings) of six recommended types (Anakkayam-1, Madakkathara-1, H-3-17, H-3-13, NDR2-1 and K-22-1) to find out the feasibilities of growing cashew in high ranges of Wynad area and to compare the performance of different types of planting materials. Maximum mortality was found in air layers and the mortality rates were very low in the case of stone grafts and seedlings. Seedlings recorded minimum spread while air layers and grafts showed spreading habits. Trees from air layers gave maximum yield which was followed by stone grafts and the seedlings gave rise to trees with very poor yield (Devadas *et al.*, 1989).

During 1986 and 1987 studies were conducted on the propagation ability of the recommended cashew varieties such as Anakkayam-1, Madakkathara-1, H-3-17, K-22-1 and NDR 2-1 to three methods of vegetative propagation viz. air layering, epicotyl grafting and softwood grafting during the months of March to May.

Types Anakkayam-1 and Madakkathara-1 showed better response to softwood grafting (89.32% and 82.35 % success, respectively) as compared to epicotyl grafting (77.16% and 81.71%). Owing to the shy rooting nature, these types performed poorly in the air layering method with 43.5% and 48.1% success, respectively. The performance of the type K-22-1 was found to be 84.58 in softwood grafting, 71.61% in epicotyl grafting and 64.23% in air layering. The type H-3-17 recorded lower percentage of success in all the three methods with 59.71% in softwood grafting, 58.05% in epicotyl grafting and 37.10% in air layering. The performance of the type Madakkathara-2 was consistent in the three methods of propagation with 62.12% in epicotyl grafting, 60.81% in softwood grafting and 62.10% in air layering.

It was concluded from the trial that for commercial production of cashew grafts softwood grafting is the most ideal method under Kerala conditions. Types like BLA-139-1, Madakkathara-1 and K-22-1 which gave more than 80% success and final recovery have to be given the first preference in any nursery programme. Research carried out at CPCRI also has clearly brought out that large scale multiplication by vegetative means is possible by adopting softwood / epicotyl grafting method (CPCRI, 1985).

Establishment of progeny orchards

One of the limiting factors in extending cultivation and increasing productivity of cashew was non- availability of elite planting materials of recommended types in large

numbers. This can be tide over by establishing clonal orchards/ plots in the locations where cashew crop expansion is possible. With this objective in view, it was envisaged to establish clonal orchards of improved types of cashew under high density planting system and good management so as to make them to function as nurseries for the supply of planting materials in the vicinity of planting. The morphological frame work and genetic make up of the clonal plants will be better than that in the seedling progenies.

Accordingly, in 1982-83 season, three close planted clonal quick multiplication plots were established with six recommended types of cashew viz Anakkayam-1, Madakkathara-1, H-3-17, H-3-13, Madakkathara-2 and K-22-1 at Central State Farm (Aralam, Cannanore), Regional Agricultural Research Station (Ambalavayal, Wynad) and Cashew Research Station, Madakkathara (Balakrishnan & Aravindakshan, 1985). Kasaragod district being a potential area for cashew, a quick multiplication clonal plot with the six improved types of cashew was established in 1985-86 at Regional Agricultural Station, Nileshwar, Kasaragod district.

In the Integrated Tribal Development Area Farm, Pattimatam, Attapady an observational trial cum demonstration plot was laid out and planted during 1983-84 season. Pattimatam exists in the rain shadow area of Attapady hills with very low rainfall that too during North Eastern monsoon. Due to lack of sufficient rains and severe summer, most of the plants died indicating that cashew is not a suitable crop for that area.

The economics of establishment and maintenance of close planted clonal plot with reference to their capacity for production of planting materials was worked out. From second year of planting, the nursery plants become ready for undertaking layering and provide scions for grafting. The studies undertaken at Madakkathara have shown that from a population of 100 nursery plants, 2600 air layerings can be done besides collection of 2000 scion sticks for grafting purposes during second year. From third year onwards, the production of following numbers of air layers and scion material was possible.

Year	Air layering	Scions
Third year	5000 Nos.	4600 Nos.
Fourth year	7000 Nos.	7500 Nos.
Fifth year onwards	7500 Nos	7500 Nos.

Thus the establishment of close planted clonal orchard has proved as an economic proposition even to a homestead gardener. This will also help in quick dissemination of the recommended types of cashew among cultivators and thus deserve implementation in large numbers in the cashew growing tracts.

References

Abraham, E.V. 1956. Air layering is a success with cashew. *Ind.Fmg* 5 (10) : 26-27

Anon. 1954. Progress Report. Cashew Research Station, Kottarakkara

Anonymous. 1962. Final report of the Cashew Research Station, Kottarakkara (1952- 1962).

Anonymous. 1978. Progress report 1976-77. All India Co-ordinated Spices and Cashew nut Improvement Project. Central Plantation Crops Research Institute. Kasaragode 54 pp.

Anon. 1993. Annual report. All India Co-ordianted Cashew Improvement Project, Madakkathara, p.34

Aravindakshan, K., George, T.E., Veeraraghavan, P.G., and Balakrishnan, S. 1986. Studies on the effects of certain growth regulators on the rooting of cashew air layers. *Cashew Causerie* Jan-March No.1: 14-15

Aravindakshan, M. and Gopi Kumar, K. 1979. Seed viability in cashew. *Cashew Bulletin* Vol. XVI (1): 6-7

Balakrishnan, S. and Aravindhakshan, K. 1985. Close planted clonal orchard – a rapid device for large scale multiplication. *Cashew Causerie* Vol 7 (3): 6-7

CPCRI. (1985) Research highlights 1985. Central Plantation Crops Research Institute P 15.

Damodaran, V.K. 1968. Research on cashew in Kerala. *Cashew Bulletin* 5 (2) : 35

Damodaran, V.K. 1970. Research on cashew. *Intensive Agriculture* 7 (12): 20-24

Devadas, V.S., Manomohandas, T.P., George, S.P. and Kannan, K. 1989. A comparative study of different planting materials of cashew types in Wynad. *The Cashew* III (3) : 10-15

Gopikumar, K. and Aravindakshan, M. 1979. Variation in seedling characters of different types of cashew in the nursery. *Cashew Causerie* April- June: 20-21.

Gopikumar, K. and Aravindakshan, M. 1979. Correlation studies in different classes of cashew nuts in nursery. *Cashew Bulletin* XVI (6): 7-8

Gopikumar, K., Prabhakaran, P.V. and Aravindakshan, M. 1979. Growth behaviour in cashew. *Cashew Bulletin* XVI (3): 5-7

Govindan, M. and Sathiarajan, P.K. 1990. Nursery blight of cashew- a new record. *Agric. Res. J. Kerala* 28:56

Joseph, K.T. (1981) Seed borne fungi on cashew (*Anacardium occidnetale* L) *Cashew Causerie*. Vol. 3 (1): p. 12.

Joseph, M., Jayalekshmy, V.G. 2002. Economic Analysis of cashew graft production. p- 42-49. In. (Eds. John, P.S and Jayalekshmy, V.G) Recent Trends in Cashew nut Production and Processing. Cashew Research Station, Madakkathara, pp 240

Joseph, M., Mathew, S.K., Salam, M.A. and Kurien, S.K. 2002. Biological, chemical and solarisation effects on seedling vigour in cashew. *Proceedings of the 5th National seminar on Indian Cashew in the New Millennium Vision 2020* - 12-13 April 2002. Vishakapatanam, pp. 45-48

KAU. 1978. Annual report. Cashew Research Station, Madakkathara under AICRP (1977-1978). Kerala Agricultural University.

KAU. 1979. Annual report. Cashew Research Station, Madakkathara under AICRP (1978-1979). Kerala Agricultural University.

KAU. 1983. Progress report till 1983. Multi Sate Cashew Research Project. KAU, Vellanikkara. p.12.

KAU. 1990. Annual Report. All India Co-ordinated Cashew Improvement Project, Madakkathara

KAU. 2003. Package of Practice Recommendations- Crops. Directorate of Extension, Kerala Agricultural University, Mannuthy, p 54- 57

Kurup, K.R. and Viswanathan, K. 1970. The cashew in Kerala. *Intensive Agriculture* 11-16

Madhavan, K. 1998. Design of a cashew nut moisture meter. *Annual report* 1998, CPCRI. 139-142

Mini, C., John, P.S. and Jose Mathew 2006. Effect of scion storage on grafting in cashew (*Anacardium occidentale* L.). *The Cashew* xx(2):14-19

Mini, C. and Jose Mathew. 2008. Effect of priming on seed viablity and vigoue in cashew (*Anacardium occidentale* L.) *Seed Res.* 36(1):37-41

Nayar, T.G. and John, J.P. 1958. Cashew grafts and layers excel seedlings. *Ind. J. agric. Sci.* 28 (2): 129-132

Pillai, M.R.C. and Thomas, E.J. 1977. Seed propagation in cashew. *Cashew Bulletin.* Vol. XIV (5): 8,16

Pushpalatha, P.B., Salam, M.A. and Rao, D.S. 1993. Influence of a mist chamber on graft take in cashew. *Cashew Bulletin* Vol. XXX (4 & 5); 11-12.

Pushpalatha, Veeraraghavan, P.G. and George, T.E. 1991. Studies on variable influencing success in softwood grafting in cashew. *The Cashew*. July- September V (3): 7-8.

Pushpalatha, P.B., Veraraghavan, P.G. and Rao, S.D. 1990. Flush grafting in cashew. *Cashew Bulletin* XXVII (12)

Pushpalatha, P.B., Veeraraghavan, P.G. and Sitarama Rao, D. 1990. A study on the propagation ability of cashew types to different methods of vegetative propagation. *The Cashew*. Vol (4) 16-17

Salam, M.A., Pushpalatha, P.B. and Suma, A. (1992) Effect of gamma irradiation on cashew (*Annacardium occidentale* L). *Indian Cashew Journal* XX (4): 19-22.

Shylaja, M.R. 1984. Standardisation of the technique of stone-grafting in cashew (*Anacardium occidentale* L) and management practices for field establishment. M Sc (Hort.) thesis submitted to Kerala Agricultural University, College of Horticulture, Vellanikkara

Usha, K.E., Pushpalatha, P.B., Narayanankutty, C., Girija, T. and Beevi, S.P. 1996. Screening of cashew seedlings at nursery stage for the use as dwarfing rootstock. *The Cashew*. Jan- March 9-10

Valsalakumari, P.K. 1978. Standardisation of vegetative propagation technique in cashew with a view to reduce the post separation mortality of air layers. MSc Hort. Thesis submitted to Kerala Agricultural University

Veeraraghavan, P.G. and Pushapaltha, P.B. 1988. Importance of seed selection for increased productivity in cashew. *The Cashew* Vol II P. 16

Veeraraghavan, P.G. and George, T.E. 1982. a study on the performance of seedlings progenies in cashew (*Anacardium occidentale* L) XIV (2) 5-6

Veeraraghavan, P.G. and Vasavan, M.G. 1977. Trial on planting material on cashew. *Ag. Res. J.* Kerala 15 (2): 204.

Veeraraghavan, P.G., George; T.E. and Nair, M.N.C. 1983. Standardisation of layering medium, planting medium and containers for cashew air layers. *Agric Res J Kerala* 21 (2) 55-57.

Vidyadharan, K.K. and Aravindakshan, M. 1977. An unusual case of precocity in seedling cashew (*Anacardium occidentale* L) *Cashew Bulletin.* XIV (11): 9

ESTABLISHMENT AND MANAGEMENT OF CASHEW PLANTATIONS

K.E. Usha
Department of Agronomy, College of Horticulture
Kerala Agricultural University, Thrissur – 680 656, Kerala
(e-mail: ushake61@yahoo.co.in)

Introduction

Cashew is adapted to warm humid tropical conditions. It can be grown in almost all types of soils from sandy to laterite and up to an elevation of 600-700m including wastelands of low fertility. It grows and yields best in well-drained red sandy loams and light coastal sands. Heavy clay soils, poor drainage conditions, very low temperature and frost are unsuitable for the crop.

Since cashew is grown mainly without applying fertilizers, the potentialities of biofertilizers as well as other management practices including efficient recycling of litter can be utilised best for improving the productivity.

Climate

According to Venugopal and Khader (1991), the higher potential production of cashew in various states of India is related to the even distribution of post-monsoon rain during plant growth and the pre-flowering phase (September to November). The cyclonic storms along the east coast of India which result in heavy rainfall, floods and water logging conditions seriously affect the productivity of cashew. In regions where rainfall is insufficient, irrigation with the use of appropriate soil conservation and fertility management practices is recommended.

The latitude where cashew grows, the relationship between latitude and flowering, the altitude, temperature and rainfall requirements and the effects of relative humidity, sunshine, day length, wind, water logging, drought and irrigation on the growth and production of cashew were studied by Rao and Gopakumar (1994). Areas receiving extremely low (<18°C) and high temperature (>40°C) for prolonged periods were found to be less suitable for cashew. Performance was poor in areas with relative humidity of < 60%. An average rainfall of 1300 – 2000 mm is necessary for rainfed cashew.

Influence of weather factors on bud break, flowering and nut quality of cashew was studied by Rao *et al.* (2001). Chronological data on the ontogeny of 3 test varieties (BLA 139-1, BLA 39-4 and NDR 2-1) of cashew grafts along with nut weight, shelling weight and nut percentage were recorded during 1995 to 1998. Daily meteorological data were also collected to study their impact on the reproductive phase of cashew. Bud break, which was dependent on the genotype, followed immediately after heavy wet spell of rains in the presence of bright sunshine. The flowering of cashew requires mild winter, which may be defined as low minimum surface air temperature ranging between 16 and 20°C coupled with more dew nights having moderate dew in humid climates. It also requires bright sunshine (> 9 h/ day) with moderate dry weather having a relative humidity between 60 and 40% in the afternoon. The unusual rains during November and December delayed the reproductive phase of late-season types. The availability of soil moisture played a key role in kernel development. Bud break in all the varieties was earliest during 1995-96.

The reproductive phase of cashew is very sensitive to weather aberrations and final crop output depends upon weather conditions if no pest complex incidence is noticed under uniform crop management condition (Rao, 2002). Cashew is both photosensitive and thermo sensitive. Reproductive phase is sensitive to weather conditions. A range of surface air temperature 15-35°C is optimum for growth and production. Flowering responds both to the light intensity and duration. Variation in heat unit requirement is observed among different genotypes. Early varieties like Anakkayam-1 require lesser amount of heat units (1953 day°C), while late varieties like Madakkathara-2 require more (2483

day^{0}C). The mid season varieties had a value in between them (2245 day^{0}C). It is found that branches on southern, SW and SE quadrant flower early compared to northern quadrant. The kernel weight was influenced by total heat units received and also by the available soil moisture.

Soil

The best soil types are brown forest soils or deep well drained laterite soils with a high water holding capacity and rich in organic matter. Eroded laterites and coastal sandy soils are unsuitable and less productive. Saline or alkaline soils are not favourable for the crop (Venugopal and Khader, 1991).

Soil characteristics in natural forests, teak and cashew plantations in Kerala were studied by Balagopalan (1995). This study was initiated to characterize the soils of natural forests and plantations of different species in the Malayattoor Forest Division of Kerala. Soils in the cashew plantations were found to be sandy loam and moderately acidic. Soils in the plantations were found to be deteriorated when compared to those in natural forests.

The effect of establishing plantations of *Acacia auriculiformis* (in 1985 and 1987) and *Eucalyptus tereticornis* (in 1985) on soil properties was investigated on deforested land at Trichur (Animon, 1999). The control plot included in the study was cashew. Soil was sampled at different depths (0-10, 10-30 and 30-60 cm) at the end of the summer and the peak of the rainy season (June and July). In cashew plantation, the soil moisture was more evenly distributed but was less in the surface and middle layers than in the deeper layer. Soil microorganism contents were more under cashew than under Eucalyptus.

The suitability of red and laterite soils for cashew cultivation was discussed by Nair *et al.* (1998). These soils support tree crops in high as well as less rainfall areas. Red and lateritic soils are mostly climatogenic, and vegetation and relief have played major roles in soil formation. In laterite areas, soil erosion is unabated during the monsoon aided by the landscape setting. Occurrences of plinthite at different depths, highly gravelly nature of subsoil, poor base status, low cation exchange capacity, moisture stress during summer coupled with low water table, and presence of free oxides of Fe and Al are problems associated with their management.

Planting

Plant seedlings or softwood grafts in pits of size 50 cm x 50 cm x 50 cm during June-July. Planting may be done at a spacing of 7.5 m for poor and 10 m for rich and deep soils and sandy coastal areas. On very sloppy lands, the rows may be spaced 10-15 m apart with spacing of 6-8 m between trees in a row. The normal spacing recommended for cashew for Kerala is 8 m x 8 m (156 plants in square system of planting and 181 plants in hexagonal system of planting) for poor soils. For rich soils and sandy costal areas 10m x 10m spacing (100 plants in square system of planting and 116 plants in hexagonal system of planting) is recommended (KAU, 1996).

Wahid *et al* (1993) reported that 72% of the active roots are concentrated within 2m radius even if different systems of planting such as square or triangular systems are adopted.

High density planting

High density planting (HDP) is a technique useful for enhancing production and productivity of cashew plantations in India (Salam, 1997). Instead of the normal planting density of 100-177 plants/ha, 312-625 or more grafts/ha are planted. The population is regulated in later years by selective felling. The success of high density planting depends on the initial spacing (planting density) and the time of thinning at later stages. The productivity of high density planting plantations was compared with that of normal plantations.

While adopting a high density planting technique, grafts may be planted initially at a spacing of 4m x 4m or 8m x 4m so that there will be 625 or 312 plants respectively. This population can be retained for a period of seven to nine or ten years depending upon the canopy expansion rate. If the soil is very rich, the canopy development rate will be faster. High density planting would be more useful in poor soils where the rate of canopy expansion is slow. Considering the fertility status of the soil, the level of management in terms of fertilization, irrigation etc., the initial plant population is to be decided carefully for every agro-climatic condition. Later, after monitoring the canopy pressure between adjacent plants, the alternate plants are to be removed. Finally, when the plants attain full growth, the spacing between the plants will be 8m x 8m (KAU, 2002).

If uniform management practices are adopted, during early years of yield, nut yield per tree will be more or less the same with all the trees, in both the conventional and high density planting. But the per hectare yield will be more from high-density plantations. During later years, when the plant population is equalized to that of normal density plantation, the productivity of both the plantations would be more or less the same. The bonus yield obtained during the early years would be substantial in high-density plantations.

In addition to obtaining higher yields, substantial quantities of firewood can be obtained during thinning, which may fetch additional revenue to the farmer. The weed growth in the interspace can be effectively checked to a greater extent.

A field experiment was conducted at the Cashew Research Station, Madakkathara, during 1982-92, to study the effect of high density planting (156-625 plants/ha) on the yield of cashew (of air layers cv. K-22-1). Cumulative yield for the initial 9 years were best (5611-6981 kg/ha) at planting densities of 625 plants/ha (4 m X 4 m) and 312 plants/ha (4 m X 8 m). Thinning of plants was not necessary to promote higher yields (Suma *et al.*, 1998).

The study on high density planting conducted at Madakkathara during 1996-2008 revealed that cumulative yield per tree of eight years was marginally high under normal density planting over high density planting. The cumulative per hectare yield was 3.8 times high under high density system (Annual Research Report, 2008). Jose Mathew and Mini (2008) conducted the economic analysis of the high density system and found significant increase in net income and benefit cost ratio.

Irrigation

Drip irrigation @ 80 litres/tree once in 4 days from 2nd fortnight of December to end of March coinciding with the flowering season resulted in significantly higher yield compared to lower levels of irrigation or without irrigation (Samuel, 2002).

An experiment was conducted at CRS, Madakkathara to study the response of six month-old cashew seedlings to different levels of soil moisture regimes: irrigation at 20, 40, 60, 80 and 90% depletion of available water (DAW), and life saving irrigation. There was a gradual decline in the morphological characters with increase in soil moisture stress. However, root: shoot ratio remained unaffected up to 90% DAW, indicating the capacity of the roots to withstand soil moisture stress. There was no significant variation in relative water content at moderate stress (up to 60% DAW). The result indicates that cashew can tolerate mild to moderate levels of moisture stress without affecting the growth of the seedlings (Latha and Salam, 2003). The varieties like Priyanka, M26/2, M44/3 and V5 were found to be tolerant to drought.

A study was conducted during 1995-97 to evaluate the effect of N at 0, 750 and 1500 g/tree, applied under different levels of drip irrigation (at 0, 40 and 80 litres of water/tree per day), on 3-year-old cashew grafts cv. H-3-17. The highest yield was obtained with the application of 1500 g N/tree at a drip irrigation regime of 80 litres/tree per day (Latha and Salam, 2001).

Weed management

A survey on the weed flora of cashew gardens in Kerala was conducted under the AICRP on weed control, KAU during 95-97 (Abraham and Abraham, 1999). Seventy five cashew plantations were selected at random from the main cashew growing areas of the state. Average species wise counts were recorded. For each species, Relative Density and Relative Frequency were worked out.

The Summed Dominance Ratio (SDR) was determined, to express the ecological significance of the weed, by taking the average of relative density and relative frequency. Out of 48 weeds identified, 41 were broad leaved and 7 were grasses. Broad leaved accounted for a total of SDR value of 87.6 indicating their relative importance in the cashew ecosystem. Among the broad leaved weeds, the highest SDR value (5.4 each) was shown by *chromolaena odorata, Hyptis suaveolens,* clearly indicating their association with cashew. *Clerodendron infortunatum, Glycosmis arborea, Zyzyphus glabrata, Canthium parviflorum, sizygium zeylanicum, Macaranga peltata, Calicopteri floribunda* were the woody shrub weeds very frequently found in cashew gardens. Among the grasses, *Pennisetum polystachyon, Ischaemum indicum* and *Axonopus compressus* were the common ones. Wild amorphophallus (*Amorphophallus bulbifer*) having

medicinal qualities, is a weed uncommon in other crops, but widely distributed in cashew gardens. *Mikania micrantha*, comparatively new introduction, has been found to be an alternate host for the tea mosquito, a major pest of cashew.

Depending upon the weed growth, weeding operation may be done during August-September. Mulch the plant base with dry leaves to reduce sun-scorch to tender plants.

Sickle weeding is the most common practice of weeding. A trial was conducted under AICRP on weed control (1986-89) with eleven treatments in RBD in three year old plantation with air layers. Even two sickle weeding could not keep the weeds under control. Sickle weeding followed by the application of Glyphosate (0.4kg/ha) was effective. Digging the field twice or one digging in September - October followed by the spraying of Glyphosate in May-June was also found to be effective. Three sprays of paraquat (0.4kg/ha) or single application of Glyphosate (0.8kg/ha) were equally effective. 2,4-D controlled broad leaved weeds whereas Dalapon was effective against grasses. Repeated spray of paraquat controlled weeds except *Hemidesmus indicus* and *Ichinocarpus fruitescens* which could regrow from their underground tubers, utilizing the stored food. This resulted in a shift in the weed flora. Similarly, Glyphosate lead to a shift to annual dicot weeds like *Synedrella nodiflora*. This suggested the need for herbicide rotation.

A study on the cost of different methods of weed control at CRS, Madakkathara revealed that sickle weeding is the expensive method costing Rs. 2500/ha for a single weeding. The cost for paraquat (0.4kg/ha) + 2,4-D (1kg/ha) application came to Rs. 874/- only. Other herbicides reduced the cost by 50% than sickle weeding (Salam *et al.*, 1993).

The yield reduction due to weed competition is estimated to be 60-70% (Salam *et al.*, 1993).

Pruning

Initial training and pruning of young cashew plants during the first 3-4 years is essential for providing proper shape. This allows proper growth of the canopy and receipt of adequate sunlight on all the branches. Thereafter, little or no pruning is necessary. The plants should be allowed to grow by maintaining a single stem up to 0.75-1.00 m from ground level. This can be achieved by removing the side shoots or side branches gradually as the plants start growing from the second year of planting. Weak and criss-cross branches can also be removed. Proper staking of the plants is required to avoid lodging due to wind during the initial years of planting. Initial training and pruning of cashew plants facilitates easy cultural operations such as terrace making, weeding, fertilizer application, nut collection and plant protection. Pruning of cashew plants should be done during May - June. The flower panicles emerging from the grafts during the first and second year of planting should also be removed in order to allow the plants to flower and fruit only from the third year onwards (KAU, 2002).

In a trial at CRS, Anakkayam, seedlings, grafts and layers of cashew cultivars viz. Anakkayam-1 and Madakkathara-1 were planted at a spacing of 7.5 m X 7.5 m (Nalini *et.al.*, 1999). Canopy surface area was smallest in grafted plants of both cultivars. These plants produced the highest nut yields (11.30 and 10.56 kg/tree).

Intercropping

The interspace available in the plantation can be utilized for raising other crops which will provide additional income to the growers. During the first year, about 90% of the area is available for intercropping which reduces to 80 and 70 % during the second and third years. Short duration crops like pineapple, papaya, cowpea, banana, ginger, groundnut, pulses, vegetables and tapioca are suitable for intercropping. Lemongrass can also be raised with less profit (KAU, 1998).

Pineapple is the most profitable intercrop in cashew plantation in the early stages of growth. It can be planted between two rows of cashew in trenches opened across the slope. Paired row of pineapple suckers can be planted in each trench at 60 cm between rows and 40 cm between two suckers within the row. These trenches can be opened at 1 m between two rows of cashew. Ginger, lemongrass and tapioca are also suitable as intercrops.

Under the AICRP on cashew, an experiment on intercropping was initiated during 1997 at Cashew Research Station, Madakkathara. The medicinal plants viz., Adalodakam and koduveli did not perform well. The performance of turmeric and coleus was also poor during 2000. The experiment was repeated with tuber

crops during 2004 to 2008. Among the test crops, tapioca was found to be the most profitable (Annual Research Report, 2008; Jose Mathew *et.al.*, 2008).

The necessity to intensify agricultural land use has led to the development of multistoried cropping and crop mixtures. The study of allelopathic interactions in cashew based multistoried cropping systems is highly essential owing to the tannin and phenol contents in cashew litter (John and Nair, 2000).

Yield forecasting

Yield prediction in cashew based on foliar nutrient levels was attempted by Mathew (1990). A new prediction equation was arrived at through a stepwise regression procedure establishing the relationship between leaf N content at flushing, flowering and fruiting stages and N/P ratio at flushing and yield (Latha, 1992). The economic optimum doses for yield were worked out to be 748 g N, 329 g P_2O_5 and 765 g K_2O/tree/year. But the maximum net return of Rs. 21840/ha was obtained at 1000 g N, 500 g P_2O_5 and 100 g K_2O/tree.

To formulate a suitable model for the forecast of production and to work out the major determinants of yield variations, secondary data were collected from the Directorate of Economics and Statistics, Thiruvananthapuram for a period of 37 years from 1956-1957 (Mini, 1996). The data on average production, productivity, price of raw cashew, kernel and annual rainfall were collected. The Distributed lag model, Log – normal diffusion model and Markov chain model were tried on the time series. Univariate ARIMA models of all the variables were considered separately and these offered a good technique for predicting the magnitude of all the variables. The log normal diffusion model was fitted to the data on production of cashew in Kerala. Yield forecasts for the period from 1997-99 were obtained using this model.

Manuring

A fertilizer dose of 750 g N, 325 g P_2O_5 and 750 g K_2O per plant is recommended for cashew (KAU, 2002). Apply 1/5th dose after the completion of first year, 2/5th dose during second year and thus reaching full dose from 5th year onwards. Broadcast the fertilizer within an area of 0.5 to 3.0 m and 15 cm deep around the tree and incorporate by light raking.

The organic materials available in the plantation can be subjected to vermicomposting. Cashew apple residue and leaf litter could be composted in ninety five days which served as an ideal ameliorant for acid soils of Kerala (Mini *et al.*, 2004).

A study on foliar application of urea with insecticides (Endosulfan (.05%) with 3% urea) under the AICRP trials did not give promising results at Cashew Research Station, Madakkathara (Annual Research Report, 1993). N, which is absorbed in the largest quantity, has significant positive effect on growth and yield of cashew (Veeraraghavan *et al.*, 1985).

General

Investigations on the different vegetative, flowering and fruiting characters influencing yield were studied by Parameswaran (1979). Percentage of flowered shoots per unit area of tree canopy was found to be the most important factor contributing the yield. Tree spread and percentage of bisexual flowers had a positive correlation with yield. Lack of pollination was found to be one of the reasons for poor fruit set and yield in cashew. Keeping beehives facilitated better pollination. Fruit drop in the early stages of development was resulted from the attack of insects and adverse climatic conditions.

A study was conducted to evaluate the problems concerned with field experimentation on cashew (Remesh, 1981). Yield records of 625 uniformly treated cashew trees at CRS, Madakkathara for a period of 5 years from 1976 were collected. The trees were found to be highly heterogeneous even though they were raised from the same parental stock. Single tree plots were found to be the most efficient when viewed from the point of view of maximum relative percentage information and consequently could be recommended for conducting field experiments on cashew. Two tree plots could also be recommended due to certain practical considerations. A selection wider evolved was found to be strongly correlated with experimental yield.

References

Abraham, M. and Abraham, C.T. 1999. Weed flora of cashew gardens in Kerala. *Cashew Bull.* March, p. 3-6

Animon, M.M. 1999. Physico chemical and biological properties of soils under *Acacia auriculiformis* and

Eucalyptus tereticornis plantations. *J. trop. For.* 15 (1) : 45-52

Annual Research Report. 1993. Cashew Research Station, Madakkathara, Thrissur, Kerala.

Annual Research Report. 2008. Cashew Research Station, Madakkathara, Thrissur, Kerala.

Balagopalan, M. 1995. Soil characteristics in natural forests and *Tectona grandis* and *Anacardium occidentale* plantations in Kerala, India. *J. Trop. Forest Sci.*7 (4) : 635-644

John, J., and Nair, M.A. 2000. Prospects of allelopathic research in multi-storey cropping systems. *Allelopathy-in-ecological-agriculture-and-forestry. Proceedings of the III International Congress on Allelopathy in Ecological Agriculture and Forestry*, August 18-21, 1998 (eds. Narwal, S.S., Hoagland, R.E., Dilday, R.H. and Reigosa, M.J.) Dharwad, India. pp. 159-179.

Jose Mathew and Mini, C. 2008. Manipulation of tree densities for yield and income maximisation in cashew. Proc. 3rd Indian Horticulture Congress, Nov. 6-9, 2008, Bhubaneswar, pp. 203.

Jose Mathew, Gregory Zacharia and Mini, C. 2008. Economic potentials of tuber crops for intercropping in young cashew plantations. *J. Plantation Crops* 36(3); 366-367

KAU. 1996. Package of Practices Recommendations – Crops, Kerala Agricultural University, Thrissur, p. 267

KAU. 2002. Package of Practices Recommendations – Crops, Kerala Agricultural University, Thrissur, p. 278

Latha, A. and Salam, M.A. 2001. Effect of N at different levels of drip irrigation in cashew *(Anacardium occidentale L.). The Cashew* 15 (3) : 18-26

Latha, A. and Salam, M.A. 2003. Response of cashew seedlings to soil moisture regimes. *The Cashew* 17(3) : 17-20

Latha, A. and Salam, M.A. 2001. Screening of cashew varieties for drought tolerance. *J. Pl. Crops* 29 (2) : 27-30

Latha, A.1992. Growth and yield of cashew in relation to foliar and soil nutrient levels. M.Sc (Ag) thesis submitted to Kerala Agricultural University, Vellanikkara

Mathew, R. 1990. Yield prediction in cashew based on foliar nutrient levels. MSc. (Ag.) thesis, Kerala Agricultural University, Thrissur, p. 210

Mini, C., John, P.S. and Sushama, P.K. 2004. Vermicompost preparation from organic waste of cashew garden. Proceedings of Indian Horticulture Congress, 6-9 November, 2004. New Delhi, 263.

Mini, K.G. 1996. Time series modeling and forecasting of the yield of cashew *(Anacardium occidentale.L)* in Kerala. MSc. thesis, Kerala Agricultural University, Thrissur, p.72

Nalini, P.V., Nair, G.S. and Babu, L.C. 1999. Canopy characteristics in cashew *(Anacardium occidentale L.). The Cashew* 13 (1) : 31-36

Parameswaran, N.K. 1979. Factors affecting yield in cashew *(Anacardium occidentale L).* MSc. thesis, Kerala Agricultural University, Thrissur, p. 74

Rao, G.S.L.H.V.P. 2002. Influence of climate on cashew growing environments across the west and east coasts of India. *Recent trends in cashew nut production and processing (eds.* John, P. S. and Jayalekshmi, V.G). Cashew Research Station, Madakkathara. pp.146-154

Rao, G.S.L.H.V.P and Gopakumar, C.S. 1994. Climate and cashew. *The Cashew* 8 (4) : 3-9

Rao, G.S.L.H.V. 2001. Influence of weather factors on bud break, flowering and nut quality of cashew *(Anacardium occidentale.L.). Ind. J. agric. Sci.* 71 (6) : 399-402

Salam, M.A, Pushpalatha, P.B, Suma, A. and Abraham, C.T. 1993. Efficacy of chemical weed control in cashew plantations. *J. Pl. crops* 21 (1) : 54-56.

Salam, M.A. 1997. High density planting in cashew - principles and practices. *The Cashew* 11(4) : 12-20

Samuel, J.C. 2002. Strategies for improved productivity through efficient water management for cashew. 5th National Cashew Seminar on Indian Cashew in the New Millennium – Vision 20/20, 12-13 April 2002, Visakhapattanam, pp. 102 – 111.

Suma, B., Salam, M.A., Suma, A. and George, T.E. 1998. Effect of planting densities on the nut yield of cashew *(Anacardium occidentale L.). The Cashew* 12 (2) : 33-37

Veeraghavan, P.G., Celina, W.A. and Balakrishnan, S. 1985. Studies on the fertilizer requirement of cashew *(Anacardium occidentale L.). Cashew Causere* 7 (2) : 6-8.

Venugopal, K and Khader, K. B. A. 1991. Effect of soil and climate on the productivity of cashew. *Ind. Cashew J.* 20 (3) : 19-24

Wahid, P.A, Kader, K.V.A and Salam, M.A. 1993. Rooting pattern of cashew. Rooting patterns of tropical crops. (eds. Abdul Salam, M.A. and Wahid, P.A.) Tata Mc Graw Hill publishing Co. Ltd. pp. 223 – 234

NUTRIENT MANAGEMENT IN CASHEW

A. Latha
College of Horticulture, Vellanikkara - 680 656, Kerala
(e-mail:lathadas2003@yahoo.com)

Plant improvement techniques for production enhancement in perennial crops can only be seen in a long-term perspective. An improvement in management techniques alone forms the practical answer to this. Formulation of objective oriented management system of cashew and its judicious application in the field will enable to meet the entire requirements of industry.

Continuous application of fertilizers tends to develop scientific nutritional environment, which determines the nature and extent of productivity in perennial crops. The management techniques need to be standardised based on such specific nutritional environment. Any management system of cashew should take into account all the major nutrients, as they are low in laterite soil in which cashew cultivation is concentrated.

Cashew manifests significant positive effects due to mineral fertilization. The response is mainly governed by soil fertility. Hence greater response to fertilizer application by cashew need be expected only in poor soils. Younger cashew responded well to mineral fertilization than older ones.

1. Nutrient management in nursery

The successful production of seedling for the quality root stock production is decided not only by the quality of seed nuts but also the constituent components in the potting medium and its nutritional status. There is tremendous scope for including biofertilizers for maintaining continuous fertility in the potting mixture since a period of about one year is required from sowing of seeds and planting of cashew grafts in the main field.

Studies on standardization of a nutrient management strategy in the nursery to produce vigorous root stocks revealed that among the three potting media compared, the best performance was observed with 1:1 soil: FYM mixture followed by 1:1:1 soil: sand: FYM mixture. The concentration of N, P and K in the seedlings were also maximum in 1:1 soil: FYM mixture and hence it is found to be the best for producing cashew seedlings in soil that contains around 60% sand (Jagadeesh, 2001). An experiment was conducted in Cashew Research station, Madakkathara to find out the best components of potting mixture with respect to cashew root stock production and the study revealed that the nutrient content in the leaves of cashew seedlings and available nutrient contents in the potting mixtures at grafting was maximum in the combination of sand: soil: poultry mixture + Azospirillum + PSB + AMF (Sinish, 2003).

Solarisation of soil to be used in the potting mixture is of great advantage. Trials conducted by Meagle *et al.* (2002) indicated that potting mixture with solarised soil, sand and FYM inoculation with *Trichoderma hazarianum* helped to enhance the growth and vigour of cashew rootstocks.

Jagedeesh (2001) observed improvement in growth when potting media was supplemented with 200 g N + 100 g P + 200 g K 100 kg^{-1}. But incorporation of lime at varying doses from 100 to 500 g 100 kg^{-1} potting media did not influence the growth as well as the uptake of nutrients by cashew seedlings.

The vigour of grafts can be sustained through supplementation of different nutrients at various stages with different sources. Sinish (2003) tried different nutrient sources for soil application to grafts and observed that N, K and Ca contents in leaves at 3 months after grafting were higher in ground nut extract + 17:17:17 mixture.

Among the different foliar sprays tried by Sinish (2003), the growth performance was best with 2% 17:17:17 spray on soil application of decanted extract of ground nut cake + 17:17:17 mixture. Analysis of leaf nutrient contents at 6 months after grafting revealed that N, P, K, Ca and Mg

contents in leaves of grafts as well as available nutrients in potting mixture were higher with 2% 17:17:17 spray. Hence the growth and vigour of cashew grafts can be improved with soil application of 100 ml of deccanted extract of ground nut cake + 17:17:17 mixture at 1 month after grafting followed by foliar fertilization with 2% 17:17:17 at 3 months after grafting coupled with biofertilizer inoculation.

Studies on the interaction effect of biofertilizers on cashew by Usha (2001) revealed that combined inoculation of AMF and Azospirillum was found to be the best among the different combinations tried in the nursery.

2. Nutrient management in adult trees

Cashew responds very well to application of nutrients. The trials conducted revealed a substantial increase in the productivity of cashew with timely application of fertilizers. The extent of response varied from place to place.

Nitrogen

Nitrogen has the most marked effect on the growth and development of cashew out of the three major nutrients. The importance of N for cashew is confirmed by experiments conducted in KAU. Significant response in increasing the vegetative characters of cashew by N (500 g $t^{-1}y^{-1}$) was noticed (Latha,1996a). A fertilizer trial at CPCRI, Kasargod revealed that very low N application was not sufficient for high yield (Nambiar, 1974). Veeraghavan *et al.* (1985) observed from an NPK trial that application of N alone increased the yield per tree significantly over no nitrogen. According to Kumar (1985) the vegetative characters, yield as well as apple and nut characters were maximum at the highest level of 450 g N $t^{-1}y^{-1}$. But Latha (1992) reported that the highest yield of 8.7 kg t^{-1} corresponded with yearly application of 1000 g N t^{-1} and it was 7 fold higher than the yield in absolute control where no fertilizer application was done since planting. But Nair *et al.* (1972) could not record any increase in cashew nut yield by the application of 220 g N $t^{-1}y^{-1}$. From the results of a long-term fertilizer experiment in seed progeny of cashew receiving constant levels of N for a period of 10 years, Mathew (1990) reported a nut yield of 8.34 kg t^{-1} at 1000 g N $t^{-1}y^{-1}$ against 6.91 kg t^{-1} at 250 g N $t^{-1}y^{-1}$. Rajeev (2003)reported that N application @ 1000 gt^{-1} was found to enhance the yield of nuts as well as apple in cashew significantly recording a maximum yield of 3.51kg of nuts per tree and 22.2 kg of apples per tree. Latha (1996c) reported that N application increased the protein content of kernels.

Veeraraghavan (1990) reported significant increase in shelling percentage of cashew from 29.5% to 35.6% by the application of N at the highest level of 500 g $t^{-1}y^{-1}$.

Response of cashew to application of N at different levels of drip irrigation was studied by Latha and Salam (2002). It was found that N application @ 1500 g per tree per year along with irrigation @ 80 litres per tree per day (through drip) is needed for obtaining best results from cashew.

Leaf nutrient status

The leaf N concentration varies from 1.2% (Gopikumar *et al.*, 1978) to 3.24% (Gopikumar and Aravindakshan, 1989) in cashew seedlings. Leaf N concentration varies with variety and the average is 1.28% (KAU, 1987).

N application increased the leaf N content in cashew (Mathew, 1990). Application of N increased the leaf N content upto 350 $gt^{-1}y^{-1}$ beyond which there was no response (Jagadeesh, 2001). At flushing application of higher levels of 500 g or 1000 gt^{-1} failed to give an increase in leaf N content over the lower level while increasing N from 250 g to 500 g resulted in a significant increase of 13% in leaf N at flowering stage (Latha, 1994a). Latha also reported that leaf N content increased from 2.46 to 3.02 per cent with increase in N level from 250 to 1000 g per tree per year. The average nutrient content of leaf samples were found to be medium for N (1.63-2.22%) (Rajeev, 2003).

The extent of variation in leaf N in the position of leaf and stage of sampling was from 1.24 to 2.76 per cent. According to Mathew (1990) leaf N content was low (1.5 to 1.96%) at fruiting and harvesting phase and high (1.85 to 2.16%) during flushing and early flowering phase. Bhaskar (1993) observed leaf N content of 2.94% at flushing and early flowering phase, which decreased to 2.21% during fruiting and again rose to 2.42% at maturity and harvest phase. Mathew (1990) reported that leaf N content ranged between 1.93 to 3.02% at different stages of growth and N distribution showed a regular pattern with highest concentration at flowering. Similar results were also observed by Latha (1992).

Pattern of variation in the content of N with the increasing age of the leaf was different. Maximum N accumulation was noticed in the top leaves at flushing and fruiting stages. N distributions at different leaf position in the other stages were rather inconsistent (Mahew.1990).

The leaf N content varied with leaf position. It was highest (2.76%) in younger leaves and lowest (1.24%) in older leaves (Mathew, 1990).

Phosphorus

The role of P in cashew nutrition is seen in the early stages and also during nut development. But in laterite soils the effect of P application is limited. Kumar (1982) reported that the trunk of cashew is one of richest store houses for P and Ca. The highest number of nuts per panicle and yield were observed in trees that received 250 g per tree phosphorus. Veeraraghavan *et al.* (1989) reported that the response of cashew to P application was very poor in laterite soils of Madakkathara. But Mathew (1990) reported a yield increase of 73 per cent when P application was raised from 125 to 500 g per tree. P application improved the quality of apple and nut also. Rajeeev (2003) reported that P application at its highest level (250g $t^{-1}y^{-1}$) recorded the highest ascorbic acid content of apple.

Leaf nutrient status

Cashew seedlings grown in Hoaglands solution containing P recorded 6.34% phosphorus in leaves, whereas seedlings in nutrient solution completely devoid of P contained 0.11% phosphorus content leaf (Gopikumar and Aravindakshan, 1989).

Mathew (1990) reported that mean P content of cashew leaves was only 1/20th of that of N. Leaf P content was increased by P and K application but reduced by N application (Kumar, 1982). Latha(1996b) reported that increase in P application increased leaf P content from 0.072 to 0.16 per cent up to a dose of 500 g P_2O_5 $t^{-1}y^{-1}$. The concentration of P differed between plant parts (leaf, apple, kernel and shell). Cashew kernel had the highest concentration of P compared to leaf, apple and shell (Bhaskar, 1992).

Mathew (1990) reported that leaf P content varied from 0.063 to 0.316% with reference to position of leaf and stage of sampling. He also reported that leaves of a ten-year-old cashew tree contained 0.12% P during flushing and it decreased to 0.04% during fruiting and post harvest phase. According to Bhaskar (1993) the leaf P content of cashew variety BLA-139-1 was 0.06% during flowering as well as harvesting phase but declined to 0.04% during fruiting and post harvest phases respectively. Irrespective of varieties, phosphorus concentration was higher at pre-flushing stage than pre-flowering stage (Jagadeesh, 2001).

The highest leaf P concentration was noticed at all physiological stages when P was applied @250$gt^{-1}y^{-1}$(Latha, 1992). Application of P resulted in significant increase in P content of cashew leaves at flushing, flowering and fruiting stages. Distribution of P at different leaf positions was rather inconsistent. However, a tendency to accumulate more P in the basal leaves was noted during different stages of sampling (Mathew, 1990).

The absorption of soil-applied ^{32}P differed with physiological phases but not between the varieties. The absorption peak was noticed at flushing and early flowering phase and lowest at maturity and harvesting phase (Bhaskar, 1993).

The leaf P content varied with leaf position. It was highest (2.76%) in seventh and eighth leaves and lowest (1.24%) in first leaf from the inflorescence (Mathew, 1990).

Irrigation of cashew trees during summer increased ^{32}P absorption compared to the unirrigated trees.

Potassium

The response of young cashew to K is limited and need not be applied during early stages (CPCRI, 1979). Veeraraghavan *et al.* (1985) observed from an NPK trial at Madakkathara that response in K application was insignificant and yield to highest doses of 1000 $gt^{-1}y^{-1}$ K was not as marked as that of N and P. The yield increased from 5.44 to 7.23 kg per tree when K application was increased from 250 to 1000 $gt^{-1}y^{-1}$ (Mathew, 1990). Rajeev (2002) reported that K at the highest level of 250 $gt^{-1}y^{-1}$ application significantly increased the apple yield over all other levels recording a highest yield of 20.27 kg per tree.

Leaf nutrient status

In cashew seedlings, the leaf K concentration varied from

0.87% (Gopikumar *et al.*, 1978) to 3.17% (Gopikumar and Aravindakshan, 1989). Cashew seedlings in Hoaglands solution devoid of K contained 1.06% K whereas it was 3.17% in seedlings grown in nutrient solution containing K (Gopikumar and Aravindakshan, 1989). Leaf K content of six month old cashew seedlings increased from 1.7% in control to 3.1% when K was applied @ 200 $kgha^{-1}$ (Latha, 1998). The leaf K content increased from 1.14 to 1.23 per cent when K level was increased from 0 to 1000 g K_2O $t^{-1}y^{-1}$ (Latha, 1994b).

The content of K in leaf was within a range of 0.54 to 2.74% with reference to leaf position and stage of sampling (Mathew, 1990). The leaf K varied between 0.57 to 1.48% at different stages of growth and distribution of K showed a regular pattern with highest concentration at flowering (Kumar, 1983). The leaves of 10 year old tree contained 2.45% K during flushing and it decreased to 1.85% during fruiting and further to 1.45% during post harvest phase (Mathew, 1990). Bhaskar (1993) reported that lower leaf K concentration ranging from 0.85 to 0.9% during maturity and post harvest phases and higher content of 1.0 to 1.17% during flushing, flowering and fruiting phases in 10 year old trees of cashew variety BLA-139-1. Leaf K content was higher at pre-flowering stage than that at pre-flushing stage in all the varieties (Jagadeeshkumar, 2001). K content of leaves decreased with increasing age of leaves (Mathew, 1990).

The K concentration varied with plant parts. The K concentration was high in apple compared to leaf, kernel and shell (Bhaskar, 1993). The leaf K content varied with leaf position also. It was highest (0.54%) in seventh and eighth leaves and lowest (2.74%) in first leaf from inflorescence (Mathew, 1990).

Influence of other nutrients

Jagadeeshkumar (2001) studied the effect of lime and $MgSO_4$ on cashew and revealed that application of lime or $MgSO_4$ did not exert any influence on either nut yield or nut weight. However, the combination treatment of 500 g lime with 1500 g $MgSO_4$ produced the highest yield.

Jagadeeshkumar (2001)reported that lime application increased the nutrient content of leaves (N, P and K) but it decreased with application of $MgSO_4$. He also reported that the calcium and magnesium content of leaves showed an increasing trend with application of lime but iron content was found to be reduced.

According to Kumar (1983) calcium concentration of leaf varied with physiological phases and it was high during vegetative phase (0.76%) and low during flowering phase (0.11%).

The Mg concentration of leaf was high in seedling (1.61%) (Gopikumar and Aravindakshan, 1989). Sulphur concentration was also high in cashew seedlings (0.23% and it ranged from 0.18% to 0.24% (KAU, 1987).

Iron, Mn and Zn concentrations were also high in cashew seedlings and varied between 95 to 146 ppm, 49 to 158 ppm and 12 to 26 ppm respectively (KAU, 1987).

Nutrient interaction

Kumar (1985) found that P and K content of leaf decreased with increased N application. While higher rate of K increased the leaf N content but decreased the leaf P content. But Latha (1992) reported that K application failed to produce significant effect on leaf N and P content. Significant response for N application on enhancing the K content of leaves at fruiting stage was reported by Latha (1992).

Nutrient uptake and removal

Bhaskar (1993) reported that in cashew, the harvested dry matter is shared between apple, kernel and shell @ 51.8, 15.5 and 32.8% respectively.

A 4 year old cashew tree yielding 4.08 kg nut and 4.15 kg apple on dry weight basis removed 239 g N, 7.51 g P, 110 g K, 14.2 g Ca, 6.40 g Mg, 6.46 g S, 1709 mg Fe, 233 mg Mn, 252 mg Zn and86 mg Cu. Between apple, kernel and shell the nutrient removal was largest through apple. Of the total annual nutrient off take, 51% N, 49.8% P, 78% K, 45.6% Ca, 68.1% Mg, 59% S, 54.5% Fe, 45.5% Mn, 44.8% Zn and 52.2% Cu were through apple (Bhaskar,1993). The quantity of nutrients removed through different plant parts is given in Table 1.

The relationship between nutrient removal and nut yield was lesser and positive in respect of N, P, K, Ca, S. Fe, Mn, Zn and Cu while that of Mg was quadratic (Bhaskar, 1993).

Table 1. Nutrient off take through different plant parts of cashew

Plant part	N (g)	P (g)	K (g)	Ca (g)	Mg (g)	S (g)	Fe (mg)	Mn (mg)	Zn(mg)	Cu(mg)
Apple (4.15 kg t^{-1})	12.2	3.74	85.8	6.47	4.36	3.81	931	106	113	44.9
Kernel (1.32 kg t^{-1})	59.4	3.05	10.3	4.46	0.70	1.99	2.74	31.3	75.4	28.0
Shell (2.76 kg t^{-1})	57.7	0.72	14.0	3.26	1.34	0.66	504	95.5	63.9	13.1
Total (8.23 kg t^{-1})	239	7.51	110	14.2	6.4	6.46	1709	233	252	86

Total nutrient removal of graft raised cashew at 11th year of planting with nut yield of 8.5 kg per tree were 268.4 g N, 18.6 g P and 137 g K through apple, nut and litter (Jagadeeshkumar, 2001).The share of harvested parts to nutrient removal is given in Table 2.

Table 2. Share of harvested parts to nutrient removal

Plant Part	Nutrient removal (%)		
	N	P	K
Apple	22.4	28.1	51.5
Nut	49.2	53.3	30.8
Litter	28.8	18.6	17.7

Total nutrient removed through harvested parts and litter was the highest (59.8 $kgha^{-1}$) with application of fertilizer@ 750:325:750 g NPK $t^{-1}y^{-1}$ (Jagadeeshkumar, 2001).

Jagdeeshkumar (2001) also reported that the average nutrient off take through nuts and apple in cashew was 279.43, 41.58 and 186.4 g of N, P and K respectively. It was also observed that increasing levels of N increased the off take of N and K by the tree with highest off take of each was @ 1000 g N/tree level of application.

The effect of major nutrients on yield and quality of nuts in graft raised cashew (*Anacardium occidentale* L.) was studied by Nair (2002). The treatments consisted of three levels of NPK on eight years old cashew trees. The study revealed that increasing levels of nitrogen significantly increased the height and spread of cashew trees, while the girth was significantly increased by the interaction effects of N and K. P significantly increased the number of nuts per panicle. The yield was increased by N and K. Among the major nutrients applied, only N showed exceedingly high effects in sustaining the growth, yield and quality parameters. K application to a certain extend affected the yield and quality parameters but the response to P was seen to be exceedingly limited. The average nutrient off take was computed to be 279.43, 41.58 and 186.4 g NPK per tree.

An attempt was made by Latha (1998) to assess the quantum of nutrient (N,P and K) absorption as well as the ratio of nutrient absorption by cashew (six month old) seedlings. The quantum of nutrient (N, P and K) absorption as well as the ratio of nutrient absorption depends on the type of nutrition. The seedlings applied with N removed 198.8 mg of N, 2.43 mg of P and 19.43 mg of K per plant with a nutrient absorption ratio of 82:1:8. The seedlings applied with P removed 89.37 mg of N, 51.29 mg of P and 33.35 mg of K per plant with a nutrient absorption ratio of 3:2:1. The seedlings applied with K removed 167.7 mg of N, 11.02 mg of P and 95.66 mg of K per plant with a nutrient absorption ratio of 16:1:9.

On an average N, P and K absorption of a six month old cashew seedling was in the order of 151.95 mg N, 21.58 mg P and 49.48 mg K per plant with a nutrient absorption ratio of 7 : 1: 2 (Latha and Salam,2001).

An attempt was also made to compare the use efficiency of N, P and K by cashew seedling when grown under green house condition. On an average, the N, P and K use efficiencies of cashew seedlings were 24.7, 8.02 and 12.17 per cent respectively.

Varietal variation on leaf nutrient content and nutrient off take

The leaf nutrient content as well as the off take of nutrients varied with varieties. Varietal variation in leaf N status ranged from 1.28% in BLA-39-4 (KAU, 1987) to 3.26% in M-26/2 at CRS, Madakkathara (Bhaskar, 1993). Variation in leaf K content among varieties from 1.07 to 1.34% was reported by Bhaskar (1993).

Among the six varieties tested (V-5, M-26/2, A-1, V-3, H-1600 and H-1598), the leaf N content was highest in M-26/2(3.26 %) and lowest in V-5 (2.68 %). The leaf P and K contents were highest in M-26/2 and lowest in V-5 (Bhaskar,1993).

Bhaskar (1993) quantified the nutrient off take of cashew varieties. It was found that the nutrient off take differed between varieties. The off take was highest with the variety M-26/2 (439 g N, 13.9 g P and 184 g K per kg of nut along with its apple respectively) and lowest in V-5 (82.7 g N, 2.23 g P and 36.1 g K per kg of nut along with its apple respectively). The nutrient off take through harvested produce differed with variety and plant parts. The cashew varieties M-26/2 and H-1600 removed the largest amount of nutrients (N, P, K, Ca, Mg, S, Fe, Mn, Zn and Cu).

Among the 10 varieties of cashew studied for tolerance to N deficient soils, N uptake was high (above 220 $mgpl^{-1}$) in H-1591, M-26/2 and H-1608 and lowest (104.5 $mgpl^{-1}$) in K-22-1. N use efficiency was high (26.87%) in H-1591 and lowest (15.18%) in K-22-1. It was concluded that the varieties H-1591 and M-26/2 are efficient for N deficient soils (Table 3) (Latha and Salam, 2000).

Latha (1998) studied the tolerance of cashew varieties to P deficient soils and the results revealed that P use efficiency was highest (14.74%) in H-1591 and lowest (4.71%) in K-22-1 and H-1591 is an efficient variety for P deficient soils. Latha and Salam (2001) reported the tolerance of cashew seedlings to K deficient soils. It was observed that K use efficiency was high (above 22 %) in H-1591 and M-26/2 and lowest (13.59%) in K-22-1. K uptake was high (above 125 $mgpl^{-1}$) in H-1591, M-26/2 and H-1598 and lowest (70.1 $mgpl^{-1}$) in V-5. Hence H-1591, M-26/2 and H-1598 are efficient for K deficient soils.

Critical nutrient levels

An experiment conducted to study the effect of N,P and K on growth and yield of cashew fixed the critical levels for N and P in leaf at 2.09 and 0.14% respectively (Kumar, 1982). The maximum level of N and P for maximum response was fixed at 2.84 and 0.17% respectively. He also estimated the critical level of 1.96 to 2.53 per cent in the case of N and 0.14 to 0.17 per cent for P but failed to work out the critical concentration for K in view of linear response to K application. Mathew (1990) worked out the critical levels for leaf N and K as 2.00 and 1.03 per cent respectively.

Latha (1992) reported that critical levels of N, P and K were maximum at flowering. The critical values for N, P and K were 1.89, 0.069 and 0.51% at flushing. At flowering the values were 2.16, 0.118 and 0.90% and at fruiting the values were 2.05, 0.115 and 0.85% for N, P and K respectively.

Optimum doses of fertilizers

Kumar (1985) worked out optimum doses for N and P as 430 and 130 g $t^{-1}y^{-1}$ respectively. The expected yield at optimum dose of N and P are 4.71 and 4.5 kg nuts $t^{-1}y^{-1}$ respectively. A higher economic optimum doses were estimated by Latha(1992).They were 748 g N, 329 g P_2O_5 and 765 g K_2O per tree per year.

Diagnostic technique for nutrient analysis

Leaf being the major metabolic organ, is an ideal choice for sampling to ascertain fertilser requirements. A standard sampling procedure should be employed to eliminate all the factors that cause variation in leaf nutrient levels. Several workers tried to standardize leaf sampling for NPK analysis. Kumar (1985) opined that three composite samples consisting of 5 trees per sample taken after fruiting were sufficient.

Mathew (1990) standardized the leaf position for sampling. The last fully matured leaf, which was not having an inflorescence in leaf axil, was found to be the best for foliar diagnosis in relation to N and K. As regards the stage of sampling, the stage after opening of all the flowers of a panicle was recommended as the best season for diagnostic purpose of K and for N, preflushing was the best.

Table 3. Tolerance rating of varieties to nutrient deficiency in soils

Type of soil	Highly tolerant	Moderately tolerant	Moderately sensitive	Highly sensitive
N deficient soil	M-26/2, H-1591	V-5, H-1598	M-44/3,H-1608	
P deficient soil		H-1591	M-26/2, V-5, MDK-1, MDK-2,	A-1, M-44/3, K-22-1, H-1608, H-1598
K deficient soil		M-26/2, H-1591, H-1598	M-44/3, A-1	H-1608

Foliar nutrition to cashew

Several reports revealed that foliar application of N and P did not influence nut yield in cashew. The shyness of this crop in response to foliar application is not known. An experiment was conducted to study the influence of foliar absorption in cashew by Abraham (1994). The results revealed the following facts.

A minimum absorption time of seven days for ^{14}C-urea and six days for ^{32}P is essential for getting greater absorption of foliar applied nutrients. About 83.4 per cent of foliar applied urea was absorbed within 144 hours. The absorption efficiency of phosphorus was low and only 38.86 per cent was absorbed within the same absorption period and it did not increase by increasing the time of absorption.

The absorption of foliar applied ^{14}C-urea and ^{32}P varied with time of application in a day. The absorption of urea was the highest when application was done between 11.00 hours and 14.00 hours and that of phosphorus was the highest when applied at 11.00 hours.

Inclusion of a surfactant namely teepol (0.05 per cent) enhanced the efficiency of absorption of foliar applied urea and decreased the absorption of foliar applied phosphorus.

The percentage absorption of urea was higher during March compared to February. Absorption of urea was highest with the terminal leaves of latest flush. Among the three months (December, February and March) the absorption of ^{32}P was more during December and March and low during February. The absorption of ^{32}P differed with leaf age and it was highest with the basal leaves of the latest flush.

Cashew roots absorbed urea and phosphorus from solution culture. The absorption of urea was in molecular form. The root absorption of urea was also more than phosphorus. The highest root absorption of ^{14}C-urea and ^{32}P from solution culture occur within a period of eight hours and it did not increase further with time.

Effect of Biofertilizers

Biofertilizers occupy a very prominent role in sustainable agriculture. They are environment friendly and provide low cost agricultural input thus playing a significant role in improving nutrient availability to crop plants. Since cashew is grown mainly in wasteland the possibilities of exploiting the potentialities of biofertilizers as well as other management practices including efficient recycling of litter can be utilized best for improving the productivity.

Influence of mycorrhizal inoculation on growth and uptake of cashew was studied by Sivaprasad et al. (1992). Four different species of AMF genus Glomus and one species of Acaulospora were tested in cashew seedlings. There were six treatments involving five mycorrghizal fungi viz. *Glomus fasciculatum, G. constrictum, G. mosseae, G. etunicatum and Acaulospora morroweae* and a control. In general, seedlings inoculated with VAM fungi showed better growth compared to uninoculated control. Significant increase in dry weight of shoot and root was noticed in the plants pre-inoculated with *G. fasciculatum and G. etunicatum*. Inoculation with different VAM fungi increased the mycorrhizal infection, colonization intensity and the uptake of total phosphorus by the cashew plants. *G. fasciculatum* was found to be more effective to enhance growth and P uptake of cashew plants than *G.etunicatum*.

Usha (2002) reported that growth characters were improved by Azotobacter and Azospirillum inoculation in seedlings and grafts and also when planted in the field. The performance of Azospirillum inoculated plants was better than Azotobacter inoculated ones. Azospirillum inoculation contributed to production of more nuts both in seedlings and grafts. An increase of 24.03% in yield due to combined inoculation of Azotobacter and Azospirillum was obtained compared to uninoculated plants. Except Fe and Mn, the content of nutrients was also higher in inoculated plants (Usha, 2002).

AMF inoculated seedlings and grafts were superior in growth and nutrient content when planted in the field (Usha, 2002). The results also revealed the enhanced absorption of ^{32}P labeled fertilizers by AMF inoculation in three-month-old cashew seedlings.

Nutrient recycling

Cashew is a crop that is having enough litter fall which contributes organic matter to a large extent. An experiment conducted at CRS, Madakkathara to study the litter contribution in cashew plantation revealed that

the average litter fall in a ten year old cashew graft plantation ranged from 1656 to 8856 kg ha^{-1} with an average of 5014 kg ha^{-1}(Usha, 2001). Decomposition studies of leaf litter revealed that there would be over 90% weight loss within 21 months after litter fall. The rate of decomposition of cashew leaf litter was slow in early stages and then became faster especially during rainy season and declined in the subsequent summer season. The low rate of decomposition is due to low N content and high lignin content of the litter.

A study was conducted in Kerala to evaluate the resource quality of green leaves and litter fall of six commonly grown homestead trees for use as organic manures. Results revealed significant differences in the chemical composition of the green leaves and litter fall among the different species. Cellulose, lignin and hemicellulose contents were higher in cashew (Issac and Nair, 2002).

Cashew leaf litter contained 0.65% N, 0.22% P, 0.72% K, 0.22% Ca, 0.19% Mg, 369 ppm Fe, 17 ppm Zn, 15 ppm Cu and 283 ppm Mn. On an average, the litter incorporated 32.1 kg N, 1.1 kg P, 36.5 kg K, 10.9 kg Ca, 9.5 kg Mg, 2.1 kg Fe, 0.1 kg Cu and Zn and 1.2 kg Mn per hectare (Usha, 2002).

Usha (2002) also reported that the average annual return through litter in the unfertilized plot was 23 kg N, 0.9 kg P, 20.4 kg K, 6.2 kg Ca, 4.5 kg Mg, 0.7 kg Fe, 0.05 kg Cu, 0.04 kg Zn and 1.5 kg Mn per hectare as against 32.1 kg N, 1.1 kg P, 36.5 kg K, 10.9 kg Ca, 8.04 kg Mg, 2.1 kg Fe, 0.1 kg Cu and Zn and 1.2 kg Mn per hectare in the fertilized plot. Lesser contribution of nutrients in the unfertilized plots was due to the lesser quantity of litter fall in the latter. Hence it is revealed that the fertilizers had their impact on nutrient return through the quantity of litter and not through the quality.

It was also observed that fertilizer application also led to larger amount of organic residues and there was an increment in organic carbon content to the tune of 142% than the unfertilized plot (Usha, 2002).

Integrated Nutrient Management (INM) and organic cashew production

Cashew being a perennial crop, their vegetative and reproductive phases are simultaneous and continuous. Due to the deeper root system there is possibility for nutrient pumping where the nutrients leached to deeper layers are taken up and brought to leaves which are returned to soil through either litter fall or green leaf manuring. Cashew is having a large quantity of litter fall and can able to maintain the soil organic carbon content and consequently soil fertility to some extend. The building up of soil fertility and productivity and crop yield through the use of different components of INM such as organic recycling, organic manuring, biofertiliser application and inorganic fertilizer use are very conspicuous in cashew cultivation. The contribution of cashew litter, organic recycling and inorganic fertilizers to nutrient requirement of cashew is already discussed in this chapter.

Jose Mathew and Mahapatro (2005) detailed the package of practices for organic cultivation of cashew. Jose Mathew *et. al.* (2008) concluded the positive effect of organic manures and biofertilizers on the growth of cashew root stock and grafts as well as growth and yield of cashew trees after reviewing the works on organic forming in cashew.

Cashew being an export oriented crop, organic cashew production is important especially in the international market. Availability of organics is the major constraint in crop production for organic farming alone. To some extent organic resource generation can be achieved through litter fall in cashew. Hence INM is the best option and is gaining importance in the present scenario of organic revolution for cashew.

Effect of nutrient application on soil nutrient levels

Venugopal and Abdul Khader (1989) suggested a deep well drained laterite soil with high water holding capacity and organic matter content as an ideal soil type for cashew. Based on root activity studies using ^{32}P, Veeraraghavan (1990) concluded that cashew forged mainly from an area of 2 m radius area. Kumar (1985) reported that N application of 450 g N per tree per year increased soil N from 0.15 to 0.17 per cent while it reduced soil P from 0.11 to 0.07 per cent and it increased soil K from 248 ppm to 290 ppm. P application increased soil N and K content while it failed to bring about any effect on soil P. Kumar also reported that K application increased soil N and soil K while when K was applied at 100 g K_2O per tree per year the soil P content was decreased.

Latha (1992) reported that soil N was increased by N, P and K application. Soil P content was not influenced by N application but P and K application increased it. Available K content of soil was not affected by application of any of the nutrients. Experiment conducted by Rajeev (2002) to study the effect of major nutrients on yield and quality of nuts in graft raised cashew revealed that application of N, P and K increased their respective available nutrient status in soil.

Manuring and method of fertilizer application

The root distribution of cashew should be considered for efficient use of fertilizers. It depends on age of tree, type of planting material, the soil environment, level of nutrition, irrigation etc. According to Wahid (1989) and Salam et al (1995), the lateral spread is 3-4 m and vertical depth is 60-100 cm. But cashew is mostly a surface feeder. The fertilizer dose for adult cashew tree is recommended by Kerala Agricultural University is 750: 325: 750 g N, P_2O_5 and K_2O per tree per year (KAU, 2002).

Cashew requires 7-10 years to attain stabilized yield. So the fertilizer recommendation in relation to age will be different. It is 1/3rd for first year, 2/3 rd for second year and full dose of the recommendation from third year onwards.

The fertilizer application should be done when the nutrient demand is the highest.i.e. at flushing and early flowering stage which usually extends from September to December.

For adult trees apply fertilizers within a radial distance of 2-3 m leaving half a meter from the tree trunk or in narrow trenches of 15 cm deep and covered with soil within entire tree basin (10 cm deep) within the canopy area.

Future Strategies

The efficacy of management techniques should be examined on the basis of absorption, translocation and transformation of nutrients applied either directly or by biometric or metabolic expression for different agro climates separately. Nutrient management strategy should be developed through integrated nutrient management using different components and utilization of natural resources so as to fetch high value in the international market.

References

Abraham, M. 1994. Foliar absorption of N and P by cashew. M.Sc (Ag) thesis submitted to Kerala Agricultural University, Vellanikkara

Bhaskar, B.1992. Uptake pattern of major and minor nutrients in slelected cashew types. M.Sc (Ag) thesis submitted to Kerala Agricultural University, Vellanikkara

CPCRI. 1979. Package of Practice for cashew pamphlet No.8E. Central Plantation Crop Research Institute, Kasargod.

Gopikumar, K. and Aravindakshan, M. and Prabhakaran, P.V. 1987. Nutrient status in relation to seedling vigour in cashew. *Cashew Bull.* 15(12): 6-9

Gopikumar, K. and Aravindakshan, M. 1989. Sand culture studies in cashew. *Ind. Cashew J.* 18(2): 9-14

Issac, S.R. and Nair, M.A. 2002. Nutrient and biochemical composition of common tree leaf biomass. *Ind. J. Agron.* 4 (2) : 145-147

Jose Mathew and Mahapatro, G.K. 2005. Organic farming in cashew. Agrohios Newsletter 4(1) : 60-64.

Jose Mathew, Mini, C. and Gregory Zachariah. 2008. Organic nutrition in cashew nursery and plantation. Proc. Nat. Conference on ORganic farming in horticultural crops, 15-18 Oct. 2008. CPCRI, Kasaragod, pp.49

Jagadeeshkumar, T.N. 2000. Nutritional characteristics in relation to growth and productivity of cashew. M.Sc (Ag) thesis submitted to Kerala Agricultural University, Vellanikkara

KAU, 1987. Agricultural Development Project Completion Report 1977-86. Kerala Agricultural University, Vellanikkara p: 40-55

KAU, 2002. Package of practices recommendations: Crops . Directorate of extension, Kerala Agricultural University, Vellanikkara

Kumar, P.H. 1982. Qualitative analysis of leaf mineralisation in cashew.*Cashew Bull.*19 :6-8

Kumar, P.H. 1985 Effect of NPK on seed progeny and air layers in cashew. M.Sc (Ag) thesis submitted to Kerala Agricultural University, Vellanikkara

Latha, A.1992. Growth and yield of cashew in relation to foliar and soil nutrient levels. M.Sc (Ag) thesis submitted to Kerala Agricultural University, Vellanikkara

Latha, A., John, P.S., and Mercy George and Krishnan, S.1994a. Productivity of cashew as influenced by chlorophyll and N content. *J. tropic. Agri.* 32: 86

Latha, A., John, P.S. and Mercy George 1994b. Evaluation of leaf elemental composition of cashew in relation to productivity . *Proceedings of Sixth Kearala Science Congress, Thiruvananthapuram.* p.165-166

Latha, A., John, P.S., and Mercy George. 1996a. Effect of NPK fertilization on the growth of cashew. *The Cashew* 10 (3):

Latha, A., John, P.S., and Mercy George .1996b. Response of cashew to long term nutrient application in laterite soil. *J.tropic. Agri.* **24**: 32

Latha, A., John, P.S., and Mercy George. 1996c. Effect of fertilizer management on the quality of nuts. *The Cashew* **11** (1) : 26

Latha, A and Salam, M.A. 2000. Cashew (Anacardium occidentale) varieties tolerant to N deficient soils. *The Cashew.* **24** (2): 29

Latha, A. and Salam, M.A. 2001. Cashew varieties tolerant to K deficient soils. *J. Plantn. Crops* **29** (1): 16-21

Latha, A. and Salam, M.A. 2001 Varietal Variation in fertilizer response in cashew seedlings. *The Cashew* **15** (2): 36-41

Latha, A. and Salam, M.A. 2002 Effect of N at different levels of drip irrigation in cashew. *The Cashew* **15** (3): 18-27

Mathew, R. 1990. Yield prediction in cashew based on foliar and nutrient levels. M.Sc (Ag) thesis submitted to Kerala Agricultural University, Vellanikkara

Meagle, J., Mathew, S.K., Salam, M.A. and Kurian, S. 2002. Biological, chemical and solarisation effects on seedling vigour in cashew. 5th National Seminar on Indian Cashew in the New millennium – April 2002. Visakhapatnam.

Nambiar, M.C. 1983. Annual Reports- 1982-83. All India Co-ordinated Spices and Cshew nut Improvement Project, CPCRI, Kasargod

Nambiar, M.C. 1974. Recent trends in cashew research. *Ind. Cashew J.* **9** (3): 20-22

Nair, R.R.K. 2002. Effect of major nutrient on the yield and quality of nuts in graft raised cashew (*Anacardium occidentale L.*) MSc. thesis, Kerala Agricultural University, Thrissur, p.82

Nair, P.S., George, C.M. and Tajuddin,E. 1972. Studies on foliar and soil applicatoion of fertilizers in cashew. *Agrl. Res.J.Kerala* **10**: 10-13

Salam, M.A., Pushpalatha, P.B. and Suma, A., 1995. Root distribution patterns of seedling raised cashew tree. *J.Plantation Crops* **23** (1): 59-61

Salam, M.A. and Kamalam, N.V., 1993. Molecular absorption of urea by cashew. *J. Plantation Crops* 21 (2): 15-18

Sinish, M.S., 2003. Nutrient management in cashew nursery. M.Sc (Ag) thesis submitted to Kerala Agricultural University, Vellanikkara

Usha, K.E., 2001. Integrated nutrient management in cashew in relation to yield and quality. M.Sc (Ag) thesis submitted to Kerala Agricultural University, Vellanikkara

Veeraraghavan, P.G, 1990. Highlights of research and extension activities of the Cashew Research Station, Madakkathara. *The Cashew* **4**(2): 10

Veerarghavn, P.G, Celine, V.A. and Balkrishnana, S., 1985. Study on the fertilizer requirement of cashew. *Cahsew Causerie* 7(2): 6

Wahid, P.A., Kamalam, N.V., Asokan, P.K. and Vidyadharan, K.K., 1989. Root activity pattern of cashew. *J.Plantation Crops* 17 (2): 85-89

BIOTECHNOLOGY IN CASHEW

R. Keshavachandran and Sandhya Sudhan
Centre for Plant Biotechnology & Molecular Biology, College of Horticulture
Kerala Agricultural University, Vellanikkara, Thrissur - 680 656, Kerala
(e-mail: rkcs@rediffmail.com)

Introduction

Propagation through seeds is the natural means of propagation in cashew. However, since cashew is a cross pollinated crop, there will be a great amount of variability between progenies raised from seeds of a single mother tree. Hence vegetative propagation methods are resorted to. Though vegetative propagation methods such as softwood grafting is widely used, the rate of multiplication and field establishment are by no means commensurate with the demand for superior planting materials. Hence, development and standardization of *in vitro* propagation techniques for rapid multiplication of quality planting materials on a large scale will be useful. The demand for clonal planting materials of high yielding varieties is so high that standardization of *in vitro* propagation technique would help in supplementing the grafting technique available in cashew either by production of clonal planting materials by direct shoot bud regeneration or by increasing the supply of scion or budwood for use in conventional vegetative propagation. Induction of somaclonal variation by subjecting to a callus mediated somatic embryogenesis and/or organogenesis may help in creation of variability for some characters in cashew such as higher productivity, quality, resistance/tolerance to diseases, pests and stress. In addition, *in vitro* propagation techniques may also have application in rootstock propagation where the clonal rootstocks produced will impart uniformity in stand and performance to scion variety in the field, for an early induction of a newly released variety due to its speedy multiplication of the hybrid or elite clone whose planting material is limited in the initial stages and for *in vitro* conservation of germplasm and regeneration of trangenics (Thimmapaiah *et al.*, 2001). Besides, use of molecular markers will help in more efficient germplasm management of cashew and in genetic fingerprinting of the improved selections and hybrids that have been evolved in cashew.

Micropropagation

Stertilization of explants

Many workers encountered serious problems of contamination while initiating cultures of tree species (Wilkins *et al.*, 1985). Microbial contamination of plant tissue cultures is usually caused by fungi or bacteria which may be epiphytic or endophytic (Litz and Conover, 1981; Leifert *et al.*, 1994). These microorganisms out grow the explant tissue and cause loss of cultures (De Fossard, 1976). Preventing contamination of plant tissue cultures is critical to successful micropropagation.

Although both fungi and bacterial contaminations were observed in cashew, Ramanayake and Kovoor (1997) observed presence of systemic fungus in shoots excised from mature trees. Similarly, fungal contaminants were found to be predominant in mature tree cultures and were identified to be *Fusarium* (Thimmappaiah and Samuel, 1996). In mature seeds, the actual contaminant was also a fungus in addition to bacteria. The pericarp and remnants of the juicy stalk attached to seeds were found to be the source of contaminants (D'Souza *et al.*, 1996). Maintenance of stock plants by periodic sprays with fungicides (carbendazim, dithane, aureofungin) is advisable before collecting the explants. D'Silva and D'Souza (1993) found reduction in fungal contamination when the explants were agitated in 200 mg/l of carbendazim (Bavistin) for 5 hours and/or by incorporating in the medium. The best resource to control contamination in cultures of seedlings is to germinate the seeds *in vitro*.

Sterilization of mature and immature seeds is done by either mercuric chloride (0.1-0.2%) or sodium hypochlorite (1%) dip. Tender shoots (3-4") collected are defoliated and made into smaller segments (shoot tips and nodal cuttings). After a brief dip in 70% alcohol, the explants are washed thoroughly in sterile distilled water by adding

a pinch of detergent and then in carbendazim (0.1%) or dithane M-45 (0.3%) for 2 min. In laminar flow, sterilization is done by constant agitation in 0.1% mercuric chloride with 1-2 drops of Tween-20 (5-8 min). After rinsing the explants thoroughly 3-5 times in sterile distilled water, they were segmented to size before inoculating them in proper media. Chlorine and hypochlorite solutions were found to cause discolouration and browning in cashew. Hence mercuric chloride, though toxic, proved useful for the control of contamination (Thimmappaiah, 1997). For shoot tips and leaf segments a lower concentration of $HgCl_2$ (0.05%) was found useful.

In the work carried out at KAU, Vellanikara, nuts were harvested from experimental plantings and washed thoroughly with tap water and then with water to which a few drops of Teepol was added. The nuts were then treated with 1% cetrimide for 45 min and then with 1.5% Emisan for 1 hour before soaking in sterile water for 3 days. The soaked nuts were then treated with 0.1% mercuric chloride for 30 min, dipped in alcohol and flamed prior to the removal of the outer shell. The seed coat was removed and the embryo with the cotyledons inoculated into proper medium (Keshavachandran, 2004).

Shoot tips and nodal segments were taken from grafted plants which were sprayed regularly with Bavistin. The explants were first washed thoroughly in tap water to which a few drops of Teepol had been added. The explants were then treated with a solution of 0.1% Bavistin and a few drops of Teepol and shaken for 45 min followed by soaking in 0.1% mercuric chloride to which 0.1% sodium lauryl sulphate had been added for 5 min. The treated explants were then inoculated into proper medium (Keshavachandran, 2004).

Interference due to polyphenols

Browning of explants (necrosis) and media due to exudation of phenolics is one of the serious bottle-necks in the establishment of cultures from trees (Preece and Compton, 1991). It is found to be extremely severe in cashew as it contains high amounts of phenols (D'Silva and D'Souza, 1993). Among the different explants studied, leaf had the highest content of phenols and orthohydroxy phenols followed by shoot-tips and nodal cuttings (Thimmappaiah, 1997, Keshavachandran and Menon, 1997). Among the various methods suggested for controlling contamination, D'Silva (1991) found that soaking of explants in 0.28 mM ascorbic acid before inoculation, keeping cultures initially in the dark (3 weeks) (Hegde, 1988; Nair and Mohanakumaran, 1993), incorporating activated charcoal (0.1-1%) in medium (Nair and Mohanakumaran, 1993; Das *et al.*, 1996; Thimmappaiah, 1997), ascorbic acid (Nambiar and Iyer, 1988; Lievens *et al.*, 1989; Thimmappaiah, 1997) and PVPP (Sigma) incorporation in media, etc., were effective in the reduction of browning. Reduction in phenolic exudation was observed when the preparation of explants and culturing was done under low temperature conditions, by adding activated charcoal (50 mg/l), ascorbic acid (150 mg/l) and calcium pantothenate (200 mg/l) into the culture medium (Hegde and Kulasekaran, 1994).

A combination of different methods have also been seen to be useful (Keshavachandran and Khader, 1990; Keshavachandran and Menon, 1997). The browning of the explants were controlled by treating the explants with 1 g PVP, incorporating 0.05% activated charcoal in the medium and keeping the cultures initially in dark for 7 days.

In vitro seed germination

As cashew is highly prone to contamination, there is a need for raising plants under sterile conditions. For this the seeds which are healthy are selected, dipped in alcohol, flamed and sterilized in mercuric chloride (0.1 %) or commercial bleach and sown in trays/polybags containing sterile sand and soil mixture and maintained under greenhouse or laboratory condition (growth chamber). To hasten and get uniform germination the seeds are soaked in 36% acetone for 2 hours (Lievens *et al.*, 1989; Sy *et al.*, 1991).

Hegde *et al.* (1991) germinated seeds from 5 to 7 week old nuts on MS (Murashige and Skoog, 1962) and LS (Lin and Staba, 1961) media containing varying levels of auxins and cytokinins. The nuts were thoroughly washed in running water and in distilled water (2-3 times) and sterilized in 2% sodium hypochlorite (30 min) followed by 3-4 times rinsing with sterile distilled water. Holding the nut with the help of forceps, an incision of 2-3 cm into the shell was made. The shell was removed, and the whole kernel with intact embryo was scooped out. Embryo with part of the cotyledon was embedded in the medium. By 6 weeks, 8-10 cm long seedlings were obtained. MS medium containing 2 mg/l of NAA resulted in 100% seed germination.

D'Silva and D'Souza (1993) obtained *in vitro* germination of mature nuts by culturing seeds on plain agar medium. After thorough washing of mature nuts in distilled water, surface sterilization, was done in 0.1% mercuric chloride and 0.1% sodium lauryl sulphate for 15 min. With several rinses in sterile distilled water, they were germinated in screw cap bottles, containing 70 ml of 0.6% plain agar medium. Similarly, immature nuts were sterilized for 15 min in 0.1% mercuric chloride followed by twice rinsing in sterile distilled water. The pericarp was cut open in laminar flow, and the seed was lifted out. After careful removal of seed coat the decoated seeds were germinated in plain agar medium.

For germinating cashew seeds *in vitro*, Sardinha *et al.* (1993) washed the seeds under running water for 10 min and then treated with 'domestic bleach' at varying concentration for 10-30 min. Seeds were germinated in solidified agar (0.3%) or MS at varying strength with BA (8-10 mg/l). At 30-50% of bleach, 66% of the cultures germinated was free from contamination. On agar and MS full-strength the germination obtained was maximum (83%).

Das *et al.* (1996) germinated both mature and immature nuts by dipping-in 70% alcohol for 1 min and flaming, followed by surface sterilizing with 0.1% mercuric chloride for 1 hour. After rinsing the nuts in sterile distilled water, the nuts were again flamed after dipping in 70% alcohol and cut open aseptically to dissect out the entire seed. The seeds were germinated on basal MS medium supplemented with 1% AC and 0.8% agar.

At the National Research Centre for Cashew (NRCC), Puttur, India, freshly harvested mature seeds were first dipped in 70% alcohol and flamed followed by a thorough washing in sterile distilled water with a pinch of detergent and fungicide. The seeds were first sterilized in 70% alcohol (30-45 sec) followed by 0.1% mercuric chloride (5-20 min) by constant agitation. After rinsing the seeds thrice in sterile water, they were inoculated into screw cap bottles containing media or wet absorbent cotton. Germination was done under dark and was observed after a fortnight. Alternatively, after dipping the seeds in 70% alcohol and flaming them, the testa was removed by shelling the nut in a pedal-operated shelling machine. The whole seed with testa or without testa was sterilized by dipping in 70% alcohol followed by 0.1% mercuric chloride (10 min) and inoculated onto B5/MS medium supplemented with 0.1 % AC. To germinate immature nut (4 to 5 week old), the green seed was wiped in cotton wetted with alcohol and washed thoroughly in sterile distilled water by adding a pinch of detergent. Sterilization of seed was done first in 70% alcohol (30-45 sec) followed by agitation in 2.5% chlorine solution containing one drop of Tween-20 for 30 min. After thorough rinsing in sterile distilled water, the green nut was held with long forceps in a big petri plate, and a transverse cut was given at the centre of it to separate proximal and distal portion of the seed with shell. The distal portion was discarded and from the proximal portion the seed portion with growing point (embryo with a portion of cotyledon) was scooped out and inoculated on to various solid media (MS, WPM, B5) containing 0.1% AC and with or without NAA (2 mg/l). The incubation was done in 2000-3000 lux light with 16/8-h photoperiod. The medium containing WPM, salts with NAA was the best with 98.4% germination (Thimmappaiah *et al*, 2001).

At the KAU, Vellanikkara, freshly harvested mature seeds were first surface sterilized and then the seed coat and the testa over the embryo were removed. The embryo with the part of the cotyledon was inoculated into solid MS medium supplemented with charcoal, 3% sucrose, kinetin, NAA, Brassinolide and cultured at 28±1°C and 12 hours photoperiod provided by cool white fluorescent lamps (2000 lux) (Keshavachandran, 2004).

Shoot bud culture

Explants from *in vitro* source as well as from mature plants have been tried in cashew. Shoot tips, nodal segments and cotyledonary nodes have been taken from *in vitro* seedlings and cultured. Multiple shoots have been observed from the explants and among these, cotyledonary node explants have shown the maximum number of multiple shoots.

Cotyledonary node culture: Multiple shoot-buds were induced in cotyledonary nodes (*in vitro* source) cultured along with cotyledonary segments on MS medium supplemented with 4% sucrose, 5.3 g/l maltose and 5 mg/l BA. The shoot-buds elongated on MS medium supplemented with CW (10%), 5.3 g/l maltose and 5% sucrose. The microshoots were rooted *in vitro* on MS medium with 4% sucrose, 0.5 mg/l IAA and 1 mg/l IBA, and the plantlets were potted and established in the field (D'Silva and D'Souza, 1992a,b).

Das *et al.* (1996) observed that cotyledonary nodes produced more buds (12 buds) than the other explants on MS medium containing 1 mg/l BA, 0.5 mg/l Kin and 2.0 mg/l zeatin.

Cotyledonary nodes with intact cotyledons obtained from *in vitro* germinated seedlings (mature seed) of H4-7 and VRI-2 showed multiple shoot induction on MS medium supplemented with 2.25 mg/l BA and 0.2 mg/l IBA. After 5-6 subcultures at monthly intervals, the shoot-bud proliferation increased and as many as 40-60 shoots could be obtained in a span of 3-4 months. Cotyledonary nodes without their cotyledons also showed shoot-bud proliferation (4-6 shoots/explant) on basal medium and with 0.5 mg/l zeatin on MS medium (Thimmappaiah, 1997).

Ananthakrishnan *et al.* (2002) developed adventitious shoots and roots from the proximal end of excised cotyledons of mature cashew embryos when cultured on MS medium with BAP and 3% sucrose. They reported that there was no vascular connection between the regenerated roots and shoots whereas isolated shoots rooted after treatment on half strength MS liquid medium containing IBA for 72 hrs. About 55% of *in vitro* raised shoots when transferred to half strength MS medium with IBA developed roots.

Node and shoot-tip culture: Hegde (1988) cultured nodal segments on modified MS and LS medium supplemented with BA (2.0 mg/l) and GA_3 (1.0 mg/l) showed only a single axillary shoot formation in two months. Initially, the cultures were kept in the dark for one month. The shoot length attained was 1.5-1.75 cm. No rooting could be obtained from such shoots. The shoot-tips from seedlings and air-layered plants were induced to grow only when cultured on MS and LS medium supplemented with 5-10 mg/l IBA and 1 % AC, under continuous darkness for 4 weeks. There was slight callus formation at the base and on transferring shoot-tips to proliferating medium containing cytokinins alone and cytokinins with low levels of auxin, and there was slight proliferation after two to three months.

At Central Plantation Crops Research Institute, Kasaragod, India, apical meristem and axillary buds of nodal region excised from mature trees were cultured on MS and obtained elongation of shoots and also observed formation of a compact, white or creamy callus at the cut-end. Further induction and growth of callus required dark incubation in the medium containing 2,4-D (2 mg/l). For rooting, NAA at 1 mg/l or at lower levels, was favourable. Multiple shoots were also observed with no rooting (Nambiar and Iyer, 1988).

Lievens *et al* (1989) reported that nodal segments excised from the 6 to 15 month old seedlings showed bud bursting on Lepoivre medium containing MS minor nutrients, glucose (3%), ascorbic acid (0.1%), 2iP (2 mg/l) and GA_3 (0.5 mg/l). On the medium containing Kin (2 mg/l) also, the axillary shoot development was similar. Although there was opening of bud in presence of BAP medium, there was limited development of the axils. Proliferation was stimulated, by the two phase technique and enhanced with the addition of BAP (0.5 mg/l) in the liquid phase for at least three days. Continuous presence of BAP in liquid phase proved toxic as the nodes became necrotic. The average number of axillary shoots per node was 2-3. Elongation of shoots was obtained on liquid medium under agitation with vitrification of shoots (59%). Rooting was obtained in 30% shoots on IBA (2 mg/l) containing medium following ten days of dark incubation.

Shoots from microcuttings of cashew were cultured on half-strength MS and SH media supplemented with zeatin riboside (5 mg/l), BA, Kin, 2iP, GA_3, TIBA and NAA alone and in combination. Only MS medium supplemented with 5 mg/l zeatin riboside supported the axillary bud growth. The shoots cultured on SH medium supplemented with zeatin appeared yellowish with lamina rolled, whereas MS with other hormones alone did not support bud growth. Shoots in the presence of zeatin riboside first showed a 'time-lag' in growth followed by elongation and node formation without successive opening of the new axillary buds indicating apical dominance. GA_3 and TIBA (0.5 mg/l each) were tried for overcoming apical growth inhibition. Gibberellic acid (GA_3) in combination with zeatin riboside favoured shoot elongation and, bud growth. NAA at 5 mg/l resulted in 25% rooting with the formation of basal callus (Leva and Falcone, 1990).

Nodal cultures were established on half-strength MS medium containing BA with IAA or NAA on both agar-solidified medium and liquid medium supported with filter paper bridges. In liquid medium, the phenolic exudation was less, and the shoots remained green with some callus formation. Budding in 85 to 100 per cent cultures were observed after two weeks in culture (Bessa, 1990).

Farrant *et al.* (1990) observed shooting of apical nodes cultured on woody plant medium (Lloyd and McCown, 1980) supplemented with BA. Rooting was less uniform and clonal variation was observed for rooting response.

Multiple shoots from leaf axils of seedlings were induced on modified MS containing ammonium nitrate (2000 mg/l), calcium chloride (650 mg/l), potassium dihydrogen orthophosphate (200 mg/l), 4% sucrose, CW (10%), 10 mg/l BA and 4.8 mg/l Kin. The buds formed showed no elongation (D'Silva, 1991).

Nair and Mohanakumaran (1993) cultured nodal segments on SH medium with either NAA (2 mg/l) + Kin (2 mg/l) + AC (0.1%) and incubated in the dark for 3 weeks at 26°C or with BA (2 mg/l) + NAA (2 mg/l) + sucrose (2%) medium. Shoots got elongated when the cultures were incubated in light (3000 lux) in a 16-h photoperiod. The shoots attained a length of 3.02-4.0 cm with 2-5 leaves. The elongated laterals were multiplied on either SH + BA (0.5 mg/l), or SH + BA (1.0) + Kin (1.0 mg/l) + IBA (0.2 mg/l) + GA_3 (1.0 mg/l) or SH + BA (2 mg/l) + IAA (1.0 mg/l) + AC (1%) + myoinositol (100 mg/l). *In vitro* rooting of single shoot was observed on half-strength MS medium containing either NAA (2.0-5.0 mg/l), or IBA (2.0 mg/l), or NAA (2.0 mg/l) + IBA (2.0 mg/l). The best rooting (50%) was seen on the medium containing NAA (2.0 mg/l) + IBA (2.0 mg/l) + sucrose (3%) + agar (0.6%) + AC (1 g/l). For the first fifteen days, the shoots were placed in auxin medium, and subsequently the rooted ones were transferred to half-strength MS without phytohormones. The number of roots formed varied from 1-5 per shoot and the root length from 6.0-8.0 cm in 14 days after initiation. The rooted plantlets after one week's exposure to light were transferred to pots containing sterile sand. Attempts to induce *ex vitro* rooting by a slow dip in IBA (100 mg/l for 24 hours), or a quick dip in IBA (2000 mg/l for 10 seconds) were not successful.

Age and plant growth conditions influenced the rate of multiplication in nodal cultures (Sardinha *et al.*, 1993). Maximum bud break (94%) was noticed on hormone-free MS medium. Better flushing and multiple shoot induction was observed on the medium containing BA (1.0 mg/l) and IAA (0.5 mg/l). BA and NAA had shown some inhibitory effect. Multiple shoots were observed from the callus produced at the base of 9 to 12 month old *in vitro* cultures. Reduction of phosphates or nitrates in standard MS medium had no impact on the results. Rooting was induced spontaneously and by auxin treatment with IAA or IBA. However, rooting results were not consistent. *Ex vitro* rooting by IBA dip was also observed though the frequency was low. On a pot mixture containing lime-free-based-compost and perlite, 83% plantlets survived the hardening process.

Nodal segments of seedlings showed axillary buds and multiple shoot development on semi-solid MS medium modified in respect of nitrogen concentration and supplemented with 44 μM/l GA_3. Functional leaves developed within 3-4 weeks of incubation at 26°C, 3000 lux illumination, 14:10-h day and night cycle and 80% RH. Tap root formation was reported from the bottom end of nodal segments on modified semi-solid Lloyd's medium supplemented with BA (2.5 mg/l), NAA (2.8 mg/l), GA_3 (3.7 mg/l) and AC (0.1%) for one week of continuous dark incubation followed by two weeks of normal incubation in light (Lad *et al.*, 1994).

Das *et al.* (1996) observed shoot multiplication in nodal (4 buds) and shoot-tip explants excised from the seedlings raised from immature embryos were cultured on MS medium supplemented with BAP (1 mg/l) + Kin (0.5 mg/l) + zeatin (2 mg/l). Rooting of microshoots increased to 80-90% when the microshoots were submerged in a suspension of *Agrobacterium rhizogenes* as compared to pulse treatment of IBA with 20-40% rooting.

Thimmappaiah and Samuel (1996,1999) reported that nodal cultures made from one-month-old seedlings and *in vitro* germinated, seedlings showed satisfactory establishment on MS medium with 75% of the explants forming single shoots. However, the shoot-tips from nursery seedlings showed poor response. Nodal cultures grown on MS medium with various levels of BA, Kin, 2iP, adenine sulphate showed only single shoot formation. Even, incorporating BA, Kin, 2iP and zeatin in combination of two at two levels (0.5 and 1.0 mg/l) produced very low multiple shoot induction (6-18%) (Thimmappaiah, 1997). However, when shoot tips and nodal cuttings excised from *in vitro* source were cultured on the above basal medium supplemented with thidiazuron (TDZ) alone (0.05-2 mg/l) or in combination of TDZ at 0.1 mg/l with BA (0.5, 1.0 mg/l), IBA and NAA (0.05-0.5 mg/l each), the multiple shoot production (1-13 shoot buds/explant) was induced in majority of the explants. When TDZ was used alone, the multiple

shoot buds (1-5 buds/explant) were obtained with an average of 1.7 shoot buds/explant, and when TDZ was combined with other plant growth regulators, the multiple shoot formation increased to an average of 3 buds/explant. The best combination for multiple shoot induction was TDZ (0.1 mg/l) with either 0.1 mg/l of IBA or NAA with an average of over 4 shoot buds/explant. The shoot-buds induced could be elongated on half MS or on Raj Bhansali (1990) solid medium supplemented with 400 mg/l glutamine and activated charcoal (0.2%). Even liquid MS medium supplemented with 2.5 mg/l Kin shaken at 100 rpm and in light was useful for elongation of shoot buds (Thimmappaiah, 1997; Thimmappaiah and Samuel, 1996, 1999).

Rooted plantlets were hardened in laboratory on liquid MS medium with gradual reduction of sucrose and also in pots containing sand and soilrite mixture 2:1 covered with polybags. In laboratory they had a survival of 80%. Later the hardened plants from laboratory were potted in normal pot-mixture and housed in the greenhouse for further hardening under diffuse light. From explant to planting of tissue culture plants a total duration of 38 - 52 weeks were required. Regenerated plants were planted in the field with 100% establishment (Thimmappaiah and Samuel, 1996, 1999).

Nodal cuttings from forced shoots (pruned frames) of cashew grafts (one-year-old) and field-grown trees (10-year-old) could be established on semi-solid half-strength MS salt, medium supplemented with glutamine (400 mg/l) and AC (2 g/l). Budding of explants was affected by age of the plant. Establishment of cultures was also affected by excessive amount of contamination and tissue browning. These shoots on subculturing in MS or WPM supplemented with 0.1 and 2.0 mg/l of TDZ showed multiple shoot induction (2-6 buds/explant). However, they failed to show elongation. Slow growth and drying (necrosis) of shoots were other problems encountered during the culture of mature tree explants (Thimmappaiah, 1997).

Experiments were conducted to investigate cultural factors affecting bud sprouting, shoot elongation and node development from shoot nodes of elite selections of one-month-old and 1-, 4- and 5-year-old greenhouse-raised cashew stock plants originating from Brazil, Guinea-Bissau and Tanzania. MS medium containing half-strength macroelements was the most effective medium for bud sprouting and shoot elongation. The presence of gibberellic acid in association with zeatin or 2iP promoted flush growth, while in association with 2iP or Kin it favoured shoot elongation. Microshoots rooted *in vitro* at a frequency of 42% when cultured for 5 days on WPM supplemented with 100 μM IBA. Almost 100% of rooted shoot survived weaning and produced healthy, vigorous plants (Mantel et al., 1997).

Using glasshouse-raised plants (1 month, 1 year and 5 years old), factors affecting shoot development from shoot nodes of 1 Tanzanian and 2 Brazilian elite selections of cashew were assessed by Boggetti *et al.* (1999). Sprouting of buds decreased strongly with increasing age of mother plants. MS salts containing half-strength macroelements were the most suitable for bud sprouting and shoot elongation. Gibberellins supported bud sprouting and shoot elongation but blocked rooting. The shoots developed in the presence of cytokinins were short and produced axillary branches. Microshoots rooted *in vitro* at a frequency of 42% when cultured for 5 days with 100 μM IBA. Over 40% of rooted microshoots survived weaning.

A study was conducted by Mneney and Mantel (2002) to develop *in vitro* culture techniques relevant to the clonal multiplication of cashew using the Tanzanian elite clone AC4. The results showed that MS medium with full strength macroelements was best for shoot proliferation and elongation and also the ability of axillary buds of juvenile explants (1-6 months old) to sprout and elongate increased compared to those from aged explants. Out of the 6 cytokinins compared, BA and zeatin were found to be optimal for axillary shoot proliferation and shoot elongation respectively. When cultured on woody plant medium with 0.5 mM IBA, 50-60% of microshoots rooted *in vitro*, and about 60-65% survived weaning and produced healthy vigorously growing plants.

Keshavachandran (1996), Keshavachandran and Shelja (1999), Keshavachandran (2004) and Keshavachandran and Riji (2005) reported that shoot tips, nodal segments and cotyledonary nodes taken from *in vitro* raised seedlings were used to establish *in vitro* cultures. The explants were isolated 7-10 days after germination of mature seeds under *in vitro* conditions and cultured in appropriate media. The explants were best established after culturing in the dark for 7 days in MS medium supplemented with kinetin, NAA and brassinolide. They

initiated growth when cultured under light after 7 days in the dark. The cultures after 3 weeks under light were transferred to MS medium supplemented with coconut water, maltose, sucrose and brassinolide for another three weeks.

The shoot buds taken from grafted plants were initially cultured in MS medium supplement with kinetin, NAA, brassinolide, activated charcoal and myo-inositol and kept in the dark for 7 days. After 3 weeks under light, the cultures were subcultured into MS medium supplemented with BA, branssinolide, activated charcoal and myoinositol and cultured for 3-4 weeks.

In vitro rooting was found feasible with pulse treatment with IBA for 24 hours followed by transfer to ½ MS liquid medium supplemented with low levels of IBA and reduced sucrose. Rooting was also obtained with ¼ MS medium supplemented with glutamic acid, IBA and reduced sucrose shoots grafted plants were pulse treated with high concentration of IBA followed by transfer to ¼ MS liquid medium supplemented with IBA, glutamic acid, reduced sucrose and myo-inositol.

Hardening was initiated under *in vitro* conditions itself by cutting the rooted plantlets in liquid ½ MS containing low levels of surcrose for 10 days and then in medium without sucrose for another 10 days. The rooted plantlets were taken out of the containers, washed with distilled water to remove the adhering media, dipped in fungicide for 5 min and transplanted into small mud pots filled with sterilized sand which were immediately transferred into the mist chamber. After around 45-60 days in the mist chamber, the plantlets were transferred into medium sized mud pots filled with normal potting mixture and kept in the net-house until planting in the field.

Micrografting

Micrografting has been used in citrus, apple, avocado and various other plants for variety of reasons. In citrus, micrografting is used to obtain virus free plants, while in the others, it is used to increase the rootability of microcuttings, and in cashew it can be used to achieve rejuvenation and to overcome slow growth of cultures of mature tree origin. Ramanayake and Kovoor (1997) reported *in vitro* micrografting using seedling material. The rootstock was 2 to 3-week-old *in vitro*-raised seedlings, and the scion used for grafting was axillary shoots or shoot-tips of seedling origin. The highest graft-take (57%) was achieved when the shoots were pre-treated with a mixture of IAA and sucrose for one week before grafting onto stock plants. Grafted plants grew well on MS medium containing AC and 5 mg/l NAA.

Micrografting of shoot-tips excised from the greenhouse raised seedlings and field grown plants by a modified side grafting procedure on *in vitro*-raised seedlings as rootstock gave a grafting success of 40-80% (Mantel *et al.*, 1997). Shantha *et al.* (1999) used excised embryos germinated *in vitro* as rootstocks. Shoot-tips and axillary shoots proliferated from seedling shoots were the source of scions. Flooding the cut-surfaces immediately with a mixture that contained citric acid controlled oxidative browning. Firm contact between the scion and rootstock was assured through the use of an aluminium foil tube at the graft junction. An IAA pre-treatment of the scions and a culture medium with NAA that enhanced rooting brought about graft fusion and development, indicating an exogenous auxin requirement.

Thimmappaiah *et al.* (2002) developed a micrografting technique in cashew using 20-25 days old *in vitro* germinated seedlings as rootstocks and axenic shoot cultures established from mature tree explants cultured on hormone free MS modified medium were made into scion of 3-15 mm length. The micrografts were then cultured on hormone free liquid half strength MS medium and potted out after 10-12 weeks. The results showed that grafting success depended on the method of grafting and size of the scion. Shoot-tip grafting and side grafting gave good result, while scion length greater than 5 mm was highly successful. Scion presoaked in either water or 0.01% ascorbic acid and 0.015% citric acid (1:1) reduced phenolic browning and drying of scion.

Keshavachandran (2004) and Keshavachandran and Riji (2005) reported that *in vitro* grown seedlings 8-9 days after germination were used as the root stock and 1-1.5 cm long shoots obtained from stage II cultures maintained in the culture room or 2-2.5 cm long shoots obtained from shoot buds taken from grafted plants were used as the scion for micrografting. Among the different methods used, side and cleft grafting were found to be suitable. Due to the ease of operation and faster union, side grafting was preferred. The *in vitro* seedling to be used as the root stock is taken out of the test tube, 3 to 4 leaves removed and a slanting cut based on the type of shoots used was made on

the seedling just above the cotyledonary node. The shoots were also prepared by making a wedge shaped cut on both sides and then inserted into the cut. The union was tied with sterilized thread and the grafted plant transferred into liquid basal medium and kept for 2 weeks after which the grafts were transplanted into mud pots and placed in the mist chamber.

Induction of callus

Callus has been induced in cashew from different explants. Cotyledonary segments and hypocotyl tissue were the explants first cultured *in vitro* in cashew (Philip, 1984; Philip and Unni, 1984). Multiple plantlets were directly induced, from cotyledonary segments without callus formation on LS medium supplemented with IAA and Kin (0.5 mg/l each). Samson *et al.* (1989) also observed multiple shoots from embryonal ends of cotyledonary sections cultured on MS medium supplemented with hormones POA, BAP and activated charcoal. Similarly, Hegde *et al.* (1991) also obtained multiple shoots from the embryonic end of cotyledonary segments of mature nut cultured on LS medium supplemented with NAA (0.5 mg/l) and Kin (1 mg/l).

Callus induction from cotyledonary slices was obtained on LS medium supplemented with 3-4 mg/l of 2,4-D. High degree of rhizogenesis was observed from the explants subcultured on hormone-free medium. The callus grew till 60-75 days and stopped. It was white in the initial stage but turned dark brown later. Subculturing callus at any stage to regenerating medium did not result in any differentiation of planlets (Hegde, 1988).

Cotyledonary segments cultured on MS medium supplemented with either IAA + activated charcoal (AC) or 2,4-D+BAP+AC showed both callus induction and rhizogenesis (Samson *et al.*, 1989). Similarly, Srivatsan *et al.* (1989) observed callus in cotyledonary segments cultured on MS medium containing PDA hormone. Lakshmi-Sita (1989) and Lakshmi-Sita and Sreenatha (1990) observed callus induction in cotyledonary and hypocotyl segments excised from germinating seedlings of cashew on MS medium supplemented with NAA (5 mg/l), BAP (1 mg/l), 2,4-D (1 mg/l) and CW (10%). In presence of NAA and BAP, a compact callus was obtained and shoot-buds got differentiated when the medium was supplemented with BAP (0.05 mg/l) and NAA (0.1 mg/l). The buds grew and became brown during subculture. Callus grown on media supplemented with 1 mg/l NAA and 0.5 mg/l Kin or BAP, showed embryo differentiation. These embryoids germinated on MS containing NAA (0.02 mg/l). The somatic embryos had well developed root system but shoot development was poor.

Young leaves of seedlings were cultured on the medium supplemented with NAA and BA at various levels. At 2 mg/l NAA with 0.2 mg/l BA, leaf lamina showed expansion in length. At higher levels of growth regulators (3.0-6.0 mg/l NAA and 0.8-1.0 mg/l BAP), proliferation of calli was observed on main veins, particularly at cut-ends. Leaves produced a mixture of compact brown and globular greenish white calli. The former calli did not show any morphogenetic activity while the latter gave rise to meristematic structures that developed into roots (Leva and Falcone, 1990).

Sy *et al.* (1991) obtained callus from leaves and petioles excised from young seedlings when cultured on modified MS medium supplemented with different levels of NAA/BA or 2,4-D/BAP combination. The best morphogenetic response was obtained from leaves in presence of NAA (9-18 mg/l) with BAP (0.05-0.17 mg/l). 90% of the foliar explants showed callus formation on cut and wounded edge of leaf midrib as well as on petiole slices. Callus formation occurred also on the secondary veins to an extent of 30%. Similar results were obtained when explants were cultured in presence of 2,4-D (5.5-11.0 mg/l), BAP (0.05-0.17) mg/l) and elicited no morphogenetic activity. The callus formed was different in consistency and colour, 60% of the calli being globular with white yellowish structures, while 30% were friable and blackish brown. NAA induced small and creamy coloured calli which later turned meristematic and produced adventitious roots. Cotyledonary pieces cultured for 12 months on SH medium supplemented with NAA (3 mg/l) and BA (0.8 mg/l) showed low embryogenesis (2%) (Sy *et al.*, 1991). A mass of white embryoids was observed with no evidence of constricted root pole on the adaxial face of the cotyledon pieces. On the apical part, the primordial leaflets could be distinguished anatomically. The embryoids turned green after maturation on modified MS or on half-strength MS medium with IAA (1 mg/l) and BA (1 mg/l) where 80% of the cotyledonary structures showed expansion in size. Percentage of callus and embryonic activity was confined to the basal portion, thus indicating a developmental gradient along the seed tissue.

Immature cotyledonary segments cultured on LS medium supplemented with IAA and BA (2 mg/l each) showed direct embryogenesis (Hegde *et al.*, 1992). Globular embryo structures appeared from swollen cotyledonary region and developed into torpedo and cotyledonary stages on low level auxin or on hormone free medium. There was bipolar differentiation with strong development of root region and poor shoot meristem growth.

Nair and Mohanakumaran (1993) also reported profuse callus formation on SH medium supplemented with 2,4-D, BAP, NAA (1 mg/l each), glutamine (100 mg/l) and sucrose (3%) and on Y3 medium supplemented with 2,4-D (20 mg/l), NAA (10mg/l), silver nitrate (5 mg/l), sucrose (4%) and activated charcoal (10 g/l). Shoot regeneration from the cotyledon-derived callus was obtained when callus induced was subcultured first on MS medium with BA (3 mg/l), GA_3 (1 mg/l) and sucrose (3%) and then onto MS + BA (2.0 mg/l) + IBA (0.5 mg/l) and sucrose (3%). Nair and Mohanakumaran (1993) also obtained profuse callusing from the midrib portion of *in vitro* grown leaf-tips grown on SH medium in presence of 2,4-D (2 mg/l), Kin (1.0 mg/l), sucrose (3%). The callus was friable and creamy white. Nair and Mohanakumaran (1993) also observed somatic embryogenesis from immature cotyledonary segments cultured on LS medium supplemented with IBA (2.0 mg/l), glutamine (100 mg/l), ascorbic acid (100 mg/l), citric acid (100 mg/l), calcium pantothenate (250 mg/l) and sucrose (3%). Here embryogenesis was observed 11 weeks after inoculation from the distal region. The embryoids were globular and creamy. Subsequently, they turned yellow and finally dark green. Embryoid development was hastened on transfer to LS basal medium. The induction period was shortened further when cotyledons were cultured on modified MS medium containing half-strength major salts and supplemented with 2,4-D, NAA. BAP (1 mg/l each) and sucrose (6%). On the same medium with reduced level of hormones (half of the original level), the callus developed into globular creamy structures but shoots were malformed. Addition of CW (15-30%) could not improve shoot formation. In three more treatments containing BA and maltose, embryogenesis was observed. For germination of embryoids MS medium containing BA (2.0-5 mg/l), IBA (0.5 mg/l), maltose (5.3 g/l) and sucrose (3-4%) was found suitable.

In vitro multiplication of cashew was achieved when callus induced at the base of the microcuttings was subcultured at monthly intervals on MS mineral medium containing Morel's vitamins. A medium with BA (1 mg/l) and IAA (0.6 mg/l) and another medium free of hormones were used. After 9-15 months, the calli started to produce multiple flushes at a high frequency. The white callus could be multiplied easily on hormone-free medium. The shoots were rooted spontaneously or by an auxin treatment (Bessa and Sardinha, 1994).

When cotyledonary segments excised from the 5- to 6-week-old nuts were cultured on both SH and MS medium supplemented with 2,4-D (0.5-4 mg/l) induced moderate callus in the dark. SH medium was better than MS. In SH medium at 1-4 mg/l 2,4-D moderated profuse callus was induced. In the beginning callus was cream coloured which turned brown and dark later. Among leaf, cotyledon and internode segments, the callus induced in cotyledon was profuse. Varietal differences were observed for callus induction. Callus in VRI-2 variety was highest and least in BPP-4. Callus in mature cotyledon fact growing accompanied by rhizogenesis (Thimmappaiah, !997). However, the callus induced from immature cotyledon was regenerative.

Cotyledonary segments excised from immature seed nuts were cultured on MS medium supplemented with TDZ (0.5-2 mg/l). It produced a cream coloured slow growing callus in light. Callus grew profusely when it was subcultured on Raj Bhansali (1990) medium (RBM). On this medium, callus turned green, nodular with meristemoid differentiation. Although there was green leaf primordial differentiation, the plantlet formation did not take place until the cultures were grown on RBM medium with 1 mg/l zeatin. The frequency of regeneration was low, and for complete regeneration of plantlets 6-8 months were required from the immature cotyledonary callus (Thiminappaiah, 1997).

When immature cotyledonary segments of H 2/11 and H 3-4 were cultured on MS medium supplemented with BAP, 2,4-D (1 mg/l each), NAA (5 mg/l) and CW (10%) and in BAP + 2,4-D (1 mg/l), somatic embryogenesis (6-8%) was observed from the callus induced. Direct embryogenesis was also observed in the cotyledon when 2,4-D was omitted from the above media. These embryogenic structures on medium containing abscisic acid (0.5 mg/l) and on hormone-free medium showed root formation but shoot development was inhibited (Thimmappaiah, 1997).

Martin (2003) showed that, type and age of the cashew explant and growth regulators supplemented to the medium significantly influenced the frequency of embryogenesis. The study showed that 35% of seed coat halves isolated from the immature cashew nuts between 15 and 40 days, induced somatic embryos and these developed best on MS medium with BA, adenine sulphate and NAA. An average of 3.3 embryos were developed per half seed coat when cultured on this medium. Secondary embryogenesis occurred when the embryos were transferred to fresh medium. 50% of the embryos underwent conversion from globular to cotyledonary upon transfer to MS medium with kinetin and 90% of the plantlets survived under field conditions.

Keshavachandran (1998, 2004) reported callus induction from internodal segments and cotyledonary section occurred in media containing 2,4-D and NAA. Addition of organic additives such as glutamine and casein hydrolysate increased the percentage of callusing as well as reducing the days taken for callusing.

Nucellus culture

In *Mangifera* another genus of Anacardiaceae, the nucellus tissue excised from immature fruits showed high embryogenic activity, and with this plantlet regeneration has been achieved in mango (Litz, 1984; Jana *et al.*, 1994). Unlike in mango, polyembryogeny has not been observed in cashew. However, there have been attempts to culture nucellus tissue from developing fruits without much success.

Nair and Mohanakumaran (1993) observed induction of profuse globular creamy white callus from nucellus within two weeks of culturing on MS medium containing half-strength major salts and hormones like 2,4-D, BAP, NAA (1 mg/l each) + sucrose (3%). However, with some more experimentation, they reported rudimentary shoot formation and profuse root growth.

Nucellus culture in cashew is done either by excising the nucellar tissue from the bisected ovule or by implanting bisected ovule with intact nucellus on a suitable medium. In the latter, injury to the tissue is minimum. The ovules are extricated from 3-week-old nuts. Nucellus tissue, scooped out carefully from the young ovules (3-week-old) and cultured in the dark on a modified MS medium supplemented with glutamine (400 mg/l), ascorbic acid (100 mg/l) and 2,4-D (0.5-4 mg/l), showed limited callus induction. Callus was slow growing, and its embryogenic nature was confirmed by histological studies. The callus grew fast and became friable and embryogenic when 2,4-D in basal medium was substituted with 1 mg/l NAA or IAA along with 1 mg/l zeatin. Globular structures (embryoids) were induced on medium containing 0.5 mg/l 2iP and coconut water (15%). The somatic embryos (globular bodies) germinated on medium containing 0.1 mg/l IAA, 1 mg/l zeatin, CW (15%) and abscisic acid (0.1 mg/l) and on hormone-free medium. The somatic embryos showed development of roots with compressed or no-shoot formation (Thimmappaiah, 1997). Bisected ovule on 2,4-D + TDZ medium induced profuse callus from its ventral portion. Calli were induced from nucellar explants excised from one-month-old developing fruits of cashew. The medium used consisted of MS formulation containing 6.78 μM 2,4-D. Differentiation of somatic embyos from calli was noticed when they were transferred to MS liquid medium supplemented with 4.52 μM 2,4-D. Divisions in the proembryo led to the globular, heart and torpedo stages of somatic embryo development. There was no further development of the torpedo stage in the liquid medium containing 2,4-D.

Cardoza and D'Souza (2002) observed that induction of embryogenic callus and proembryos from nucellar tissues when cultured on MS medium with 0.5 mg/l picloram and 20 g/l sucrose. Globular embryos were produced when these proembryos were cultured on MS medium with 0.5 mg/l picloram and 1 mg/l putrescine. Globular embryos gave rise to somatic embryos when grown on MS + 30 g/l sucrose and 0.5 mg/l ABA. MS medium devoid of growth regulators promoted the germination of mature embryos.

Keshavachandran (2004) reported extraction of the nucellus from immature nuts and culturing on media containing 2,4-D and polyamines resulting in the proliferation of globular structures.

Embryo culture

Immature zygotic embryos showed callus formation on modified MS medium supplemented with NAA (4 mg/l each), Kin/BAP (2 mg/l), activated charcoal and PVP. The callus induced in complete darkness was compact and brown, which on the same medium developed into

numerous globular structures that were later transformed into either embryoids or leafy structures in the presence of 2,4-D and Kin (2 mg/l each) and PVP (250 mg/l). Reculturing of embryoids produced fresh morphogenic calli. A number of embryos showed a typical development, i.e., formation of cotyledonary leaves and an equal root/shoot ratio (neomorphs). Cytological studies of globular protuberances revealed normal as well as variable chromosome numbers (Jha, 1988).

Study conducted by Gogate and Nadgauda (2003) showed the induction of somatic embryos directly from radical tip of immature zygotic embryos of cashew when cultured on MS medium with 0.5% activated charcoal, 2,4-D, BAP and gibberellic acid (with 10% frequency of embryogenic response). Only 9% embryogenic response was obtained when 2,4-D was alone or with kinetin. For further maturation the somatic embryos were transferred to medium with abscissic acid and 3% maltose. A histological study showed that somatic embryos arose from the outermost cell layer of radical tip.

Root culture

Roots have not been much used for *in vitro* culturing. However, Hegde (1988) observed callus formation from the root-segment cultured on, Lin and Staba (1961) medium supplemented with 2,4-D (3 mg/l). Similarly, Nair and Mohanakumaran (1993) also observed callus formation from root-segments, cultured on SH medium containing 2,4-D (2 mg/l) + Kin (1 mg/l) + glutamine (100 mg/l) and sucrose (3%).

Protoplast Culture

Protoplasts were isolated from young green cotyledonary segments, leaf and hypocotyl segments of young cashew seedlings (1 month). The enzyme mixture consisted of cellulase (2%), macerozyme (0.5%), sorbitol (0.5 M) and $CaCl_2.2H_2O$ (10 mM) and their pH adjusted as 5.5-5.7. The hypocotyl and cotyledon protoplasts were bigger in size and were liberated within 4 hours after incubation, whereas leaf protoplasts were small and numerous and took 24 hours for their release under an ambient temperature (Thimmappaiah, 1997).

Biochemical and molecular markers

Mneney *et al.* (1997) has worked on RAPD profiling of Tanzanian cashew. They have defined the conditions for extracting PCR-amplifiable high molecular weight DNA from young cashew leaves and the PCR conditions for RAPD analysis of cashew DNA using random 10-mer primers and anchored microsatellite primers. The optimized PCR-reaction conditions were then used to analyze DNA-level differences within a pool of 21 elite Tanzanian cashew lines, and a small selection of cashew varieties obtained from diverse geographical locations around the world.

Mneney *et al.* (2001) developed a method for extracting PCR-amplifiable, high molecular weight DNA from young cashew leaves and PCR conditions for RAPD analysis were optimized. Differences in RAPD profiles were analysed within and between a selection of cashew varieties obtained from diverse geographical locations around the world and within a pool of 20 elite Tanzanian cashew lines. These studies showed that, between the Tanzanian accessions there was a high degree of DNA level similarity, while accessions from India, Mozambique and Tanzania showed the closest relationship. Accessions from Brazil being the most distinct from the other provenances.

33 cashew accession based at CRS, Madakkathara, were screened with different primers and 17 primers were identified which would identify the cashew cultivars (Anon, 2002). Ushavani (2002) studied RAPD markers as a potential tool to characterize cashew germplam.

In the study conducted by Dhanaraj *et al.* (2002), the diversity among 90 cashew accessions from National Cashew gene bank were estimated using RAPD markers. The study confirmed that, the Indian cashew collection showed a 'moderate' to 'high' diversity. Based on this study, a core collection representing the same diversity as the entire population was identified.

Rao *et al.* (2003) developed molecular profiles of 24 selections and 11 hybrids using a combination of 5 RAPD and 4 ISSR primers pre-selected for maximum discrimination and repeatability. 94 markers were generated which discriminated all the varieties with a probability of identical match by chance of 2.8 x 10-11. The results showed no correlation between the relationships based on molecular data and the pedigree of the varieties, while the average similarity coefficient difference between selections and hybrids were found to be low.

In the study conducted by Archak *et al.* (2003), 19 cashew accessions were analysed using 50 random primers, 12 ISSR primers and 6 AFLP primer pairs to compare the efficiency and utility of these techniques for detecting variation in cashew germplasm. The results showed that AFLP exhibited maximum discrimination efficiency and utility than RAPD and ISSR. AFLP displayed no correspondence with RAPD and ISSR, while correlation between ISSR and RAPD similarity matrices were low. The overall conclusion was that AFLP was the marker choice for cashew genetic analysis.

Future strategies

Cashew is a difficult crop to work with respect to biotechnological aspects. Attempts to standardize a micropropagation protocol has been hampered by the three problems normally associated with *in vitro* culture of tree crops, namely, polyphenol exudation, endogenous contamination and recalcitrance of mature explants. Protocols have been standardized for *in vitro* multiplication by using explants from *in vitro* source. Mature explants have also been used but further work is needed to increase the number of multiple shoots and reduce the interference of endogenous contamination. Induction of somaclonal variation by subjecting to a callus mediated regeneration system is important in creation of variability for important characters such as higher productivity, quality resistance/tolerance to diseases and pests, stress and induction of dwarfness. The germplasm material available including the advanced selections need to be fingerprinted. The use of molecular markers will also help in better management of the germplasm. Genetic transformation methods need to be developed in cashew for transferring resistant genes especially against the insect pests.

Conclusion

Biotechnological techniques used in cashew include attempts to standardize an *in vitro* regeneration protocol by using explants from *in vitro* source as well as from mature trees. There has been some success in this aspect. Callus induction has been achieved but plantlet conversion via organogenesis or somatic embryogenesis has not been satisfactory. Molecular markers have been developed mainly using RAPD, though there are a few reports on use of AFLP and ISSR techniques. Further work on these lines will help in fingerprinting the germplasm available including the advanced selections and hybrids. This will also lead to better management of the germplasm. Attempts need to be made to transfer resistant genes especially against insect pests through genetic transformation.

REFERENCES

Ananthakrishnan, G., Ravikumar, R., Girija, S., Ganapathi, A. (2002). *In vitro* adventitious shoot formation from cotyledon explants of cashew (*Anacardium occidentale* L.). *Scientia Horti*, Vol. 93, (3-4): 343-355.

Anon (2002). Annual Report of CRS, Madakkathara.

Archak, S., Gaikwad, A.B., Gautam, D., Rao, E.V., Swamy, K.R., Karihaloo, J.L. (2003). Comparative assessment of DNA fingerprinting techniques (RAPD, ISSR and AFLP) for genetic analysis of cashew (*Anacardium occidentale* L.) accessions in India. *Genome* 46, (3): 362-9.

Bessa, A.M.S. (1990). *In vitro* propagation of cashew (*Anacardium occidentale* L.) by nodal culture. Abstr VII. Intl cong. Plant Tissue Cell Cult., Amsterdam, June 24-29, Abstr D 1-8.

Bessa, A.M.S., Sardinha, R.M.A. (1994). *In vitro* cashew (*Anacardium occidentale* L.) propagation from callus culture. Abstracts of the VIII[th] international congress on plant tissue and cell culture. IAPTC Firenze Italy, June 12-17, p.23.

Boggetti, B., Jasik, J., Mantel, S. (1999). *In vitro* multiplication of cashew (*Anacardium occidentale* L.) using shoot node explants of glasshouse raised plants. *Plant Cell Rep.*,18: 456-461.

Cardoza, V., D'Souza, L. (2002). Induction, development and germination of somatic embryos from nucellar tissues of cashew (*Anacardium occidentale* L.). *Scientia Horti*, Vol. 93, (3-4): 367-372.

Das, S., Jha, T.B., Jha, S. (1996). *In vitro* propagation of cashew nut. *Plant Cell Rep.*, 15: 615-619.

De Fossard, R.A. (1976). Tissue culture for plant propagators. Department of Continuing Education, University of New England Printery, Armeidale, Australia.

Dhanraj, A.L., Rao, E.V.V.B., Swamy, K.R.M., Bhatt, M.G., Prasad, D.T., Sondur, S.N. (2002). Using RAPDs to assess the diversity in Indian Cashew (*Anacardium occidentale* L.) germplasm. *J Horti Sci and Biotech*, Vol 77, (1): 41-47.

D'Silva, I. (1991). Micropropagation of *Ailanthus* and *Anacardium occidentale* through tissue culture. Ph.D. thesis, Mangalore University, India.

D'Silva, I, D'Souza, L. (1992a). *In vitro* propagation of *Anacardium occidentale* L. *Plant Cell Tissue Organ Cult.*, 29: 1-6.

D'Silva, I., D'Souza, L. (1992b). *In vitro* bud proliferation of *Anacardium occidentale* L. *Beitr Biol Pflanzen*, 67: 273-279.

D'Silva, I., D'Souza, L. (1993). Controlling contamination and browning of *in vitro* cultures in cashew. *J Plantation Crops*, 21(1): 22-29.

D'Souza, L., D'Silva, I., Mallaya, S., Augustine, A.C., Rajendra, K., Kulkarni, K.R., Cardoza, V. (1996). *Anacardium occidentale* L. (Cashew nut). (*In*) Bajaj, Y.P.S. (ed). Biotechnology in Agriculture and Forestry, Vol. 35, Trees IV. Springer - Verlag, Bulin, Heidelkerg.

Farrant, J.M., Berjak, P., Myoock, D.J. (1990). *In vitro* propagation of *Anacardium occidentale* L. (Cashew). Abstracts VII Intl Cong Plant Tissue Cell Cult., Amsterdam, June 24-29, Abstr A 3-65.

Gogate, S.S., Nadgauda, R.S. (2003). Direct induction of somatic embryogenesis from immature zygotic embryo of cashew nut (*Anacardium occidentale* L.). *Scientia Horti.*, Vol. 97, (1): 75-82.

Hegde, M. (1988). Ph.D. thesis, Tamil Nadu Agricultural University, Coimbatore, India, p. 169.

Hegde, M., Kulasekaran, M. (1994). Proc. XI Symp. on Plantation Crops, Tamil Nadu Agricultural University, Coimbatore, India.

Hegde, M., Kulasekaran, M., Jaya Sankar, S., Shanmugavelu, K.G. (1992). *In vitro* embryogenesis in cashew (*Anacardium occidentale* L.). *Indian Cashew J.*, 21(4): 17-25.

Hegde, M., Kulasekaran, M., Shanmugavelu, K.G., Jayasankar, S. (1990). *In vitro* culture of cashew seedlings and multiple plantlets from mature cotyledons. *Indian Cashew J.*, 20: 19-24.

Jana, M.M., Nadgauda, R.S., Rajmohan, K., Mascarenhas, A.F. (1994). *Cell Dev. Biol.*, 30: 55-57.

Jha, T.B. (1988). *In vitro* morphogenesis in cashew nut (*Anacardium occidentale* L.). *Indian J. Exp. Biol.*, 26: 505-507.

Keshavachandran, R. (1996). Morphogenic potential of shoot buds in cashew (*Anacardium occidentale* L.). *Developments in Plantation Crop Research*. pg. 34-39.

Keshavachandran, R. (1998). Induction of callus in cashew (*Anacardium occidentale* L.). Proc. of the Tenth Kerala Science Congress, pp. 263-264.

Keshavachandran, R. (2004). Report submitted to the DBT., New Delhi.

Keshavachandran, R., Abdul Khader, M.D. (1990). Micropropagation of cashew (*Anacardium occidentale* L.). *Journal of Plantation crops*, 20: 299-300.

Keshavachandran, R., Abdul Khader, M.D. (1994). Protoplast isolation and culture in cashew. *South Indian Horticulture*, 42:3,194-196.

Keshavachandran, R., Rema Menon. (1997). Control and estimation of phenolic exudation in *in vitro* culture of cashew (*Anacardium occidentale* L.). National Symposium on Emerging trends in Plant Tissue Culture and Molecular Biology, Hyderabad. p. 37.

Keshavachandran, R., Riji, V.S. (2005). Rapid multiplication of cashew through *in vitro* methods. Proc. of National Symposium of Biotechnological Interventions for Improvement of Horticultural crops: Issues and Strategies, KAU. p.204.

Keshavachandran, R., Riji, V.S. (2005). Standardisation of *in vitro* micrografting techniques in cashew. Proc. of National Symposium of Biotechnological Interventions for Improvement of Horticultural crops: Issues and Strategies, KAU. p. 205.

Keshavachandran,R., Shelja, P.B. (1999). Genotypic difference in shoot bud culture of cashew (*Anacardium occidentale* L.). Proc. of Eleventh Kerala Science Congress.

Keshavachandran, R., Shelja, P.B., Daisy Jacob. (1999). *In vitro* micrografting in cashew (*Anacardium occidentale* L.). *Recent advances in Plantation Crop Research*. p. 52-54.

Lad., B.L., Chvan, S.S., Madgum, M.B. (1994). Proc. 2nd Asia Pacific Intl. Conf. Agric. Biotechnol., Madras, March 6-10, p. 215.

Lakshmi Sita, G. (1989). Differentiation of embryos and leafy shoots from callus cultures of cashew (*Anacardium occidentale* L.). Abstracts XIII Plant Tissue Culture Conference, Oct. 18-20, Shillong, India. Abstr 71.

Lakshmi Sita, G., Sreenatha, K.S. (1990). Clonal propagation of economically important trees-Cashew (*Anacardium occidentale* L.) and red sandal wood (Pterocarpus santalinus). Abstr Intl Sem New Frontiers Horti., Nov. 25-28, IAHS, Bangalore, India, Abstr 146.

Leifert, C., Morri, C., Waites, W.M. (1994). Ecology of microbial saprophytes and pathogens in tissue culture and field grown plants; Reasons of contamination problems *in vitro* CRC. *Critical Rev. Plant Sci.*, 13: 139-183.

Leva, A.R., Falcone, A.M. (1990). Propagation and Organogenesis *in vitro* of *Anacardium occidentale* L. *Acta Horti.*, 280: 143-156.

Lievens, C., Pylser, M., Boxus, P.H. (1989). First results about micropropagation of *Anacardium occidentale* L. by tissue culture. *Fruits*, 44: 553-557.

Lin, M.L., Staba, J.E. (1961). *Lloydia*, 24: 139-143.

Litz, R.E. (1984). *In vitro* somatic embryogenesis from nucellar callus of monoembryonic *Mangifera indica* L. *Hort Sci.*, 19: 715-717.

Litz., R.E., Conover, R.A. (1981). *J. Amer. Soc. Horti. Sci.*, 106: 792-794.

Lloyd, G., McCown, B.H. (1980). Commercial feasible micropropagation of mountain laurel (*Kalmia latifolia*) by use of shoot tip cultures. Proc. Intl. Plant Prop. Soc., 30: 421-427.

Mantel, S.H., Boggett, B., Bessa, A.M.S., Lemos, E.P., Abdelhadi, A., Mneney, E.E. (1997). Micropropagation and micrografting methods suitable for safe int. transfer

of cashew. Proceedings of Int. Cashew and Coconut Conf. 1997 - Dar es Salaam. 95-107.

Martin, K.P. (2003). Plant regeneration through direct somatic embryogenesis on seed coat explants of cashew (*Anacardium occidentale* L.). *Scientia Horti*, Vol. 98, (3): 299-304.

Mneney, E.E., Mantel, S.H. (2002). Clonal propagation of cashew (*Anacardium occidentale* L.) by tissue culture, *J Horti Sci. and Biotech*, Vol. 77 (6): 649-657.

Mneney, E.E., Mantel, S.H., Bennett, M. (2001). Use of RAPD markers to several genetic diversity within and between populations of cashew (*Anacardium occidentale* L.). *J Hort Sci and Biotech*, Vol. 76, (4): 375-383.

Mneney, E.E., Mantel, S.H., Tsoktouridis, G., Amin, S., Bessa, A.M.S., Thangavelu, M. (1997). RADP profiling of Tanzanian cashew (*Anacardium occidentale* L.). Proceedings of international cashew and coconut conference, Dar-es-salaam, Tanzania, February 17-21.

Murashige, T., Skoog, F. (1962). A revised medium for rapid growth and bioassay with tobacco tissue cultures. *Physiol Plant*, 15: 473-497.

Nair, S.R., Mohanakumaran, N. (1993). Standardisation of tissue/apical/meristem culture techniques in horticultural crops of Kerala, Final Technical Report (USDA). IN-AES-343, Thiruvananthapuram, Kerala, pp. 3-15.

Nambiar, M.C., Iyer, R.D. (1988). Tissue culture in cashew: Potential, priorities and applications. (*In*) Tata SN (Ed). Proceedings of the National Seminar on Plant Tissue Culture, ICAR, New Delhi, pp. 149-155.

Philip, V.J. (1984). *In vitro* organogenesis and plantlet formation in cashew (*Anacardium occidentale* L.). *Ann. Bot.*, 54:149-152.

Philip, V.J., Unni, P.N. (1984). *In vitro* propagation of cashew for crop improvement. (*In*) Bhaskara Rao, E.V.V., Khan, H.H. (eds). Cashew Research and Development. CPCRI, Kasaragod, p. 78-82.

Preece, J.E., Compton, M.E. (1991). Biotechnology in Agriculture and Forestry, Vol. 17. (*In*) Bajaj, Y.P.S. (ed)., Springer - verlag, Berlin, Heidelberg, New York, p. 168-189.

Raj Bhansli, R. (1990). *Ann. Bot.*, 16: 249-253.

Ramanayake, S.M.S.D., Kovoor, A. (1997). Proc. XIII Plant Tissue Cult. Conf., Oct 18-20, Shillong, p.86.

Rao, E.V.V.B., Swamy, K.R.M., Karihatoo, J.L., Gaikwad, A.B., Archak, S., Gautham, D. (2003). DNA finger printing of Indian Cashew (*Anacardium occidentale* L.). Varieties using RAPD and ISSR techniques. *Euphytica*, Vol. 130, (3): 397-404.

Samso, N.P., Ponsamuel, J., Ganeshan, S. (1989). *In vitro* studies on callus induction and morphogenesis of cashew (*Anacardium occidentale* L.). Abstracts XIII Plant Tissue Culture Conf., Oct. 18-20, Shillong, India, Abstr. 86.

Sardinha, R.M.A., Bessa, A.M.S., Blake, J., Guyyer, D., Cassami, C., Tamba-Bungue, P. (1993). Selection of superior genotypes of cashew (*Anacardium occidentale* L.) in Guinea-Bissau and the development of *in vitro* technique for their propagation. Final Summary Rept., Contract TS-2-A-01, Lisbon, p. 67.

Shantha, M.S., Ramanayake, D., Kovoor, A. (1999). *J Horti. Sci. Biotech.*, 74: 265-268.

Srivatsan, T.T., Sathya Prakash, V., Ebenezer, G.A.I., Ponsamuel, J. (1989). Effect of plant growth regulators on callus induction and rhizogenesis of cashew (*Anacardium occidentale* L.). Abstracts XIII Plant Tissue Culture Conf., Oct. 18-20, Shillong, India, Abstr. 82.

Sy, M.O., Martinelli, L., Scienza, A. (1991). *In vitro* organogenesis and regeneration in cashew (*Anacardium occidentale* L.). *Acta Hort.*, 289: 267-268.

Thimmappaiah (1997). Ph.D. thesis, Mangalore University, India, p. 264.

Thimmappaiah, Anil, S.R., Iyer, R.D. (2001). Cashew. (*In*) Biotechnology of Horti Crops, Vol. 2. Parthasarathy, V., Bose, T.K., Das, P. Naya Prakash, Calcutta. 609-629.

Thimmappaiah, Puthra, G.T., Anil, S.R. (2002). *In vitro* grafting of cashew (*Anacardium occidentale* L.). *Scientia Horti.*, Vol. 92, (2): 177-182.

Thimmappaiah, Samuel, S.R. (1999). *In vitro* regeneration of cashew (*Anacardium occidentale* L.). *Indian J Exp Biol*, 37: 384-390.

Thimmappaiah, Samuel, S.R. (1996). Natl. Symp. on Horti. Biotech., Bangalore, p. 65.

Ushavani (2002). M.Sc. thesis, Kerala Agricultural University, India.

Wilkins, C.P., Cabrera, J.L.P., Dodds, J.H. (1985). Outlook on Agriculture, 14: 1-13.

BIO-ECOLOGY OF INSECT PESTS OF CASHEW AND THEIR MANAGEMENT

G.K. Mahapatro*
Cashew Research Station, Kerala Agricultural University, Madakkathara - 680 651, Kerala

The pest spectrum

Pest infestation is a serious constraint in cashew production. Key insect pests are tea mosquito bug (TMB) and cashew stem and root borers (CSRB), though multitude of insect-pests inclusive of other arthropod-pests are recorded ravaging cashew in Indian subcontinent (Abraham, 1958; Abraham and Nair, 1981; Basheer and Jayaraj, 1964; Nair, 1975; Devasahayam and Nair 1986; Rai, 1984; Sundararaju, 2002, 2004). At Madakkathara, twenty insects were identified as pests of cashew (Beevi *et al.*, 1991). TMB, CSRB, apple & nut borers, leafminer, leaf and flower thrips were described as major pests by them. Two insect pests – spiraling whitefly and mango leaf webber are reported as minor pests at Madakkathara.

Twenty species of beetles, five species of caterpillars and some psocids and mites infest stored cashew kernels. Among these *Cadra cautella* (Wlk.), *Corcyra cephalonica* (St.) (Pyralidae), *Tribolium castaneum* (Herb.) (Tenebrionidae) and *Necrobia rufipes* (De C.) (Cleridae) cause direct damage to the kernels while others contaminate them with their presence and excreta. Strict sanitation of the processing sheds and premises, keeping processed nuts in closed containers, undertaking peeling, grading and packing in quick succession are suggested as measures to control these pest infestations (Nair et al. www.actahort.org).

1. Tea mosquito bug: Out of 41 species of *Helopeltis* recorded in old world tropics (Stonedahl and Gary, 1991), only three species (*H. antonii* Sign., *H. theivora* Wat. *and H. bradyi* Wat.) are confined to Indian subcontinent, and these are also prevalent in Kerala (West coast), though the first one is only dominant. *H. antonii* is distributed in most of cashew growing regions of Kerala, Karnataka, Goa, Maharashtra, Tamil Nadu, Andhra Pradesh and Orissa. Losses in nut yield of 25 to 50 per cent has been reported from Karnataka, Goa, Kerala and West Bengal. *H. bradyi* and *H. theivora* are confined to West Coast and Western Ghat region on cashew (Sundararaju, 2004).

Bio-ecology: The egg and nymphal periods, longevity of adults and fecundity ranged from 6-12, 8-14 and 4-14 days and 13-82 eggs respectively. The egg and nymphal period are negatively correlated with temperature (Sundararaju, 2004). A mass culture technique by using tender cashew shoots and seedlings has been standardized (Sundararaju and John, 1992). Presence of female sex pheromone in the adult virgin females was demonstrated (Sundararaju and Sundarababu, 1999) and advocated its use in pest management strategy.

Adult bug is reddish brown with black head, red thorax and black and white abdomen. The scutellar horn (not in first instar) is reddish brown, erect and tapering with the tip knobbed and funnel shaped. The female is 8.0 mm long and 0.76 mm at thorax and the male is smaller. Eggs (dimension, 1 x 0.25mm) are inserted into the epidermal tissues of the tender shoots, inflorescence axes and nuts. Eggs are laid in two rows of three each, hatches in 7-8 days, usually. Nymph is red, ant-like with long legs, feeds on the plant juice, undergoes five instars and becomes adult in about 15 days. The total life cycle is completed in 22-days. The mean longevity of females is 6.5 days, but 5.2 days in males. During the monsoon period they can be seen damaging young plants. The insect feeds from tender shoots, inflorescence, developing nuts and apples. The shoots show die-back symptoms and 'blossom blight'. The whole inflorescence dies ultimately. Both nymphs and adults suck sap from tender shoots, panicles, immature nuts and apples. The typical damage symptom is the formation of necrotic

* Present Address: Division of Entomology, IARI, Pusa, New Delhi-12, e-mail: gagan_gk@rediffmail.com

lesion around the point of stylet insertion by the bug. The lesions on shoots and panicles coalesce and ultimately result in shoot or blossom blight. During new flush emergence the severely infested trees a scorched appearance. Each nymph/adult during its lifetime damages at least three tender shoots/panicles. A single nymph can cause blighting of emerging tender shoot/ panicle within 3-4 days of feeding. In general 1-3 nymphs were seen in each emerging tender shoot/panicle, whereas in each flowering panicle with immature fruits, up to The fungi *Gloeosporium mangiferae* and *Phomopsis anacardii* have been reported to cause blossom blight in association with TMB.

Host range: *Lawsonia alba*, mango, *Syzygium* sp, portia tree, ornamental *Acalypha* and *Annona reticulata*. Neem is the primary host especially in Tamil Nadu and Southern parts of Karnataka and Andhra Pradesh for *H. antonii*. It spreads to cashew from neem as a regular pest.

Management

1. Chemical Management

Effective control of *H. antonii* has been suggested as one of the short-term strategies for increasing cashew productivity (Nambiar, 1976). A detailed discussion on the critical aspects of chemical control was given by Mahaptro and Mathew (2005) and reviewed Mahapatro (2008a).

Two crucial components of application technology are – the *knowledgebase – when to, what to and how to to apply* and the delivery system (*pesticide appliances, types etc*).

When to apply?

1. Based on ETL: To combat with pestilence, answering this question is a must. Needless to cite that, economic threshold levels (ETLs) at the appropriate crop-phenophase is the right answer. Unfortunately, despite 4-5 long decades of cashew-research, no ETL is available for major pests including the TMB that at times risk the crop to total loss in outbreak situations (Mahapatro, 2008a). As an *ad hoc* recommendation, 10% damaged fresh flushes (foliar and floral) may be considered as the ETL for tea mosquito bug (Mahapatro, 2008b; Mahapatro and Mathew, 2005).

2. Based on calendar: Though three-round spray schedule (KAU, 2002 – Table 1) is essentially required for TMB in most cases, if spray schedule is to be curtailed to two in IPM programme, then spraying at flushing may be avoided.

3. Crop-age and phenophase: The application strategy must agree to the crop-age as suggested in Table 2. When the farmer has mixed varieties (early, mid and late) in his orchard, he should resort to spraying according to the right phenophase rather than going by month-wise application strategy (Mahapatro *et al.*, 2006d). Spraying must be depending upon the variety's phenological stage coincides in a calendar year, which is to be worked out by the farmer suiting his locality.

Table 1. Recommended timing for insecticide spray for control of tea mosquito bug

Spray No.	*Month*	*Stage of crop*
First	Oct – Nov	Emergence of new vegetative flushes
Second	Dec – Jan	Commencement of panicle-emergence
Third	Jan – Feb	Completion of flowering/initiation of fruit set

Table 2. Pest management options in cashew based on age of plants

Age of the plants	*Comments/ remarks*
Seedlings	Hard chemicals can be used in nursery stage
≤ 3 years	Frequent spraying required against TMB. Population is often found in Jun-Aug (monsoon). Hard chemicals may be used during this period in case of severe infestation.
3 -10 years	Precaution against TMB but with 3-round sprays
10 -25years	Need based spraying for TMB and minor pests (like mealy bugs). Promote red-ant colonies. Avoid sprays on trees with ant-colonies. Precaution against CSRB.

4. Application timing: The sprayings should be before 9 am or after 4 pm in order to save non-target pollinators.

What to apply?

The recommended pesticides for TMB management are listed in Table 3. Farmers should keep in mind, the following crucial points:

1. When the crop is in vegetative stage, hard chemicals like monocrotophos and phosphamidon can be used. Bearing crops should be sprayed with 'soft' chemicals like carbaryl and dimethoate (Table 4).
2. When spray combination is required, follow the compatibility-chart (Mahapatro and Mathew, 2005)
3. Avoid spraying carbaryl and phosphamidon at the time of flowering as these are highly toxic to honey bees.

How to apply?

In tea mosquito bug management, following points are crucial in application technology.

1. Young plants need more care which means more frequent sprayings. The problem may be due to the bug-fungi complex.
2. Dusting powder formulations are not recommended for TMB (KAU, 2002).
3. Use the right insecticide at right time with right dose and right method (Table 1).
4. Pesticides are to be rotated based IRAC – recommendations (IRAC, 2007).
5. Use 5-8 litres of spray fluid for grown up trees with high volume spray. Use rocker sprayer with Hi-tree lance or power sprayer for fully covering the canopy. In tractamount sprayers, the total volume of spray fluid is reduced substantially. In mechanized sprayings, hard chemicals are to be avoided.

Spraying pattern: As the insect dispersion in field is clumped in localized pockets rather than random, the blanket spraying i.e., total plot or orchard is unwarranted and it is an addition to environmental pollution. Thus, tree-to-tree basis spraying is advocated (Rickson and Rickson, 1998). Trees harbouring ant nests should be spared of spraying.

2. Non chemical methods
Host- plant resistance

Even though, a number of germplasm accessions had been reported as least susceptible under field condition, none of them had shown any resistant reaction when again screened under laboratory and net house condition. However, the accession, Goa 11/6 had shown pseudo-resistance mainly with pest escapism mechanism. Mid and late season cashew varieties are able to escape the severity of TMB to certain extent (Sundararaju, 2002).

Table 3. Recommended insecticides for prophylactic spraying

Spray No.	*Insecticides recommended*	*Remark*
First	Monocrotophos, quinalphos, carbaryl, lambda-cyhalothrin, chlorpyriphos, triazophos, profenophos, phosphamidon	Rotation of insecticides between sprays is advised
Second	Quinalphos, lambda-cyhalothrin, chlorpyriphos, triazophos, profenophos, phosalone, dimethoate	
Third	Carbaryl, lambda-cyhalothrin, chlorpyriphos, triazophos, profenophos, phosalone, dimethoate	

Table 4. Classification of pesticides recommended in cashew, based on toxicity class (to non-target mammals)

*ToxicityClass**	*Warning on the label*		*Examples*	*Remarks*
	Colour	*Word*		
Extremely Toxic	RED	POISON	Monocrotophos, phosphamidon, phorate	'Hard' or 'High risk' pesticides
Highly Toxic	YELLOW	POISON	Lambda-cyhalothrin, quinalphos, triazophos, chlorpyriphos, profenphos, endosulfan, dimethoate	
Moderately Toxic	BLUE	DANGER	Carbaryl, copper oxychloride, tridemorph, acephate	'Soft' or 'Low risk' pesticides
Slightly Toxic	GREEN	CAUTION	Ethofenprox, carbendazim, mancozeb, dithane M-45, sulphur, botanicals like neem-pesticides	

* Classification of insecticides based on Insecticide Rule, 1971

Beevi and Mahapatro (2007) offered a new methodology (two-way matrix) for classifying the genotypes based on their susceptibility to TMB (Table 5).

Natural enemies

A large number of natural enemies of *Helopeltis* spp. occurring in Old World tropics (Africa & Asia) is compiled in various reports (Simonds, 1970; CIBC, 1983; Sundararaju, 1984; Sundararaju and Sundarababu, 1999).

(i) Parasitoids: Four species of solitary egg endoparasitoids *viz.*, *Telenomus* sp. (laricis group), *Chaetostricha* sp. *Erythmelus helopeltidis* and *Gonatocerus* sp. were recorded and maximum parasitism upto 59.8% was observed. Among them *Telenomus* sp. is the dominant species. None of the egg endoparasitoids is amenable for mass culture. Existence of one unidentified species of nymphal hymenopteran and nematode parasitoids was also confirmed. Occurrence of one species of ectoparasitic mite (*Bochartia* sp.) was also reported.

(ii) Pathogens: Myco-insecticides like *Beuverai bassiana, Metarrhizium anisopliae* are not evaluated against TMB in cashew though reports are there in tea-ecosystem.

(iii) Predators: A number of general predators consisting of six species of spiders (*Oxyopes schireta, Oxyopes* sp., *Phidippus* patch, *Phidippus* sp., *Matidia* sp. and *Hyllus* sp. and six species of reduviid bugs (*Sycanus collaris, Sphedanolestes signatus, Irantha armipes, Occamus typicus, Endochus inornatus* and *Panthous bimaculatus*) were recorded. Beevi and Mahaptro (2008) listed 10 ant and 35 spiders species in central Kerala.

Ant-technology in cashew

Red ants has been used to control insect pests in citrus orchards in China for at least 1600 years, but its role in cashew plantations has not been reported previously till by Peng *et al.* (1995, 1997, 1998) in Australia. Though as an indigenous technical knowledge (NRCC, 2004), red-ants are believed to check the TMB infestation, no systematic and scientific investigation was carried out in India except that in Madakkathara center (Mahapatro et al., 2006a-d). However, abroad, in Australia this is reported to be very much viable even in commercial scale. Latest, in 2004-05, the technology is being introduced in Vietnam also. Pollination and pest-control are two major areas where payoffs for cashew production occur. A pre-requisite in fruit bearing, pollination has been identified as one of the major limiting factors in getting potential cashew yield (Reddi, 1987, 1991). Cashew is entomophily, rather than anemophily. As auto-pollination, apomixes and anemophily are not operating in this crop, the flowers depend totally on insects for pollination. It is obvious, ants will act as pollinators in cashew. Ohler (1979) is of the opinion that ants are responsible for a greater part of pollination in India than assumed (1979).

Monitoring and surveillance: A strong surveillance programme and proper monitoring of the pest-situation has become imperative to rationalize management strategies and thus to avoid the need for blanket sprays of three-sprays, by way of prophylaxis. To deal with this, reliable forewarning systems is indispensable, and for this prediction modeling-works were carried out by Prasad Rao and Beevi (2008). More concerted research efforts are needed for standardizing the pheromone technology (Sundararaju and Sundarababu, 1999).

2. Cashew Stem & Root Borers (CSRB)

Three main species of beetles were recorded to infest cashew viz. *Plocoederus ferrugineus, Plocoederus obesus* and *Batocera rufomaculata.* The *Plocaederus* spp. are encountered as primary pests while *B. rufomaculata* occurs as a secondary pest of cashew.

Table 5. Susceptibility status based on damage by TMB of some released varieties of Kerala: Two-matrix (shoot X panicle)

	Damage scoring (Ambika et al., 1979)	Damage to panicles	
		0 – 0.5	0.51 – 1.0 or more
Damage to shoots	0 – 0.5	**Less susceptible** Amrutha, Damodar, Dhana, Dharasree, K-22-1, Raghav	**Susceptible** Akshaya, Annakkayam-1, Kanaka, Madakkathara (Mdk) –1, Mdk-2, Sulabha,
	0.51 – 1.0 or more	**Moderately susceptible** Poornima (H-1593)	**Highly susceptible** Anagha, Priyanka

Host range: Lab studies on food preference of *P. ferrugineus* showed silk cotton; (*Bombax malabaricum*) and share (*Diospyros* sp.) to support the pest development.

Biology: The adult is a reddish brown longicorn beetle with the head and thorax dark brown to black in colour. It has a length of 25 - 40mm. Eggs are deposited in crevices on the bark of tree trunk exposed roots. Egg is oval measuring 4.5 x 2mm and dirty white in colour. It hatches in 4-6 days. The grub on hatching bores into the living tissues of the bark and sapwood making tunnels within them. It matures in 6-7 months growing to a length of 7.6cm. Grub tunnels down into the root and bores into the heart-wood, forms a chamber tightly packed with fibrous tissues and frass for pupation. The grub makes a calcareous cocoon within this chamber. Pupal period lasts for 20-60 days. The trees attacked by the grubs die and dry up. During early phase of attack bore holes with gum and frass emerges at the collar region. Adult-beetles of *Plocaederus ferrugineus* are dark/brownish, while *P obesus* adults are light chestnut brown. *B. rufomaculata* adults are greyish with yellowish-orange spots on their elytra. The males have antennae longer than the body length, while it is smaller than body length in females. Adults are typically nocturnal in habit. Silk cotton logs smeared with CNSL, fluorescent mercury light traps, luminescent light trap could not attract high numbers of stem and root borer adults.

The egg period was reported to be 4-8 days, grub/larval period comprising of 7-10 instars, to be 116-205 days for females of *P. obesus*, while it was 17-49 day for males and 14-28 day for females of *P. ferrugineus*. The fecundity was 22-63 eggs per female and percent hatch ranged from 48-78% (Raviprasad, 2004).

Population dynamics: The level of infestation was reported to be 1.6 - 4.0 per cent in few tracts of Kerala, Karnataka and Tamil Nadu. Infestation reported in patches and a single tree had repeated infestation as evidenced by overlapping generations of grubs. Grub population was high during Mar - May and Aug - Nov. Pupation was observed from Nov-Jan. and peak adult emergence based on egg laying was during Feb - Apr.

Management

Prophylactic control trials: It was observed that coal tar: kerosene (1: 2) protected the trees for 2 months. In trials, neem oil 3%, and 6% neemark (80 EC) at 0.4%, BHC 2%, Aldrin 0.2%, coal tar: diesel 1: 2 were evaluated as stem swabbing and neemark and neem cake were applied at tree base. Of these BHC, coal tar: kerosene (1:2) neem-oil and neemark had lowest infestation of 2.8%. Commercial neem products such as neem oil 6% Limanool, Nimbecidine, Godrej Achook and RD-9 Repellin all at 0.5% showed prophylactic effect during 1993 and 1994 while during 1996 they were found to be on par with control (CRS, 2005; 2006). Lab evaluation of all these treatments indicated absence of oviposition deterrancy.

Curative trials: Various chemicals like monocrotophos, fenthion and fenitrothion at 15,30 and 45 ml/tree were applied over cotton wool as stem padding below live bark. Only those trees in early stages of infestation showed 39% recovery, with monocrotophos 30 ml/tree, however reinfestation was observed. In another trial, carbaryl + Sevidol led to 80% recovery at initial stages, chlorpyriphos and carbaryl alone led to recovery of 83.3 and 75.0 per cent of trees in initial stages only. Root feeding of monocrotophos led to partial translocation and only trees in early stages of infestation showed recovery.

Fumigants: EDB, Aluminium phosphide, chloroform, petrol and kerosene were tried at different doses by application into the tunnels of stem borer. Highest mortality was observed with chloroform followed by EDB and kerosene. The high cost of treatment and potential hazards of these chemicals do not permit recommendation.

Biological control: The nematode DD-136 (*Neoplectana carpocapsae + Achromobacter nematophilus*) led to 60% mortality of CSRB grubs in 24 days at 100 nemas/g body weight. Use of baculovirus of *Orycte* induce no mortality in grubs of both species of CSRB. The laboratory evaluation of entomopathogenic fungi as *Beauveria bassiana,. B. brongniartii and Metarhizium anisopliae* were done as topical application, soaking feed (bark) in spore suspension and mixing spore suspension in sawdust. Only direct application led to higher mortality. Efficacy order is: (*B. bassiana* > *M. anisopliae* > *B. brongniartii)*

Median lethal concentration (LC_{50}) for *B. bassiana* was worked out as 1.41 x 10^6 spores/ml. Field evaluation of *B. bassiana* and *M. anisopliae* as prophylactic treatment protected trees upto 90 days and on 120 days the

infestation levels were on par with untreated control (Raviprasad, 2004). However, at Madakkathara condition these we are found ineffective (CRS, 2005, 2006). Persistence of *B. bassiana* and *M. anisopliae* in soil, soil + FYM, soil + neem-cake indicated survival of fungi upto 180 days and induced 57-71% mortality of grubs for *B. bassiana.*

Natural enemies: An egg parasitoid *Avetiniella batocerae*, an unidentified hymenopteran larval parasitoid were recorded along with field strain of *M. anisopliae* on grubs of the pest. Mass rearing technique was standardized at NRCC, Puttur (Raviprasad, 2004).

Attractants and sex pheromone: The bark of infested tree and fresh frass elicited response from virgin and mated females under olfactomater trials. Under free choice bark of infested tree had highest oviposition.

Virgin females, unmated males elicited highest attraction from unmated beetles of opposite sex in *P. ferrugineus* and from both mated and unmated beetles in case of *P. obesus.* This implies the possible presence of dual sex pheromone.

Kerala recommendation: Mechanical extraction of the grub and swabbing the tree with 2% carbaryl solution minimises the damage. Pouring 2% carbaryl solution in the soil at tree basin also helps to minimise the incidence of stem borer. Application of neem oil 5 per cent (50 ml of neem oil + 1 lit of water + 0.5 ml of teepol/5g of bar soap) on collar portion upto 1m height and on exposed roots keep the insects away for a period of 3-months. Soil application of 75g of Sevidol (4G) in tree basin also minimises the attack of the stem and root borer (KAU, 2002).

3. Other important insect pests

i. Apple and nut borers: A serious pest noticed in Andhra Pradesh and Goa. The larva is pinkish dark sparsely hairy and very active. Caterpillar bores into tender apples and nuts, entry-holes are plugged with faecal matter. Attacked fruits shrivel and nuts drop down prematurely. Spraying carbaryl 50% WP @0.1% or quinalphos 20% EC @ 0.05% effectively controls this pest.

ii. Thrips: They are minute, slender, fragile, soft bodied, fast moving insects and adults have fringed wings. Nymphs and adults infest the leaves (leaf/ foliage thrips) or inflorescence (Inflorescnce/ scab thrips) and suck the sap. Panicles nuts and apples show scab-like rough skin @ 0.05 – 0.1%. For foliage thrips, hard pesticides (like monocrotophos) may be used in non- bearing stage. Nuts drop in severe cases of attack. If infestation is severe spray dimethoate or monocrotophos.

iii. Leaf miner: Small sized silvery grey moth lays eggs on tender leaves. The reddish brown larva (caterpillar) mines through the leaves and as a result white blister-like patches appear on the leaves sometimes on stem portion also (up to 8 larvae can be seen per leaf). Spraying with monocrotophos or neem-pesticides at the time of new growth checks the damage.

iv. Mealy bugs: They are soft bodied, and covered with milky white coating on body. *P. Lilacinus* is found on tender shoots and fruits while *F. virgata* infests the inflorescence resulting in shedding, and drying of flowers. Honeydew excreted by them attracts ants and sooty molds. Remove and destroy the affected parts.

v. Aphids: Nymphs and adults are soft bodied, ovate and brown. Adults may be winged or wingless. They suck the sap from tender shoots, inflorescence, apples and nuts. Honeydew excreted by them falls on leaves on which sooty mold grows. Severe infestation results in shedding and drying of flowers, or distorted nuts and apples. Normally the natural enemies keep the populations low. In case of population explosions systemic insecticides like dimethoate, phosphamidon or methyl demeton may be tried.

vi. Bark-eating caterpillar: Moths of this polyphagous emerge with the onset of monsoon, larva continues damaging throughout the year. Spherical, single eggs are laid in bark cracks by the moths having brown markings on forewings. Caterpillar is brown to dark brown, sparsely hairy, about 5 cm long when mature. They bore short distances, the trunk or branches, usually at the forks. At night the larvae come out and feeds on bark of the tree. Small trees may succumb, large trees may fail to flush if infestation is severe. Removal of the galleries plastered on the tree trunks, or pouring kerosene or dichlorvos during early stages of infestation reduces the damage.

vii. Non-insect pests

Mites: *Oligonychus mangiferae*

Infestation occurs mainly in prolonged drought

situations. Mites feed on leaves remaining on the underside. Affected leaves lose lustre, become whitish and crispy. Normally does not require any chemical measures, but if very serious spray sulphur, dicofol or ethion.

Birds

Common Babbler, *Turdoides affinis*
Jungle Babbler, *Turdoides Striatus*
Green Barbet, *Megalima zeylonica*

Bats

Flying fox, *Pteropus edwardseii*

Rodents: Rats, squirrels, bandicoots and porcupines have been observed to damage cashew in India. Mouse, *Mus booduga booduga* causes damage in the field. The house rat, *Rattsu rattus rufescens* has been reported to gnaw open nuts in godowns and eat away the cotyledons of the germinating cashew in the field (Abraham, 1958). The south Indian palm squirrel, *F. palmarum* has also been observed to destroy the cashew seedlings by consuming the cotyledons (Basheer and Jayaraj, 1964). The lesser bandicoot, *B. bengalensis* reportedly damage cashew nuts in the field and hoard large numbers of nuts in their burrows. In one instance as many as 145 nuts were collected from the burrow system of a bandicoot (Bhat and Mathew, 1982). This bandicoot has also been reported to damage cashew seedlings in the field (Rai, 1984). The white tailed wood rat, *R. blanfordi* is yet another species of rat observed to damage cashew nuts in the field. On an average 5-7 nuts were gnawed open and eaten by this rat per day (Bhat, 1990). The Indian crested porcupine, *Hystrix indica* has been observed to split open cashew nuts and damage the seedlings in the field.

The management of the above non- insect pest species deserve no special care as these are quite local and causes no serious damage.

The changing scenario of pesticide use

Till 1960s, cashew trees were grown in marginal conditions without much attention on pest-control. Trees, which have been attacked by insects, such as *Helopeltis* damaging young shoots, induced excessive branching, bushy canopy and short main stem ramifying into heavy branches, often resting on or near the ground level. Such situation was of course conducive for soil conservation. Amongst the chemical insecticides, DDT was the first to be used widely against *Helopeltis* spp. followed by carbaryl, endrin and dieldrin. As the use of DDT fell off in 1970s, gamma HCH or lindane rapidly became established as the standard chemical. From 1963 onwards agro-chemicals like endrin were used in Government owned estates, which were subsequently brought under Plantation Corporation of Kerala (PCK) (Mahapatro, 2008a). From 1980, aerial spraying was started in PCK plantations with endosulfan during flushing, flowering & fruiting (George *et al.*, 1984; Krishnamurthy *et al.*, 1985). From 1960 to till date dozens of chemicals were tested against TMB. Different generations of pesticides such as organo-chlorines, organo-phosphates and carbamates, synthetic pyrethroids and botanicals tested. Some of the newer and novel molecules like imidacloprid, cartap, profenphos, etofenprox etc were also attempted. The development of softwood grafts in the 1980s with intensive branching and short stature again favoured the uninterrupted pest build-up which led to severe pest outbreak, thus has warranted more number of sprays in young grafts. Many-a-media reports appeared around 2000-2001 implicating that endosulfan spraying in cashew plantations by aerial-method was responsible for health hazards such as deformed births, epilepsy, cancer, cerebral palsy, suicidal tendencies and many more ailments in Padre village of North Kerala. The Centre for Science and Environment (CSE) has reported high level of endosulfan residues in samples (water, soil, cashew-leaves, cow's milk and human blood). However, in subsequent studies by the then Fedrick Institute of Plant Protection and Toxicology (FIPPAT), Padappai (Tamil Nadu); no residue in blood samples was detected. Traces of residues were only found in soil and leaf-samples. Subsequently endosulfan was banned in 2003 in Kerala.

Research on TMB in India – the trend

Even very small population of bug are capable of causing colossal loss, therefore, need based spraying cannot be recommended in cashew (Abraham, 1984). The three-round standard spray-schedule is being adopted across the country for last 25 years or so, providing desirable control. Endosulfan, monocrotophos, carbaryl and quinalphos were established as standard chemicals. A sense of complacency seemed to prevail as the pesticide-

load is reduced substantially (in Australia, a six-round application of dimethoate is being resorted with control threshold of 6-10% freshly damaged flushes (Peng *et al.*, 2004) However, very often it has failed in several occasions, our past experience with Kerala farmers provided this beyond doubt.

No data is available on resistance development for TMB against chemicals and is attributed to the lack of an artificial diet and/or a handy mass-rearing technique for *H. antonii*. Though, rearing techniques are available (Sundararaju and John, 1992), these methods are based on and depends upon the natural host food (cashew flushes) which is limited during on-season only. The costly and cumbersome way of rearing complicates the research on resistance aspects. That is why, in lab it is quite difficult to establish resistance development. For the same simple reason, lethal dose/ concentration (LD_{50}, LC_{50} etc.) values for TMB were not worked out anywhere so far.

Limited literature on residue-research in India reported no residue-risk in cashew both inclusive of experimental trials and farm-gate sample analyses (Bhat, 2001). No pesticide-residue was found for monocrotophos, quinalphos, carbaryl and chlorpyriphos in cashew kernels from experimental plots of Madakkathara (Mahapatro and Mathew, 2007).

Before going for IPM in cashew in India, deriving ETL is the first and foremost task to be done. The only literature available on ETL for *Helopeltis pernicialis* in cashew is by Peng *et al.* in Australia (Peng *et al.*, 1995, 1997, 1998, 2004). The control threshold is calculated as 6-10% of freshly affected flushes. Through the rating scale (0-4) for TMB was devised (Ambika *et al.*, 1979) in 1979 in India, no refinement has been done afterwards. The scoring methodology was recently modified by Mahapatro (2008b) that is based on the tea mosquito bug damage intensity and extensity.

Damage Intensity (DI): It is the degree of insect-pest infestation onto the target tissues (flushes). This is calculated based on the number of necrotic lesions produced by TMB.

Refined scoring methodology (on 0 – 4 grid)

Score	Description
0	No lesions/ streak.
1	Upto 3 necrotic lesions/streaks; general vigour of the shoot/panicle unaffected, otherwise for leaves 1 – 25% damage to midribs.
2	4 – 6 coalescing/non-coalescing lesions; otherwise for leaves 26 – 50% damage to midribs.
3	Above 6 coalescing/non-coalescing lesions, otherwise for leaves 51 – 75% damage to midribs.
4	Lesions/streaks confluent complete drying of affected panicles/shoot; otherwise for leaves 76 – 100% damage to midribs.

Damage Extensity (DE): It is the degree of insect-pest infestation onto the target tree/plant. This is calculated based on the percentage of flushes affected/infested in the tree/plant.

DE = Affected or infested flushes / total no. of flushes observed x 100

Damage profile index (DPI) is formulated as the product of damage intensity and damage extensity.

Damage profile index = DI x DE / 4

As damage profile index for nut formation stage is a function of DPI at flowering and in turn DPI at flowering is a function of DPI at flushing, ultimately yield loss assessment should be done accordingly.

Yield = f(DPI at nut formation)
[f means function]
DPI at nut formation = f(DPI at flowering)
DPI at flowering = f(DPI at flushing)

We should not attempt to take average for the three critical stages, and arrive at a mean score value. By doing so, we loose lot of information inadvertently.

The bug and fungi complex

A perusal of available literature depicts that TMB and certain fungi are often associated with blossom blight and shoot dieback (Abraham, 1958; Anonymous, 1960, 1966,1972; Basu Choudhury, 1962; Nambiar *et al.*, 1973). In 1960-70, recommendations for the control of the malady was spraying of cuman in combination with dimecron (Anonymous, 1966) or DDT (Damodaran and Nair, 1969). However, TMB is the primary causal agent for the malady and fungi (*Gloeosporium mangiferae*), were only secondary saprophytic colonizers (Nambiar

et al., 1973). A suitable insecticide alone at appropriate time to combat the malady is recommended. Afterwards, we could find a gap of 25 years on research efforts on bug-fungi complex. This is only after the severe outbreak of TMB-*Colletotrichum* complex across the West Coast and Maidan parts of Karnataka and Kerala resulting half of the cashew crop loss in 1998-99 (Prasada Rao, 2002); research efforts were rejuvenated again in this regard. The role of *Colletotrichum gloeosporoides* in aggravating the shoot dieback was clearly established (Bindu et al., 1998; Deepthy, 2003). The involvement of the fungus in dieback complex calls for appropriate modifications in the protection strategies for young cashew plantations in particular. A combination of sprays (fungicides + insecticides) as prophylactic spray on monsoon flushes may help reducing the disease severity (Sally *et al.*, 1999). It has to be confirmed further from field-trials (Bindu *et al.*, 1998).

One most probable reason, why endosulfan was proved most effective in field trials across the country for the last 4-decades, is its fungicidal property. It could protect the cashew from bug-fungi complex, though nobody till-date has clearly spelt it out. In laboratory tests, it was established that insecticides like quinalphos, carbaryl are inhibiting the fungus, *Colletotrichum* growth (Deepthy, 2003). This calls for more research endeavors on screening pesticides having both insecticidal and fungicidal properties to combat the bug-fungi menace.

Monitoring, surveillance and prediction/forecasting of pest incidence

A strong surveillance programme and proper monitoring of the pest-situation can rationalize management strategies and avoid the need for blanket sprays by way of prophylaxis. To deal with this, reliable forewarning systems is indispensable, and for this prediction modeling-works was done by Sundararaju (2005) and Prasada Rao and Beevi (2008) based on regression equations. These are static models, and actually we need dynamic models. Nevertheless, research on TMB vis-à-vis weather factors are limited. Prasada Rao (2002) reported that, night temperature 13-18°C, cloudiness and relatively dry weather with afternoon relative humidity, 40-60 per cent may be optimum for triggering TMB population. The cold (<12°C min.), hot (>35°C of max.) and wet (continuous heavy rains) weather conditions on the other hand are not conducive for triggering pest population. Based on the above limits, the hot spots are demarcated across the country.

Economics of pest management

Evaluation of new insecticides (chlorpyriphos, triazophos, lambda-cyhalothrin, profenophos) against TMB at Madakkathara revealed that, lambda-cyhalothrin was most cost-effective, when calculated per tree-basis (CRS, 2005 & 2006; Mahapatro and Mathew, 2007; Mahapatro, 2008a). Though non-significant, comparing yields obtained amongst treatments, Kerala recommendation (KAU, 2002) was (3-round schedule) found to be the most effective and profitable spray schedule.

Some suggestions for efficient pest management

- Young plants need more care, means more frequent sprayings. The problem may be due to the bug-fungi complex. Take appropriate care accordingly (Mahapatro and Mathew, 2005; Mahapatro, 2008a).
- Spray before 9 am or after 4 pm in order to save non-target pollinators. Apropos canopy-size, use 5-10 litres of spray fluid for grown up trees with high volume spray. Use rocker sprayer with Hi-tree lance or power sprayer for fully covering the canopy (KAU, 2002).
- *Critical spraying stages*: Though three-round spray schedule is essentially required for TMB in most cases, if spray schedule is to be curtailed to two in IPM programme, then spraying at flushing may be avoided (Godse et al., 2002).

Pesticide delivery system

Proper delivery system is the key to a successful spray schedule. Though, different systems are tried-and-tested in cashew, conventional high volume spray (HVS) is the most common which can be carried on a tree-to-tree basis, but laboursome and time-consuming. On the other hand, mechanized spraying is economic and time-saving.

Combinatorial chemistry

Normally, diseases don't pose serious threat to cashew plantation. However, in nursery, diseases like seed rot, seedling blight and root rot causes serious damage which can be effectively managed with integrated approach. Application of 2g of *Trichoderma* or 10g of *Mycorrhiza* per bag at sowing time in nursery can reduce disease infestation. Drenching with 200ml mancozeb/ copper-

oxychloride (2g/lit) or potassium phosphonate (Akomin®, 3 ml/lit) is also effective. In plantations, diseases like anthracnose, pink-disease, gummosis, red rust and leaf blight can be combated by application of 1% Bordeaux mixture or copper-oxychloride (3 g/lit). Sooty mold (often seen associated with mealy bug and aphids) can be managed by 1% Bordeaux mixture or 2% starch application. When insects and pathogens combinely infest/infect the crop, the application technology plays pivotal role. Mostly TMB and anthracnose complex is to be mitigated by combined spray (Table 6), and appropriate pesticide combination is to be made on correct compatibility-basis.

Additional Points

Agro-techniques: Timely pruning can keep the tree in a hygienic manner and thereby avoids the incidence of pests and diseases. This is more important in old plantations. Urea spray (3%) along with first round spray of insecticide increases cashew yield. This practice is mostly followed in Maharastra. In coppicing orchards (detopped trees for rejuvenation), the wound must be pasted with pesticide treated coaltar in order to prevent both insect and pathogen attacks.

Monitoring and pest-surveillance: If the pest infestation is detected and located at the correct time, local and limited treatments with chemicals, which are ecologically safe, can take care of the issue.

Botanicals: Natural as well as proprietary botanical insecticides are good biological weapons that can be best integrated with chemicals. Neem oil (3-5%), Karanj (*Pongamia*) oil (2%) and Fish oil Rosin Soap and Neem Seed Kernel Extract (1%) are some of the botanical preparations effective against common pests. While using botanicals, emulsifiers [soap-water/ bar-soap 0.5% (5g in 1 lit) or teepol (0.1%) should be used in the spray fluid. Spraying in evening hours is suggested. While spraying, follow all the precautions. Negative point with botanicals is, they need frequent application increasing the cost, and cannot be relied upon in heavy pest-infestation (Mahapatro and Mathew, 2005).

Biocontrol options: So far very little progress could be made in this line. However, some efforts can be resorted to for conservation and augmentation of the existing natural enemies in the cashew plantation. During insecticide spraying, try to avoid application on non target areas such as tree trunks, tree bases etc., so that the natural enemies like predatory mites and other insect predators are selectively protected. Lepidopteran pests in cashew like nut borers, leafwebbers and other caterpillar-pests can be well managed with Bt (*Bacillus thuringiensis*)-pesticides.

Role or red ants: Trees harbouring ant-colonies (particularly red ants, *Oecophylla smaragdina*) are to be spared of spraying (Mahapatro and Mathew, 2006; Mahapatro et al., 2006 b, c). Ants help in increased pollination and minimizes the infestation of some of the insect pests including TMB. However, appropriate care should be taken as ants help spreading mealy bugs and scales.

Conclusion

Despite certain negative consequences (Mahapatro, 1999; Mahapatro et al., 2008), pesticide is an inevitable ingredient in IPM. The rational approach must be in reducing the pesticide-load, judicious use, adapting 'low-risk', 'soft-chemistry' and 'low to ultra-low' dose pesticides like (Mahapatro and Mathew, 2007; Mahapatro, 2007, 2008a) rotating the pesticides based on their mode of actions as per IRAC-recommendation, use more of botanicals and biopesticides. Use of weaver ants (*O. smaragdina*) often termed as 'living pesticides' may be validated and adapted in Indian context (Mahapatro et al., 2006b,c). Proper application technology must be communicated to the common farmers effectively.

Pest control with chemicals only received serious

Table 6. Recommendation for combined sprays against tea mosquito bug and anthracnose in endemic areas (Sally et al., 1999; KAU, 2002)

Name of pesticides	*Dose (per litre)*	*Stage of crop*
Monocrotophos 0.05% + Copper oxychloride 0.2%	1.5ml (36 EC) + 2g	Flushing
Quinalphos 0.05% + Mancozeb 0.2%	2ml (25 EC) + 2g	Flowering
Carbaryl 0.1%	2g (50 WP)	Nut initiation

attention in cashew. The use of chemicals for short-term strategies, ease of operation and market profit maximization with farmers' demand all led to chemical control playing a pivotal role. Contrary to this situation, chemicals are to be used as last line of defense. By integrating several options available for pest control, it is possible to realize increased yield and profit from our cashew plantation without impairing environment.

Organic farming is gaining momentum across the globe with increased awareness about ill effects of harmful chemicals on health and environment. However, organic pest management module is not well validated yet in cashew. Botanicals are not as effective as chemicals, and are associated with higher cost due to the need for frequent spraying and higher prices. However, organic cashew can fetch a premium price compensating for the higher crop-protection cost.

References

Abraham, C.C. and Nair, G.M. 1981. Effective management of the tea mosquito bugs for breaking the yield barriers in cashew. *Cashew Causerie* 3 (1): 6-7.

Abraham, C.C. 1984. Step up cashew nut production by effective pest control. *Cashew Causerie* 5 (1): 10-11.

Abraham, E. V. 1958. Pests of cashew (*Anacardium occidentale* L.) in south India. *Indian Journal of Agricultural Sciences* 28 (4): 531-543.

Ambika, B., Abraham, C.C. and Vidyadharan, K.K. 1979. Relative susceptibility of cashew types to infestation by *Helopeltis antonii Sign.* (Hemiptera: Miridae). In: Proc. PLACROSYM-II, pp. 513-516.

Anonymous. 1960. *Report of Indian Council of Agricultural Research*, 1957-58, 7-57.

Anonymous. 1966. Ibid : 1965-66, 1966, 48p.

Anonymous. 1972. *Annual News Bulletin for the year* 1971-72, *Indian Forester* 98: 715-781.

Anonymous. 1981. *Cashew Bulletin* 7 (6): 4-7.

Anonymous. 1999. *The Cashew* 13 (4): 49-52.

Basheer, M. and Jayaraj, S. 1964. Cashewnut pests. In: *Entomology in India*. Entomological Society of India, New Delhi, pp. 261-266.

Basu Choudhuri, J.C. 1962. Preliminary investigations on the insect pests of cashew plantations in Kerala. *Indian Forester* 88: 516-522.

Beevi, S.P., Rao, D.S., and Abraham, C.C. 1991. Pest complex associated with cashew and their seasonal occurrence. In: *Proc. Third Kerala Science Congress* (ed. Balakrishnan Nair, N.). State Committee on Science, Technology & Development, Thiruvananthapuram, Kerala, pp. 327-329.

Beevi, S.P. and Mahapatro, G.K. 2007. A new field screening of cashew genotypes against tea mosquito bug, *Helopeltis antonii* Sign. *Journal of Plantation Crops*, 35 (3): 139-145.

Beevi, Pathummal S, Mahapatro, G.K. 2008. Species-spectrum and interrelationship between ant and spider fauna in cashew agroecosystem. Journal of Plantation Crops 36(3): 375-381

Bhat, P.S. 2001. Insecticide residues in cashew. In: *Proc. XV Biennial Workshop*, NRCC, Puttur, Karnataka, pp. 85-93

Bhat, S.K. 1990. Ecology, biology, economic status and control of economically important rodents in plantation crops. *In CPCRI Annual Report for 1989-90*, Kasaragod, India. pp.106-110.

Bhat,, S.K. and Mathew, D.N. 1982. Record of *Bandicota bengalensis* Gray as a pest of cashew, *FAO Plant Protection Bulletin* 30:160.

Bindu, N., Pathummal Beevi, S., and Sukumara Varma, A. 1998. Shoot die back in cashew infested by tea mosquito bug *Helopeltis antonii* Sign. as influenced by the fungus. *The Cashew* 12 (2): 13-19.

CIBC, 1983 (Commonwealth Institute of Biological Control). Possibilities of the use of natural enemies in the control of *Helopeltis* spp (Miridae). *Biocontrol News and Information* 4: 7-11.

CRS (Cashew Research Station) 2005. *Annual Report 2004-05* (eds. Jose Mathew, G K Mahapatro and A Mareen), Cashew Research Station, Madakkathara, KAU, Thrissur, 81p.

CRS (Cashew Research Station) 2006. *Annual Report 2005-06* (eds. Jose Mathew and G K Mahapatro). Cashew Research Station, Madakkathara, KAU, Thrissur, 78p.

Damodaran, V.K., and Nair, M.P.B. 1969. Studies on the insecticidal control of *Helopeltis antonii* Signoret on cashew *Agriculture Research Journal of Kerala* 7(1), 28-30.

Deepthy, B. 2003. Evaluation and management of pest complex in cashew grafts. *M.Sc. Thesis*, KAU, Thrissur, Kerala.

Devasahayam, S. and Nair, C.P.R. 1986. The tea mosquito bug *Helopeltis antonii* Signorett on cashew in India. *Journal of Plantation Crops* 14 (1): 1-10.

IRAC (Insecticide Resistance Action Committee) 2007. IRAC Mode of Action Classification, Revised and re-issued, July 2007, pp.1-10. (www.irac-online.org)

George, M.V., Singh, V. and Peter, T. 1984. Aerial spraying against tea mosquito in cashew. In: *Cashew Research and Development* (eds.) Rao, E.V.V.B., and Khan, H.H., Indian Society for Plantation Crops, CPCRI, Kasargod, Kerala, pp. 120-125.

Godse, S.K., Bhole, S.R. and Munj, A.Y. 2002. *The Cashew* 16 (2): 43-45.

KAU. 2002. (Kerala Agricultural University). Package of Practices recommendations: Crops. KAU, Thrissur, pp. 54-62.

Krishnamurthy, K., Khan, M.M. Hiremath, I.G., Nagaraju, A.P., Mallik, B. and Hedge, M. M. 1985. Three decades of cashew research at the agricultural research station. *Technical Bulletin No. 3*, NARP, UAS, Agricultural Research Station, Ullal, 34p.

Mahapatro, G.K. 1999. Pesticides: boon or bane? Discussing its changed role in integrated pest management. *Pestology* 23 (6): 30-36.

Mahapatro, G.K. 2007. Pesticides and ant-technology: the emerging trends in India (Lead-paper). In: *Souvenir, National Symposium on Sustainable Pest Management*, 6-7 December, OUAT, Bhubaneswar, pp.75-83.

Mahapatro, G.K. 2008a. *Helopeltis* management in cashew: a critical review. *Indian Journal of Entomology* 70 (4): 293-308.

Mahapatro, G.K. 2008b. A refined damage rate scoring method for tea mosquito bug infestation in cashew. *Indian Journal of Entomology* 70 (3): 273-277.

Mahapatro, G.K. 2008c. Evaluation of insecticidal sprays for control of tea mosquito bug *Helopeltis antonii* and other insect-pests in cashew. *Indian Journal of Entomology* 70 (3): 217-222.

Mahapatro, G.K., Ajanta, B. and Gupta, G.P. 2008. Pesticides in India: the emerging trends. *Indian Journal of Entomology* 70 (1): 1-11.

Mahapatro, G.K. and Mathew, Jose 2005. Integrated pest management in cashew: concepts and practices. *Cashew Bulletin* 43 (7): 5-15.

Mahapatro, G.K. and Mathew, Jose 2006. Cashew trees harbouring red ant nests need no spraying. *Abstracts*. In: *National Symposium on Improving Input Efficiency in Horticulture*, IIHR, Bangalore, 9-11 August, p.186.

Mahapatro, G.K. and Mathew, Jose 2007. Search for new insecticides with added advantages for the management of tea mosquito bug in cashew. In: *Proc. 19th Kerala Science Congress*, 29-31 January, Kannur, Kerala, pp. 433-435.

Mahapatro, G.K., Pathummal Beevi S., Jose Mathew and Biju, C.R.. 2006a. Advancing in ant-technology in cashew: issues and strategies, *Cashew Bulletin* 44 (1): 11-20.

Mahapatro, G.K., Pathummal Beevi S., Mathew, Jose and Biju, C.R.. 2006b. Special Issue on Ant-technology in Cashew. *Cashew Week* 6 (8): 5-7. (www.commodityIndia.com)

Mahapatro, G.K., Pathummal Beevi S., Mareen A. and Mathew, Jose 2006c. Advancing towards organic technologies for pest management in cashew: a holistic approach. *Abstracts*. In: *National Seminar on Convergence of Technologies for Organic Horticulture*, TNAU, Coimbatore, July 20-21, 2006: 184-185.

Mahapatro, G.K., Mathew, Jose and Mini C. 2006d. Critical cashew crop-phenophases verses pest management, In: *National Symposium on Plant Physiology*, Thrissur, Kerala, 28-30 Nov. 2006: 124p.

Mathew, J. and Mahapatro, G.K. 2005. Organic farming in cashew. *Agrobios Newsletter* 4 (1): 60-65.

Nair, M.R.G.K. 1975. *Insects and Mites of Crops in India.* Revised edition, 1986. ICAR Publication, New Delhi, 408p.

Nair, M.R.G.K., Oommen, C.N., Mohandas, N. Pests of processed cashew and their control. ISHS International Cashew Symposium, *Acta Horticulturae* 108: http:// www.actahort.org.

Nambiar, M.C. 1976. In: *Increasing Production and Productivity of Cashew in India*, (eds. Bavappa, K.V.A., and Haridasan, M.). Central Plantation Crops Research Institute, Kasargod, pp. 21-24.

Nambiar, K.K.N., Sarma, Y.R., and Pillai, G.B. 1973. Inflorescence blight of cashew (*Anacardium occidentale* L.). *Journal of Plantation Crops* 1: 44-46.

NRCC, 2004. Indigenous Technical Knowledge in Cashew, *NRCC Technical Bulletin No. 9*, NRCC, Puttur, 20p.

Ohler, J.G. 1979. *Cashew*. Unrevised Print, 1988, Department of Agricultural Research, *Koninklijk Instituut, voor de Tropen*, Amsterdam, 1979, 260p.

Peng, R.K., Christian, K., and Gibb, K. 1995. The effect of green ant, *Oecophylla smaragdina* (Hymenoptera: Formicidae), on insect pests of cashew trees in Australia. *Bulletin of Entomological Research* 85: 279-284.

Peng, R.K., Christian, K., and Gibb, K. 1997. Control threshold analysis for the tea mosquito bug, *Helopeltis antonii* (Hemiptera: Miridae) and preliminary results of the control efficiency by the green ant, *Oecophylla smaragdina* (Hymenoptera: Formicidae) in northern Australia. *International Journal of Pest Management* 43: 233-237.

Peng, R.K., Christian, K., and Gibb, K. 1998. *Effect of native vegetation on cashew arthropod fauna*, RIRDC Publication No. 98, RIRDC Project No. UNT-3A, 38p.

Peng, R.K., Christian, K., and Gibb, K. 2004. *Implementing ant technology in commercial plantations and continuation of transplanted green ant colony monitoring.* RIRDC Publication No. W04/088, Project No.UNT-5A, 15p. (www.rirdc.gov.au)

Prasada Rao, G.S.L.H.V. 2002. *Climate and Cashew.* KAU, Thrissur, Kerala, 100p.

Prasada Rao, G.S.L.H.V. and Beevi, P.S. 2008. Forewarning tea mosquito bug in cashew. KAU, Thrissur, Kerala, 72p.

Rai, P.S. 1984. *Hand Book on Cashew Pests*, Research Co-publications, 199 East Azadnagar, Delhi, 124 p.

Ravirasad, T.N.. 2004. In: *Proceedings of National Group Meeting of Scientists of AICRP on Cashew*, 4-6 June, NRCC, Puttur, Karnataka.

Reddi, E.U.B. 1987. Under-pollination: a major constraint of cashewnut production. In: *Proc. Indian Notational Academy B53*, 3: 249-252.

Reddi, E.U.B. 1991. Pollinating agents of cashew – wind or insects? *Indian Cashew Journal* 20 (4): 13-18.

Rickson, F.R. and Rickson, M.M. 1998. The cashew nut,

Anacardium occidentale (Anacardiaceae), and its perennial association with ants: extrafloral nectary location and the potential for ant defense. *American Journal of Botany* 85: 835-849.

Sally, K. Mathew, Abdul Salam, M., Vilasini, T., Susannamma, K. 1999. Anthracnose disease – an emerging threat to cashew. *Cashew Bulletin* 37 (8): 3-4.

Simmonds, F.J. 1970. *Commonwealth Institute of Biological Control, Report* (Mimeographed), 9p.

Stonedahl, M. Gary. 1991. The oriental species of *Helopeltis* (Heteroptera: Miridae): a review of economic literature and guide to identification. *Bulletin of Entomological Research* 81: 465-490.

Sundararaju, D. 1984. Studies on cashew pests and their natural enemies in Goa. *Journal of Plantation Crops* 12: 38-46.

Sundararaju, D. 2002. Biotic stress on cashew pests and disease management, pp.87-91, In: *Indian Cashew: Issues and Strategies* (eds. Singh, H.P., Balasubramanian, P.P. and Venkatesh N. Hubballi). DCCD, Kochi, 170p.

Sundararaju, D. 2004. Status of management of tea mosquito bug on cashew. In: *Proceedings of National Group Meeting of Scientists of AICRP on Cashew*, 2004, 4-6 June, NRCC, Puttur, Karnataka, pp.12-16.

Sundaraju, D. 2005. Seasonal abundance and extent of damage of tea mosquito bug on cashew. *Journal of Plantation Crops* 33 (1), 53-58.

Sundararaju, D. and John, J.N. 1992. Susceptibility of cashew accessions to *Helopeltis antonii* Sign. (Heteroptera: Miridae) in the pre-flowering phase. *Journal of Plantation Crops* 21, 50-53.

Sundararaju, D. and Sundarababu, P.C. 1999. *Helopeltis* spp. (Heteroptera: Miridae) and their management in plantation and horticultural crops of India. *Journal of Plantation Crops* 27 (3): 155-174.

Venkatesh, N. Hubballi and Balasubramanian, P.P. 2003. *Organic Production of Cashew: Guidelines*, Directorate of cashew and Cocoa Development, Kochi, 162p.

CASHEW PATHOLOGY

Sally K. Mathew
Dept. of Plant Pathology, College of Horticulture, Kerala Agricultural University - 680 656, Kerala
(e- mail: sallykmathew @yahoo.com)

Introduction

Cashew is one of the important commercial crop of Kerala. One of the major factor responsible for the low productivity of cashew in Kerala is the infestation of tea mosquito bug (TMB). As compared to pest problems, disease incidences are less in cashew. So cashew pathology hasn't received much attention in Kerala. Hence the research work on cashew diseases are also meagre and scanty.

Nursery diseases

Eventhough, diseases are not a serious problem in cashew plantations, it has now become a threat in cashew nurseries, with the use of new varieties and new scientific adaptations. Among the various nursery diseases, pre-emergence and post emergence damping off, seedling blight, root rot, dieback and leaf blights caused by *Colletotrichum gloeosporioides*, *Pestalotia sp.* and *Phytophthora palmivora* are observed in the nursery of Cashew Research Station, Madakkathara (Mathew, 2000).

As far as seedling diseases are concerned, much emphasis has been given on seedling die back. Bindhu (1996) isolated the fungus, *Colletotrichum gloeosporioides*, associated with the necrotic lesion on cashew shoots. She studied the role of fungus in aggravating the shoot die back when inoculated on the grafts infested by TMB. She also observed that, TMB feeding on its own without the association of fungus or inoculation of fungus alone with or without injury did not produce dieback symptoms. The secondary association of the fungus is thus proved to be responsible for the initiation and spread of dieback of young cashew grafts, in which the TMB feeding lesion acted as the mode of entry for the pathogen. Spraying of one percent Bordeaux Mixture was found to be effective in preventing the progression and spread of dieback symptoms (Bindu *et al.*, 1998).

Deepthy (2003) also isolated *C.gloeosporioides* from dieback affected cashew grafts. Her study on TMB - *Colletotrichum* complex revealed that the plants infected with TMB alone caused slight damage and regain their growth and recovered later. But the plants inoculated with TMB + *Colletotrichum* in combination, the plants could not regain the growth. She also reported that, inoculation of fungus without injury caused any disease symptoms on shoots and it is clear that, the fungus gains entry through the wound caused by TMB feeding. In her study, variety H-1600 showed tolerance to TMB-*Colletotrichum* complex and H-1610 and Kanaka were tolerant to TMB damage. Varieties Anakkayam-1, and Madakkathara-1 were highly susceptible to TMB-*Colletotrichum* complex under *in vivo* condition.

Lab studies conducted to test the effectiveness of different pesticides and their combinations against *C. gloeosporioides* revealed that, the fungicides, carbendazim 0.1% and copper oxychloride 0.2% and their combination with quinalphos 0.05%, imidachloprid 0.05%, azadirachtin 1% and carbaryl 0.1% were effective in inhibiting the growth of the fungus. Combination sprays of carbendazim 0.1% or copper oxychloride 0.2% with quinalphos 0.05% were most effective against TMB- *Colletotrichum* complex in cashew nursery (Deepthy and Kurien, 2004).

Damping off, seedling blight and root rot diseases are other menace in cashew nursery. In order to find out the effect of solarisation, bioagents and chemicals on control of these nursery diseases, a study was conducted at Cashew Research Station, Madakkathara in 2001. From the experiment, it was observed that, use of solarised potting mixture, use of *Trichoderma harzianum* @ 2g/ bag, AM fungi, *Glomus fasiculatum* @ 10g/ bag at the time of sowing and soil drenching with mancozeb 2g L^{-1} or copper oxychloride @ 2g L^{-1} before sowing were effective in reducing soil borne diseases in nursery.

Seedling mortality was less and observed in treatments consisting of non solarised potting mixture, soil application with *Trichoderma*, mancozeb or AMF, in which incidence varied from 1.33- 2.66 per cent only. It is also noted that no saprophytic nematodes were observed in any of the treatments other than AMF treated and control ones. Saprophytic nematodes were numerous in control bags. In addition, weed growth was comparatively less in bags having solarised mixture.

Isolation of fungi from infected seedlings revealed association of *Pythium aphanidermatum, Phytphthora palmivora* with pre-emergence and post emergence damping off; *P.aphanidermatum, Pythium* sp., *P.palmivora, Fusarium* sp., and *Cylindrocladium* sp. with seedling blight; and *P.aphanidermatum* with root rot diseases (Mathew 2000)

Soil solarisation, application of bioagents and chemicals not only reduced seed borne pathogens but also found to increase germination percentage and growth vigour of cashew rootstock. Use of *Trichoderma* enhanced early germination, but soil drenching with copper oxychloride delayed germination of cashew seeds (Joseph *et al.*, 2002).

Application of potassium phosphonate 0.3% is found to reduce soil borne diseases as well as *Phytophthora* leaf blight in cashew nursery.

Another study was conducted at Cashew Research Station, Madakkathara in 2003 to find out the effect of *Trichoderma* on growth and vigour of cashew grafts. *Trichoderma viride* (3 g/ bag) was applied to soil at the time of sowing and after grafting and compared with soil drenching of one per cent bordeaux mixture. It was observed from the experiment that, the application of *Trichoderma* at the time of sowing itself enhanced the growth and vigour of rootstocks as well as cashew grafts. But the application of bordeaux mixture affected the germination of seeds and also retarded the growth of seedlings as well as the grafts. Both treatments reduced soil borne diseases in nursery.

Plantation diseases

Diseases such as die back and inflorescence blight (anthracnose), pink disease, gummosis, sooty mould, red rust, *Pestalotia* leaf spot were observed in research plots of Cashew Research Station, Madakkathara. Another leaf spot caused by *Colletotrichum gloeosporioides* is reported from Kerala by Abraham and Padmakumari (1980). Among the plantation diseases, dieback and inflorescence blight is the most serious one and much work has been done on this malady.

Nambiar *et al* (1973) studied the role of *Helopeltis antonii* (TMB) and the fungi *Gloeosporium mangiferae* and another non sporulating fungus in inciting inflorescence blight in cashew. TMB was found to be the primary causal agent and the fungi were only secondary saprophytic colonizer. Spraying with 0.1 per cent ziram and 0.03 per cent phosphamidon is recommended for the control of inflorescence blight. Pillai and Abraham (1975) reported TMB infestation and the concomitant association of various fungal colonizers leading to shoot die back and inflorescence blight symptoms in cashew. The involvement of fungal wound pathogens in the acceleration and aggravation of dieback symptoms has also been reported by them. In a study conducted at CPCRI, Kasaragod fungi like *Colletotrichum, Fusarium* and *Botryodiplodia* have been isolated from the affected dried twigs, however they did not have any direct role on the disease incidence (CPCRI, 1983). Varma and Balasundaram (1990) studied the shoot dieback in cashew and a fungus, *Botryodiplodia theobromae* was isolated consistently from the dead tissues with rare occurrence of *C.gloeosporioides*. They also reported that, the primary cause for the entry and establishment of the pathogen was attributed to be the infestation of TMB. Bindu *et al* (1998) isolated *C.gloeosporioides* from shoots, panicles and nuts during the regular flushing and flowering period that extended from the month of October to March. Apart from the commonly occurring fungus, *C. gloeosporioides*, other fungi isolated were *Fusarium* sp. and a non- sporulating fungus. *Fusarium* sp was isolated from shoots, panicles and nuts during January and also from the shoots during June - July, whereas, the non- sporulating fungus could be observed on TMB infested regular flushes and panicles during October to December.

Severe out break of TMB- anthracnose complex resulted in huge loss of yield in northern part of Kerala during 1998-99. Crop loss of 80-100 per cent has been reported from Hosdurg, Periya and Chemeni cashew plantations in Kasaragod district due to this pest-disease complex.

The fungus, *Colletotrichum gloeosporioides* was isolated from affected shoots, inflorescence and nuts (Mathew *et al.*, 1999).

From the laboratory studies conducted, it was observed that the dieback symptoms could be produced only on inoculation of fungus with an injury after 24 h of TMB feeding. However, in case of inflorescence blight, symptoms were produced even without any injury, but the symptom expression was delayed. Water socked lesions appeared 48h after inoculation of the fungal spore suspension where injury was given but it was seven days in case of without injury.

A trial was conducted at Cashew Research Station, Madakkathara during 1999-2001, for the management of anthracnose- TMB complex. From the study, combined spraying of copper oxychloride 2 g L^{-1} + quinalphos (25 EC) 2ml L^{-1} during flushing and mancozeb 2g L^{-1} + endosulphan (35 EC) 1.5 ml L^{-1} during flowering and carbaryl 50 WP 2g L^{-1} during fruiting stage were recommended for the control of anthracnose- tea mosquito bug complex in cashew plantations (Kurien *et al.*, 2001), eventhough systemic fungicides like carbendazim (1g L^{-1}) and tridemorph (0.05 ml L^{-1}) in combination with above insecticides were found most effective, being systemic, these two fungicides can be used in nursery against seedling dieback.

In consequences with the events arisen on using endosulphan in cashew plantations of northern Kerala, another study was conducted, and based on this an adhoc recommendation was proposed for the management of anthracnose-TMB complex consisted of copper oxychloride (2g) + monocrotophos 35 EC (1.5 m/l) during flushing, mancozeb (2g) + quinalphos 25 EC (2 m/l) at flowering and carbaryl (2g/l) at fruiting stages (KAU, 2002).

Deepthy (2003) also observed that TMB-*Colletotrichum* complex was responsible for causing severe crop loss in cashew and also suggested a combined application of insecticide + fungicide for the effective control of TMB - *Colletotrichum* pest complex. She reported that, Anakkayam-1 showed higher panicle and nut infection, whereas Dhana showed higher shoot infection, but less panicle and nut infection.

Based on the various studies conducted, it is suggested that, a combined application of insecticide and fungicide is necessary for the control of TMB-*Colletotrichum* complex in nursery as well as in cashew plantations.

References

Abraham, M. and Padmakumari. 1980. A new leaf spot disease of cashew. *Indian Phytopath.* 33 (6) 26-27.

Bindu, N. 1996. Die back in cashew incited by the tea mosquito bug, *Helopeltis antonii* Signorett, as influenced by wound pathogens and plant bio chemicals. M Sc (Ag) thesis, Kerala Agricultural University, Thrissur, 52 p

Bindu, N., Beevi, S.P. and Varma, A.S. 1998. Shoot dieback in cashew incited by the tea mosquito bug, *Helopeltis antonii* Signorett, as influenced by the fungus *Colletotrichum gloeosporioides*. *The Cashew* 12 (2): 13-18

C.P.C.R.I (Central Plantation Crop Research Institute).1983. Annual report for 1981. Kasaragod, Kerala p.14.

Deepthy, K.B. 2003. Evaluation and management of pest complex in cashew grafts. M.Sc (Ag) thesis; Kerala Agricultural University, Thrissur, 53p.

Deepthy, K.B. and Kurien, S. 2004. An integrated strategy for the management of tea mosquito bug- *Colletotrichum* complex in cashew grafts. Proceedings of National symposium on "Input use efficiency in agriculture- issues and strategies". 25-27 November 2004, KAU, Thrissur, 126p.

Joseph, M., Mathew, S.K., Salam, M.A. and Kurien, S.K. 2002. Biological, chemical and solarisation effects on seedling vigour in cashew. Proceedings of the 5th National seminar on Indian Cashew in the New Millennium Vision 2020 - 12-13 April 2002. Vishakapatanam, pp. 45-48

Kurien, S., Mathew, S.K. and Salam, M.A. 2001. "Vilasamrakshanam Kasumavil" Directorate of Cashew and Cocoa Development, Cochin. 16 p.

KAU, 2002. Package of Practices Recommendations- Crops 2002. Kerala Agricultural University, Directorate of Extension, Mannuthy, Thrissur. p.189

Mathew, S.K., Salam, M.A., Vilasini, T.N. and Kurien, S.1999. Anthracnose disease - An emerging threat to cashew. *Cashew Bulletin* 37 (8) 3-5

Mathew, S.K. 2000. Is fungal attack in cashew nursery. Karshakasree 5 (1): p.37

Nambiar, K.K.N., Sarma, Y.R. and Pillai, G.B. 1973. Inflorescence blight of cashew (*Anacardium occidenatle* L) *J. Plantation Crops* 1: 44-46

Pillai, G.B. and Abraham, V.A.1975. Tea mosquito a serious menace to cashew. *Indian Cashew J.* 10 (1): 5-7

Varma, R.V. and Balasundaran, M. 1990. Tea Mosquito (*Helopeltis antonii*) feeding as a pre disposing factor for the entry of wound pathogens associated with dieback in cashew. *Entomon.* 15: 249-251

ECONOMICS OF CASHEW CULTIVATION AND CASHEW INDUSTRY

K. Jessy Thomas, Shibu Sebastian and K.G. Sreeja
Department of Agricultural Economics, College of Horticulture,
Kerala Agricultural University 680 656, Kerala

Introduction

Cashew (*Anacardium occidentale* L.), a native of eastern Brazil, was introduced to India by the Portuguese about five centuries ago. The cashew industry in India has assumed a very important and vital role in building the national economy. Cashew processing is a labour intensive industry. It has gained significant economic and social importance as it provides employment to large number of people in farms and factories. Cashew kernels are one of the most important items of international trade. Any effort in increasing the production of raw cashew nuts in India would not only generate high levels of employment in farms and factories but also save foreign exchange outflow of at least Rs.700 crore per annum on raw nut imports. The Governments in various states have realised the potential for developing cashew not only as a major foreign exchange earner but also as a vehicle for economic and social change.

Area, production and productivity

Cashew is being cultivated in Kerala in an area of 84000 ha with a production of 78000 tonnes and an average productivity of 900 kg per ha. As shown in Table 1, Kannur district has the largest area of 25066 ha with a production of 29252 tonnes followed by Kasargode district. The productivity of cashew is also highest in Kannur, which is higher than the state average.

Looking at the trend in area, production and productivity of cashew in the state in the last decade (Fig. 1 & 2), it is evident that there has been a more or less steady decline in the area under cultivation. Production also has been declining over the years. The average productivity of cashew shows certain peaks but generally a downward trend was observed.

A study by Salam *et al.* (1992) which analysed the trend in the area, production and productivity of cashew in the state of Kerala during the period 1961-62 to 1987-88 revealed that the area under cashew increased rapidly from 1975-76 to 1983-84 and declined thereafter. The productivity showed a declining trend in the late seventies and eighties. The cashew production in the state showed a steady increase from 1962 to 1975 after which there was a declining trend. Sebastian (2001) analyzed trends in area, production and productivity of cashew in Kerala using time series data for the period 1952-53 to 1999-2000 and reported that the area under cashew was showing an increasing trend till the year 1983-84 and thereafter a gradual decline has been noticed. From 1989-90 a steady declining trend in production was noticed till 1996-97. From next year onwards the production picked up at a slow pace. A slight increasing trend in productivity was observed from 1984-85 to 1991-92. Thereafter a steady declining trend was exhibited till

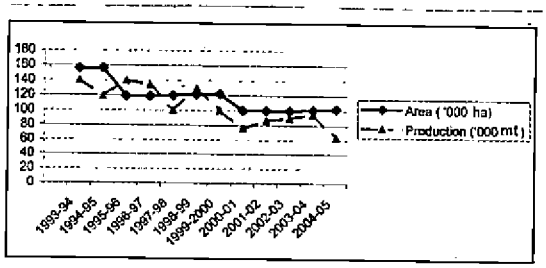


Fig. 1. Trends in area and production of cashew in Kerala

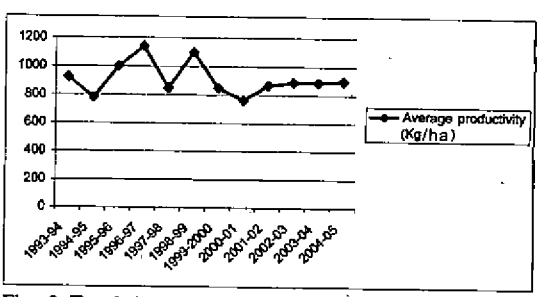


Fig. 2. Trends in productivity of cashew in Kerala

Table 1. District-wise area production and productivity of cashew - 2005-06

District	Area (ha)	Production (t)	Productivity (kg/ha)
Thiruvananthapuram	1869	1087	582
Kollam	4271	3003	703
Pathanamthitta	1048	528	504
Alappuzha	3525	1182	335
Kottayam	638	269	422
Idukki	1197	746	628
Eranakulam	1130	507	449
Thrissur	3356	1687	503
Palakkad	4391	1785	407
Malappuram	9123	7394	810
Kozhikode	3368	2200	653
Wayanad	1235	697	564
Kannur	25066	29252	1167
Kasaragod	18068	17925	992
State	**78285**	**68262**	**872**

Source: Farm guide 2008, Farm Information Bureau, Thiruvananthapuram

1999-2000. As shown in Table 2, during the whole period annual compound growth rate of area was estimated at 2.22 per cent. Regarding production, stagnation in growth was noticed (0.02 per cent). In the case of productivity, there was a decline in growth during the whole period under study recording-2.11 percent per annum.

Cost of production

The total maintenance cost of cultivation consists mainly of the cost incurred for the material inputs and labour charges. Sivanatham *et al.* (1990) revealed that the total labour cost for local variety accounted 50.72 per cent of the aggregate maintenance cost. In improved variety it accounted 40.24 per cent. For improved variety, material cost contributed 51.88 per cent of the annual maintenance cost. Senthilnathan and Balamohan (1992) worked out establishment cost and annual maintenance cost separately and revealed that labour cost accounted 50.79 per cent of the aggregate maintenance cost. The share of material cost was 38.68 per cent and other cost like depreciation, interest etc. contributed 10.6 per cent. The annual maintenance cost per hectare of cashew plantation in Kerala has been estimated by Sebastian (2001). As shown in Table 3, annual maintenance cost was estimated to Rs.7709.77 per hectare. Material cost which included the cost incurred for purchasing manures, fertilisers and plant protection chemicals was worked out to Rs.1765.89

Table 2. Compound growth rates of area, production and productivity of cashew in Kerala

Particulars	Growth rate (%)
I Whole period (1952-53 to 1999-00)	
a. Area	2.22
b. Production	0.02
c. Productivity	-2.11
II Period I (1952-53 to 1975-76)	
a. Area	5.97
b. Production	3.76
c. Productivity	-2.08
III Period II (1976-77 to 1999-2000)	
a. Area	-1.82
b. Production	-1.18
c. Productivity	0.87

Source: Sebastian (2001)

and it accounted for 22.9 per cent of the total. Labour costs include costs incurred in weeding, harvesting nuts and application of organic manure, fertilizer and plant protection chemicals. Total labour costs came to Rs. 5943.88 which was 77.10 per cent of the total cost. The costs for application of organic manure, fertiliser and plant protection chemicals were found to be 3.67, 2.21 and 4.71 per cent of the total operational costs.

Gross and net returns

It was found that the average yield per hectare of cashew was 768 kg. The average price per kg of raw cashew nut for the season was computed at Rs.27.90. The gross and net returns at the aggregate level was worked out to Rs.21427 and Rs.13717.23 respectively (Table 4).

Marketing aspects

In Kerala the marketing of raw nuts starts by December and continues up to the second week of June. But a major portion of the raw nuts is marketed during the period from March to May.

Both family and hired labourers were engaged in the collection of fruits. Storing of nuts was not a very common practice as it may result in loss in weight. Very few farmers stored raw nuts so as to have sufficient quantity for transportation using a vehicle. The nuts were transported by head load, jeep and auto. At the farmer level, no attempt has been made to grade the nuts, on account of the fact that the buyers were buying the nuts in single lots and the prices quoted were for ungraded nuts.

Table 3. Maintenance cost of cashew per hectare

Item of cost	Cost (Rs./ha)
I Material Costs	
a) Cost of organic manure	747.90 (9.70)
b) Cost of Fertilisers	569.41 (7.38)
c) Cost of Plant protection chemicals	448.58 (5.82)
Sub Total	1765.89 (22.90)
II Labour costs	
a. Application of organic manure	345.05 (4.48)
b. Application of fertilisers	154.00 (2.00)
c. Application of plant protection chemicals	271.60 (3.52)
d. Weeding	2018.84 (26.19)
e. Harvesting	3154.38 (40.91)
Sub Total	5943.88 (77.10)
Grand Total	7709.77 (100.00)

Source: Sebastian (2001) *Figures in parenthesis are percentage to the total

Table 4. Average yield and returns per hectare

Particulars	Value
Average yield (kg)	768.00
Average price (Rs./kg)	27.90
Total value (Rs.)	21427.00
Total cost (Rs.)	7709.77
Net returns (Rs.)	13717.23

Source: Sebastian (2001)

Market functionaries

a) *Village traders*

They are the licensed merchants operating at the village level with shops, and collecting nuts from the producers. They also deal with agricultural produces like rubber, arecanut, ginger, pepper etc. Raw nuts were brought to their shops by the farmers. They purchased raw nuts every day and sold on the same day or once in two days. They sold raw nuts to semi-wholesalers or wholesalers.

b) *Primary wholesalers*

They are also licensed merchants and act as the intermediary between village traders on the one hand and the secondary wholesale dealers on the other. They purchased nuts from farmers also.

c) *Secondary wholesalers*

Secondary wholesalers purchased nuts from farmers, village traders and primary wholesalers. They sold raw nuts to processors through commission agents.

d) *Commission agents*

Commission agents acted on behalf of processors. They do not take title to the product but receive commission from both wholesalers and processors.

e) *Processors/Exporters*

Processors purchased raw nuts from the wholesalers through commission agents. The nuts were transported to the drying yards of the processors located at different places in the state. After drying, nuts were again transported to the processing factories. Processors were invariably exporters of cashew kernels. Therefore, in addition to processing, grading, packing and transportation of kernel to the port were done by the processors themselves.

Marketing channels and market structure

Cashew trade in the state is mainly in the hands of private parties. Usually farmers sell raw nuts, which are being processed by the processors and further, marketed in the form of processed kernels, both in the domestic and in the foreign markets.

Sivaswamy (1949) had reported that in the marketing of cashewnut, village traders deducted 3-5 per cent of the weight as trade allowance. The wholesalers sold through brokers to the factories. The market structure and marketing margin of cashew nuts in Kerala was analysed by Rajasekharan (1987) and the impact of changes in marketing organisation and structure on pricing efficiency was examined. Among the various marketing channels operating in each panchayat, producer-village merchant-wholesaler-processor was identified as the main channel. The study revealed that the net share of producer was found

to be 59.50 per cent of the total income of the processor. The marketing margin ranged between 40 to 43 per cent in various channels identified. Net profit of the processors averaged at 18.57 per cent of the total realization of the processor. The study also reported that itinerant traders, village traders, wholesalers and processors were the major intermediaries involved in the marketing of cashew nuts. A study by Sebastian (2001) reported the following channels for marketing of cashewnut in Kerala.

Channel I --- Producer - village trader - primary wholesaler - secondary wholesaler - processor

Channel II --- Producer - primary wholesaler - secondary wholesaler - processor

Channel III--- Producer - secondary wholesaler - processor

Channel IV--- Producer - village trader - secondary wholesaler - processor

The first two channels were the most important as far as marketing of cashew nuts was concerned since a good proportion of farmers market through this channel. About 55 per cent of respondents sold their produce to the village traders, which formed 40.55 per cent of the total quantity of raw nuts, sold by them. 28 per cent sold the produce directly to primary wholesalers and this constituted 39.34 per cent of the total quantity sold. Eight per cent sold to both village traders and primary wholesalers and the quantity sold by them was 6.49 per cent of the total. Nine per cent sold directly to secondary wholesalers forming 13 per cent of quantity sold. The major factor that determined the selling behaviour of farmers to various intermediaries was the distance to the market. The difference between prices given by secondary wholesaler and village trader was only Rs.50 per quintal. Since the secondary wholesalers operated in towns, the farmers in remote areas will incur higher marketing cost if they want to sell the produce to the secondary wholesalers. Undulating topography of the area also added to the marketing cost of the producers. So the farmers invariably sold their produce to the buyer nearest to their place so that they incurred lesser marketing cost.

Marketing costs and margins

Marketing costs of respondents included cost of transport, unloading charges and cost of packing material. Sebastian (2001) reported that the cost of transportation formed the major item of cost which contributed more than 80 per cent of the total marketing cost in all the three channels (Table 5). Loading and unloading formed the next major item of cost. The higher share of transportation cost to the total marketing cost was also reported by Rajasekharan (1987), which came to over 95 per cent. Marketing costs incurred by the intermediaries include cost of loading nuts in trucks, handling charges given for filling and weighing the nuts, cost of transport, permanent labour charges, rent, telephone and electricity charges etc.

Price spread

The price spread consists of the cost involved in moving the produce from the point of production to the point of consumption and the profits of the various market functionaries involved in transferring the produce from the initial point of production till it reaches the ultimate consumer. A higher price spread indicated lower share of the producer on the consumer's rupee. According to Sebastian (2001), the net profit of the intermediaries like village traders, primary wholesalers and secondary wholesalers was less than one per cent of the total returns

Table 5. Marketing costs of producers (Rs./q of raw nuts)

Item of cost	Channel I	Channel II	Channel III
i) Cost of transportation	31.03	32.07	37.77
	(83.91)	(83.30)	(84.88)
ii) Cost of packing material	2.10	2.01	2.18
	(5.68)	(5.22)	(4.90)
ii) Loading/unloading	3.85	4.42	4.55
	(10.41)	(11.48)	(10.22)
Total	36.98	38.50	44.50
	(100.00)	(100.00)	(100.00)

Source: Sebastian (2001) *Figures in parenthesis are percentage to the total

of the processor. Regarding processors' profit, a wide fluctuation has been noticed during the months from January to May. The major factor influencing the profit of the processor is the price of cashew kernels in the international market. A higher price assures a higher profit to the processor. The price of cashew kernels in the international market declined steadily from 2.46 $ per pound in January to 2.0 $ per pound in May and it affected the profit of the processors. So the profit of the processors varied from 10.04 to 20.99 per cent of the total realisation averaged to 16 per cent. Rajasekharan (1987), also found the net share of producer to be 59.50 per cent of the total income of the processor. The marketing margin ranged between 40 and 43 per cent in various channels identified. The net profit of the processors averaged at 18.57 per cent of the total realization of the processor. The average net share of the producer was the highest in channel III which accounted for around 49 per cent of the total realization of the processor.

Marketing efficiency

The ratio of the total value of goods marketed to the marketing cost may be used as a measure of efficiency. It is expressed as index of marketing efficiency. Marketing efficiency index of various channels as revealed by Table 6, indicated that efficiency indices for channels I, II and III were 1.86, 1.88 and 1.90 respectively. It was the highest in channel III indicating the highest efficiency in this channel followed by channel II and channel I.

Processing

The Indian cashew industry, mainly centred in south Kerala, Mangalore region of Karnataka and the Kanyakumari district of Tamil Nadu, has an installed processing capacity of about 10 lakh tonnes. The record production of raw cashew nut at 5.2 lakh tonnes obtained from an area of 6.86 lakh ha during 1999-2000 could barely meet 50 per cent of the demand of about 825 cashew processing unit in the country (Economic Survey, 2000-2001). This shows that the production of raw cashew nuts is far below the demand of the processing sector and necessitated the import of raw nuts from African and South Asian countries. The availability of raw cashew nuts from imported sources is likely to suffer drastically in the years to come as more and more producing countries resort to the processing and export of cashew kernels. International development agencies have recognized cashew cultivation and processing as an effective poverty alleviation measure in less developed and developing countries. They are providing grants and loans to the countries in Africa and South East Asia for the development of cashew industry. The development of cashew processing in these countries is bound to affect the availability of raw nuts for import by India.

Processing costs

Processing of raw cashew nuts is done in the cashew processing factories located mainly in Kollam district. Though there are some factories operating in other districts, the majority of the factories in Kerala are located in Kollam district. Processors purchased raw cashew nuts from different producing areas within the state during the harvest season. These nuts are dried and stored in the factories for the subsequent processing.

As Table 7 indicates, the total processing cost incurred per quintal of raw nuts was estimated to Rs. 1892.82. The major cost included transportation cost of raw nuts, cost of packing material of raw nuts, loading and unloading charges, purchase tax, wages to labourers, establishment charges, interest, packing and export charges etc. Out of the different items of cost listed, wages including bonus and other benefits given to the labourers working in the processing factories accounted for the highest share (54.48 per cent) of the processing cost. Purchase tax for raw kernels paid by the processors at the rate of 8 per cent of the value of the nuts was the next major item of cost with a share of 17.83 per cent to the total. Packing and export charges of processed kernels

Table 6. Marketing efficiency of different channels

Particulars	Channel		
	I	II	III
Value of commodity sold (Rs.)	5704.74	5704.74	5704.74
Total marketing cost (Rs.)	1988.26	1977.85	1970.51
Marketing efficiency	1.86	1.88	1.90

Source: Sebastian (2001)

Table 7. Processors' cost

Items of cost	Rupees per quintal
a) Transportation cost of raw nuts	75.00 (3.96)
b) Cost of packing material of raw nuts (gunny bags)	15.00 (0.79)
c) Loading & unloading, drying cost etc.	25.00 (1.32)
d) Taxes (@ 8% of the value of raw nuts)	337.5 (17.83)
e) Wages including bonus & other benefits	1031.25 (54.48)
f) Establishment charges (including fuel, electricity etc.)	75.00 (3.96)
g) Interest	125 (6.60)
h) Packing and export charges	187.5 (9.92)
i) Depreciation	21.57 (1.14)
Total	1892.82 (100.00)

Source: Sebastian (2001) *Figures in parenthesis are percentage to the total

accounted 9.92 per cent of the aggregate cost. Interest which was paid for the amount drawn from the bank for the purpose of purchasing raw nuts from different localities had a share of 6.60 per cent to the total cost. Transportation cost involved in transferring raw nuts from wholesaler's place to the drying yards or factory was paid by the processor himself and this cost worked out to 3.96 per cent of the aggregate cost. Establishment charges which include fuel, electricity charges etc. also had a share of 3.96 per cent to the total. Depreciation on machinery and buildings was worked out to 1.14 per cent of the aggregate cost.

Grading and packing of cashew kernels

The standard specification for Indian cashew kernels for export has been laid down by the Government of India under the Export (Quality Control and Inspection) Act 1963. The Act prescribed 33 grades of cashew kernels. Only 26 grades are commercially available and exported. Cashew kernels in bulk are packed in four gallon prime tins with a net weight of 11.34 kg in each tin. The filled tins are then vacuumed and filled with carbon dioxide gas and sealed. Two such tins of the same grade are packed in a carton for export. The net weight of each carton is thus 22.68 kg (50 pounds). In recent years, the importers/buyers in major markets abroad requesting for change over to new generation flexible packaging for cashews. The exporters are now changing from tin containers to flexible packaging. Cashew kernels are filled in flexible bags of either 25 or 50 pound packs which are vacuumed and gas flushed. Export of cashew kernels from India is normally subjected to voluntary quality control and pre-shipment inspection. Inspection of cashew is being conducted under the consignment-wise inspection. It is ensured that the product is processed and packed as per the standard prescribed, by drawing samples from the finished product.

Processors' revenue

Cashew kernel is the major source of revenue for the processor. So its recovery is an important variable determining the revenue of the processor. Average cashew kernel recovery per quintal of raw nuts was estimated based on the information furnished by the factory owners. Wholes and brokens are normally exported which came to 24.5 per cent of the weight of raw nuts. Total kernel recovery was found to be 26 per cent. The rejects constituted 1.5 per cent of the weight of raw nuts. Byproducts formed in the cashew processing are cashew nut shell liquid (CNSL), shell and the skin (testa) of kernel. The demand for cashew nut shell liquid has been declining over the years in the domestic as well as the international market. So none of the processors, from whom information on processing was collected, was found producing and selling cashew nut shell liquid. Cashew shell and skin were the major items of byproduct. The used gunny bags are sold after the completion of the processing work. These bags are not reused in the following season.

As given in Table 8, the total revenue apart from the sale of kernels i.e., from sale of shell, skin and empty gunnies was Rs.43.75 per quintal of raw nuts. The cashew nut shell liquid (CNSL), another byproduct usually obtained could not be accounted as the processors adopted drum roasting method for processing in which CNSL cannot be recovered.

Table 8. Returns from byproducts

Item	Kg/quintal of raw nuts	Total realisation (Rs.)
a. Shell	43.75	28.75
b. Skin (testa)	1.0	2.50
c. Empty gunny bag		12.5
Total		43.75

Source: Sebastian (2001)

Pricing trends

The report of the marketing survey on cashew nut in Kerala (1975) pointed out that the cultivators got the highest price in March and April during the peak season of the crop. This type of paradoxical price level was noticed for rawnuts because dealers engaged in the collection of nuts rushed to the market to collect as much nuts as possible and consequently price increased. Fig. 3 shows the wholesale price index number of cashew in Kerala from 2002-2004. Table 9 provides the yearly trends in price of raw cashew nuts in different states from 1990 to 2008.

Pricing mechanism

Price is one of the most important determinants of the producers' decision about planting, output, employment etc. Price mechanism operates as a balancing factor between supply and demand. Nair (1970) studied the acreage response of important crops in Kerala for the period 1951-52 to 1968-69. Cashew gave a negative area response to price. Prabhakaran (1987) reported that in general farmers in Kerala were less responsive to price fluctuations and were slow in adjusting their acreage according to expectations. On the contrary, it was observed by Sebastian (2001) that average relative price of cashew nuts in the previous three years had a significant influence on area. The other significant variable was trend, which showed a negative influence

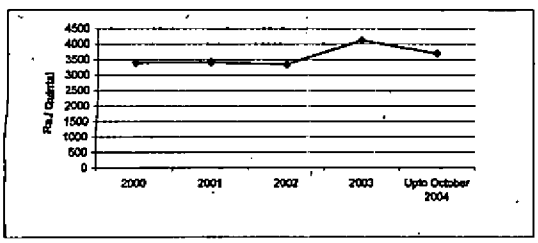


Fig. 3. Wholesale price index number of cashew in Kerala

Table 9. Pricing trend of raw cashewnuts in different states (Rs./kg)

Year	Kerala	Karnataka	Andhra Pradesh	Tamil Nadu	Goa
1990	12.25	14.50	13.00	13.19	16.75
1991	14.50	19.75	17.50	21.25	23.00
1992	22.00	25.40	20.75	23.51	29.13
1993	20.63	19.50	19.50	19.60	24.13
1994	20.50	21.50	23.20	22.80	29.50
1995	25.00	26.00	25.50	27.50	32.30
1996	29.00	29.00	29.00	29.00	30.15
1997	26.40	21.50	30.00	24.00	33.10
1998	30.60	25.00	30.00	24.00	33.10
1999	42.30	NA	33.75	NA	47.00
2000	42.00	47.00	34.50	36.20	46.50
2001	26.75	29.90	28.25	29.60	33.50
2002	25.00	28.00	27.75	29.14	34.10
2003	29.75	31.50	28.00	35.00	35.50
2004	28.50	30.00	28.75	35.63	35.10
2005	37.88	35.20	38.10	47.75	45.20
2006	28.35	28.70	31.70	37.20	37.60
2007	27.10	30.50	29.40	36.25	37.77
2008	34.00	33.00	30.00	36.50	47.20

Source : Directorate of Cashewnut and Cocoa Development, Kochi

on area. A positive relationship between yield and price of cashew as well as relative yield was obtained. The estimated elasticity of yield with respect to price of cashew lagged by one year was low indicating practically no response of yield to price. It was found that the price of rubber had more pronounced influence on area of cashew than the relative price. The above findings on the response of area and yield to price would be immensely useful in evolving suitable policies directed at better predictions of supply. This is of utmost importance in a free economy where the price mechanism is allowed to operate as a balancing factor between supply and demand. It is, perhaps, even more important in our economy where the price mechanism is used deliberately as a method of directing production.

Export and import situation

Eventhough the quantity of export of cashew kernels from India is showing an increasing trend since 1996-97, the value realised came down. Among the agricultural products exported from India during the year 2001-02, cashew ranked number two in position as a foreign exchange earner and contributed 0.86 per cent

of the total foreign exchange earnings of the country through exports.

Export of cashew kernels

The export of cashew kernels from India showed an increasing trend from 1996-97 to 2002-03, with wide fluctuations during the next few years and showing a declining trend by 2007-08 (Table 10). Out of the total exports of cashew kernels from India, around 63 per cent was from Kerala during the last five years. Major markets of India's cashew kernels are USA, Netherlands, UK, Japan, UAE, France, Canada, Saudi Arabia, Spain, Israel, Singapore, Italy and Germany. The export of cashew nut shell liquid from India during 2007-08 was 7813 MT valued at Rs. 11.98 crores, which is an all time record (Table 11). Kerala's share was 6139 MT valued at Rs. 7.41 crores. The major markets are USA, Korea, Japan etc.

Import of raw cashewnuts

The total raw cashew nuts imported into India during the period 1996-97 was 212866 MT valued at Rs. 687.6 crores (Table 12), which increased to 605970 MT valued at Rs. 1746.80 crores during 2007-08, which is an all time record. Apart from African countries Indonesia was the major supplier of raw cashew nuts to India.

Table 10. Export of cashew kernels

YEAR	Quantity of exports (MT)			Value of Exports (Rs. Crores)		
	Kerala*	India	Share of Kerala (%)	Kerala*	India	Share of Kerala (%)
1996-97	38546	68663	56	731.79	1285.5	57
1997-98	39441	76593	52	746.88	1396.1	54
1998-99	43665	77076	57	940.47	1630.1	58
1999-00	50022	96805	50	1342.1	2569.5	52
2000-01	49874	89155	56	1152.36	2049.6	56
2001-02	54717	98203	56	971.11	1788.7	54
2002-03	76119	127227	60	1188.6	2006.4	59
2003-04	68119	100828	51	1204.56	1804.43	67
2004-05	79950	126667	51	1715.94	2709.24	63
2005-06	74377	114143	51	1622.82	2514.86	65
2006-07	72861	118540	51	1504.87	2455.15	61
2007-08	69298	114340	51	1395.02	2288.90	61

Source: Cashew Bulletin (Various issues) *Export through Cochin Port

Table 11: Export of cashewnut shell liquid

Year	Quantity (MT)			Value (Rs. Crores)		
	Kerala*	India	Share of Kerala (%)	Kerala*	India	Share of Kerala (%)
1996-97	814	1735	47	0.78	2.77	28
1997-98	2932	4181	70	3.59	6.74	53
1998-99	1185	1912	62	1.81	4.21	43
1999-00	1040	1930	54	1.54	3.74	41
2000-01	907	2246	40	1.31	3.89	34
2001-02	3365	4178	81	4.56	5.93	77
2002-03	5170	6023	86	5.95	8.36	71
2003-04	6784	6926	98	6.68	7.03	95
2004-05	6674	7474	89	6.58	7.91	83
2005-06	5892	6463	91	6.10	7.21	85
2006-07	3736	5589	67	5.70	9.20	62
2007-08	6139	7813	79	7.41	11.98	62

Source: Cashew Bulletin (Various issues) *Export through Cochin Port

Table 12: Import of raw cashewnuts

Year	Quantity (MT)		Value (Rs. Crores)	
	Kerala	India	Kerala	India
1996-97	49169	212866	159.76	687.60
1997-98	70527	247181	237.46	769.60
1998-99	109660	241161	448.83	958.03
1999-2000	156488	253577	736.63	1186.16
2000-01	152516	249318	552.74	960.84
2001-02	191579	355443	502.46	949.25
2002-03	252605	401199	774.45	1230.60
2003-04	294551	452398	909.45	1400.93
2004-05	283149	578884	1052.35	2190.94
2005-06	306765	565400	1134.63	2162.95
2006-07	322443	586044	971.79	1811.62
2007-08	372497	605970	1071.21	1746.80

Source: Cashew Bulletin (Various issues) *Import through Cochin Port

Constraints in production and marketing

Cashew growers experience a large number of constraints that limit the production of cashew nuts. Sebastian (2001) reported that the major constraints were incidence of pests/ diseases, unavailability of grafts at proper time, lack of technical guidance, low price of raw nuts, lack of labourers for various operations, lack of plant protection equipment, not getting sufficient protection even after spraying plant protection chemicals, lack of knowledge about various government schemes, high cost of inputs, marketing problems and soil erosion. Low price of raw nuts was another important problem faced by the farmers.

Conclusion

Though cashew is one of the most important commercial crops in Kerala, there has been a more or less steady decline in its area and production over the years. On the other hand, production of raw cashew nuts is far below the demand of the processing sector necessitating the import of raw nuts. Marketing policies play a crucial role in ensuring reasonable price to the producer thereby increasing the area under cashew to meet growing domestic demand of raw nuts.

References

Cashew Export Promotion Council of India. Cashew Bulletin (various issues)

Directorate of Cashewnut and Cocoa Development. 2003. Statistics on cashew. *The Cashew* 17(3):37-38

Government of India. 2001. *Economic Survey 2000-2001.* Government of India, New Delhi. p.257

Government of Kerala. 1975. Report of the marketing survey on cashew nuts in Kerala. *Cashew Bull.* 12(6):8-13

Government of Kerala. *Statistics for Planning* (Various Issues). Directorate of Economics and Statistics, Thiruvananthapuram

Nair, N.U. 1970. Acreage response of important crops in Kerala. M.Sc.(Ag.) thesis, Indian Agricultural Research Institute, New Delhi, India. pp.16-55

Planning Board. *Economic Review* (Various Issues). Government of Kerala, Thiruvananthapuram

Prabhakaran, P.V. 1987. Impact of price variability in acreage allocation of selected crops of Kerala State. *South Indian Hort.* 35(4):318-319

Rajasekharan, P. 1987. A study on marketing margins and market structure of cashewnut in Kerala. M.Sc.(Ag.) thesis, Kerala Agricultural University, Thrissur, India. pp.35-80

Salam, M.A., Babu, K.S. and Balasubramanian, P.P. 1992. Trends in cashew production in Kerala - An analysis. *The Cashew* 6(3):3-7

Sebastian, S. 2001. Economic analysis of production and marketing of cashewnut in Kerala. M.Sc.(Ag.) thesis, Kerala Agricultural University, Thrissur, India. pp.69-75

Senthilnathan, S. and Balamohan, T.N. 1992. Cash flow in cashew plantation and credit needs - A study in Tamilnadu. *Cashew* 6(1):16-21

Sivanatham, M., Pugalendhi, L., Jeeva, S. and Somasundaram, D. 1990. An economic analysis of cashew cultivation in South Arcot district of Tamilnadu. *Cashew* 4(3):17-19

Sivaswamy, K.G. 1949. Price spreads in the marketing of agricultural produce. *Indian J. agric. Econ.* 4(1):223-29

TRANSFER OF TECHNOLOGY AND DEVELOPMENT ASPECTS OF CASHEW

Venkatesh N. Hubballi
Directorate of Cashewnut and Cocoa Development, Govt. of India, Kochi - 11, Kerala

Cashew has attained commercial importance because of its high demand in the international market as well as domestic market. The first introduction of cashew in India was made in Goa from where it spread to other parts of the country. The nuts, apple and other by products of this crop are of commercial importance. Though its commercial exploitation began from the early 60's, marginal lands and denuded forests were the areas set apart for cashew plantations. Because of its adaptive ability in wide range of agro climatic conditions it has become a crop of high economy and attained the status of an export oriented commodity bringing considerable foreign exchange to the country. It is a matter of prestige that India leads the production and export of cashew kernels in spite of the entry of several other countries in this sector in recent years.

Production scenario

Cultivation of cashew in India confines mainly to the peninsular areas. Cashew production in India takes place in a major way in eight states and in the minor way in six non traditional areas. Now, cashew occupies an area of 8.37 lakh hectares in the country as on 2005-06 with a production of 5.73 lakh MT of rawnuts. Out of this, nearly 2.50 lakh ha of the plantations were developed from the beginning of 8th plan onwards alone and have been with superior clones of high yielding varieties. The present production scenario in relation to global scenario is indicated in Table 1. From the Table 1, it is evident that India is the largest area holder and producer of this crop.

Statewise production in India is given in Table 2.

Export scenario

India has a creditable record of attaining good amount of foreign exchange by way of export of cashew kernels. Among the agri-horticulture commodities exported from India, cashew ranked the 2nd position as a foreign exchange earner and contributed 0.66% of the total foreign exchange earnings of the country through exports. The exports of cashew kernels during 2006-07 was 1,18,540 MT valued at Rs. 2455 crores. Nearly 39% of the quantity of cashew kernels exported during 2006-07 were to American Zone mainly to USA,

Table 1. World area and production of cashewnut (2005-06)

Country	Area (ha)	Production (MT)
Angola	2,800	1,100
Belize	931	1440
Benin	185,000	40,000
Brazil	688,831	2,51,268
Burkina Faso	9,000	3,500
China	2,400	900
Cote d' Ivoire	125,000	90,000
Dominican Republic	5,800	1,000
El Salvador	3,600	2,600
Ghana	13,000	7,500
Guinea - Bissau	212,000	81,000
Honduras	1,291	1,800
India	837,000	5,73,000
Indonesia	268,000	1,22,000
Kenya	2,000	10,000
Kyrgyzstan	150	100
Madagascar	16,000	6,500
Malaysia	7,000	13,000
Mexico	4,333	650
Mozambique	50,000	58,000
Nigeria	324,000	2,16,000
Peru	380	2,300
Philippines	17,000	7,000
Senegal	16,000	4,500
Sri Lanka	23,000	6,200
Tanzania	80,000	1,00,000
Thailand	24,000	24,000
Togo	300	300
Vietnam	285,000	3,00,000
Total	32,04,816	19,26,358

Table 2. Area and production of cashew in India 2005-06

States	Area (000 ha)	Production (000MT)	Productivity (Kg/ha)
Kerala	80	67	900
Karnataka	100	45	700
Goa	55	27	690
Maharashtra	160	183	1300
Tamil Nadu	121	56	640
Andhra Pradesh	170	92	880
Orissa	120	78	860
West Bengal	10	10	950
Gujarath	4	4	900
NE states	14	10	640
Others	3	1	400
Total	837	573	815

Netherlands, UK, Japan, UAE, France, Canada, Saudi Arabia, Singapore, Italy, German Fed. Republic, Austria, Israel and Spain are the major international buyers of Indian Cashews.

Cashew is primarily an export oriented commodity. It is procured and marketed on an industrial basis as a part of small scale industrial sector. Private entrepreneurs to a great extent are remaining engaged in this industry. This industry flourished in Kerala in large scale from the second half of the 20th century. These Industrialists utilize/utilized locally available production and also the rawnuts imported from African countries and processed for export as well as internal consumption. India has been the pioneering country in this industry and commerce, ever since the global trade on cashew kernels began. Towards the later part of 20th century, some of the traditional African nuts suppliers and countries like Brazil and Vietnam started processing and export of this commodity, whereby Indian share to the global market gradually declined. Yet even now, India continues to be the major supplier of cashew to be global market. The position of India in relation to global trade is indicated in Table 3.

Industry and commerce

Cashew industry in India is one of the largest network of aggregation of a large number of small scale units which are primarily depending upon the imported raw materials. It generates employment in the processing sector employing over 3 lakh person, 95% of them being women. Indian production of raw cashewnut is around 5.73 lakh MT. India also is importing raw cashewnuts

Table 3. Global export (Kernels)

Countries	Quantity (MT)	% share
India	1,26,667	45
Brazil	41,569	15
Vietnam	83,900	30
Tanzania	1,809	1
Others	27,224	9
Total	2,81,169	100

from other Asian and African countries. During the year 2006-07, India has imported 5.92 lakh MT of raw cashewnut. Thus, the total availability (indigenous + import) amounts to 11.65 lakh MT of raw cashewnuts. This will involve nearly 3.12 lakh labourers per year for processing raw nuts becoming available from indigenous sources and import. Statewise details of processing units available in the country is presented in Table 4.

Developmental strategies adopted

A concerted effort for the development of cashew started only from 4th plan onwards with focus on area expansion, production of quality planting material and development of production technology including rejuvenation and plant protection. The 6th plan was an era of land mark when the World Bank aided Multi State Cashew Project (MSCP) was implemented both under public and private sector in four major states of Kerala, Karnataka, Andhra Pradesh and Orissa. With the finance obtained from the World Bank assisted project 77 ha of cashew plantations in the coastal sand dunes of Orissa was established with windbreaks. Considering the poor condition of the feeder roads of Kerala, a programme to improve 32 feeder roads of 200 km was aimed at, out of which 31 feeder roads of

Table 4. Cashew processing units in India

State	Production (000 MT)	No. of units
Kerala	64	432
Karnataka	43	266
Goa	26	45
Maharashtra	174	350
Tamilnadu	53	417
Andhra Pradesh	88	175
Orissa	74	60
West Bengal	8	30
Others	14	20
Total	544	1795

220 km length were completed. A study was also conducted to examine the need for possible institutional reorganisation of the cashew industry with particular emphasis on improving efficiency and competitiveness of the industry. Cashew research and training was another component of the project.

Until the end of 7th plan cashew development was not received adequate support financially, technologically and administratively. Only from 8th plan onwards, as a part of overall development of horticulture, cashew also received a substantial allocation with which an integrated approach with effective programmes to improve the production build up became possible. The technological advances supported the strategy of cashew development in the 8th plan and further plan periods. The following programmes are implemented during the plan with the outlook of increased production and productivity of cashew in the country.

1. Development of new plantations with clones conforming to export qualities and maintenance - to expand the area with high yielding clones of recommended varieties.
2. Replanting/rejuvenation by top working of old senile and uneconomic cashew gardens - to reduce the senility as was posing a serious problem towards augmenting the production.
3. Adoption of comprehensive production technology in growers orchards - to improve the productivity status of the yielding plantations by way of adoption of recommended package of practices in a comprehensive manner.
4. Adoption of intensive pest control measures - to control the incidence of major pests attacking cashew by way of adoption of prophylactic plant protection measures to prevent the loss in yield.
5. Establishment of regional nurseries for generation of planting materials - to eliminate the use of seeds and seedlings for plantation purposes by producing required quantity of clones of high yielding nature.
6. Transfer of scientific technology to the farming community.
   a. Pilot demonstration of clonal cultivation - development of model clonal cashew gardens - to transfer the scientific production technologies as a visual aid.
   b. Farmers training programme - to train farmers on various production technologies.
   c. Publicity measures for crop promotion - to provide wider publicity on promotional aspects of cashew.

Achievements

The use of seeds and seedlings for plantation purpose were abandoned for ever and wider adoption of clonal planting materials were made. Nearly 63000 ha were planted with clones of high yielding varieties of cashew in this plan period. The replanting programme even though was introduced to replace the highly uneconomical old and senile plantations, instantaneous removal of older trees did not take place in many of the states as the farmers were not willing to loose the revenue he obtains continuously, however small it may be, since the incentive provided was unattractive.

The regional nursery concept was a novel approach of the 8th plan, where in nurseries have to generate clones of high yielding varieties to distribute to the programme beneficiaries. Involvement of private sector in the nursery activity besides the public sector organisations was another significant turn in the promotion of development programmes of cashew.

The model clonal gardens of cashew developed are at present serving as extension tool for imparting training to the farming community. With this, an awareness on the use of clones and adoption of proper nutrition and crop protection measures besides the conservation measures on soil and moisture could be brought about on a wider range whereby the concept of scientifically economical plantation development is percolating among the farming sector.

The farmers' training programme was another salient approach towards the transfer of scientific technologies which gained a substantial momentum by way of imparting training to 6227 farmers in the vicinity of the farmers fields at village/block level and with the association of scientists and extension workers.

Publicity on crop promotion was taken up to disseminate the scientific information through literatures developed on regional vernacular languages.

The financial assistance provided by the Government of India for the development of cashew in the country from

1966-67 onwards till the end of 8th plan are indicated in table.

Plan	Outlay (Rs. in Crores)	Utilisation
Prior to 4th plan	1.363	0.905
4th plan	6.051	1.986
5th plan	10.564	4.846
6th plan	47.730@	32.293@
7th plan	7.620	4.611
8th plan	58.320	48.265
Total	131.648	92.906

@ including world bank aid for 45.7 million US$ and utilisation of 31.2 million US$

The objective of the 9th plan was to increase domestic production of raw cashewnut to meet the needs of the industry by reducing the dependence on import to augment the export trade, in addition to the demand for domestic consumption. Specific emphasis was given in the clonal plantation development, its maintenance and technology dissemination centering the various practices on clonal plantation development. More or less the similar approach of 8th plan has been adopted. During 9th plan an out lay of Rs. 70.00 crores had been allocated for the implementation of cashew development programmes in the country. Eventhough the 9th plan started from 1997-98, the actual execution of the approved programmes commenced for its execution in 2000-01 only, till then 8th plan programmes were continued. Further, the development programmes comes under the purview of state workplan (Macro Management System) from 2000-01 onwards as per new policy of the Govt. of India. Under this, the state has its own priority to choose the crop for its development. Because of this policy, some of the approved programmes of 9th plan have been included under the state work plan.

However, the Government of India has retained the programme for establishment of regional nurseries, transfer of technology to the farming community and publicity aspects under the direct control of the Directorate of Cashewnut & Cocoa Development, the details of achievements made on these programmes in the 9th plan in the country are shown in the Table 5.

Impact of development programme

An area of 2.41 lakh ha was available in the country prior to the commencement of the execution of development programmes (1965-66). The production and productivity were 1.04 lakh MT and 400 kg/ha respectively. The area increased to 8.20 lakh hectares in 2004-05. The rawnut production and productivity increased to 5.44 lakh MT and 810 kg/ha respectively.

In the 9th plan more than one lakh hectare of cashew plantations have been raised and maintained with clones

Table 5. Details of achievement during 9th plan

(Fin Rs. in Lakhs)

Programme	9th Plan Target		1997-98 to 2001-02 Year to year			
			Sanctional		Achievement	
	Phy	Fin	Phy	Fin	Phy	Fin
1. Farmers' participatory demonstration cum training areas (No. of plots)	F 300 M 975	43.292	403 1045	53.01	349 773	24.159
2. Regional nursery (Nos.)	103.5	162.000	47	197.000	31	132.000
3. Training of farmers and field level workers (No. of trainees)	21650	48.32	27750	57.471	25373	45.753
4. Plant protection campaign (Nos.)	140	10.360	270	25.480	197	16.511
5. Publicity measures for crop promotion		39.750		50.350		38.549
6. Model processing unit for cashew apple (Nos.)	1	15.000	1	15.000	1	15.000
7. Development of infrastructure for processing and marketing (No. of units)	10	50.000	---Not sanctioned---			
8. Executional infrastructure to DCCD		162.246		53.746		51.460
Total		530.698		452.062		323.432

S. No.	Aspect	Impact 1965-66 Prior to the inception of DCD	2004-05
1.	Area under cashew (lakh ha)	2.41	8.20
2.	Production (lakh MT)	1.04	5.44
3.	Productivity (kg/ha)	400	810
4.	Export (kernel '000 MT)	51	127
5.	No. of processing units	530	1795

of high yielding varieties. As in the case of 8th plan, replacement of old and senile trees was limited to the extent of 10454 ha. only in 9th plan under private sector. Due to the late commencement of the execution of the programmes of 9th plan, the corporations also could cover only 1670 ha. An area of 115110 ha. could be covered under plant protection programme till 1999-2000, where after the programme has been discontinued and a new programme viz., Plant Protection Campaign for the demonstration of Plant Protection Operation in the farmers field with right chemicals in right doze at right time has been started for execution from 2000-01 onwards.

The regional nursery programme was concentrated to private entrepreneurs and development departments of the North East states. Complete elimination of the use of seeds and seedlings for plantation development and use of clones of the recommended varieties alone became possible in this plan period. Now a total capacity of production of 75 lakh clones is possible from the nurseries established so far. There is no scarcity in planting material production as 60 lakhs clones of high yielding varieties have been produced annually which can cater for development of 30,000 ha. More than 25,000 farmers have been trained on various production technologies. High density concept was also included in the 9th plan as a measure for popularisation with different production technologies and in most of the states, this concept was accepted partly and normal density planting was generally done. Publicity measures in order to make full awareness on modern production technologies on cashew among the farming sector through development of publicity literatures and organizing seminars, workshops and field days have been done. In order to popularise the usage of cashew apple, for the preparation of cashew apple products such as cashew apple juice, jam, candy, syrup etc., a processing unit for cashew apple as a model has been established in Kerala (under co-operative sector) with the technologies available at Kerala Agriculture University during 1997-98 and the unit has launched its production.

Future thrust areas

Inadequate availability of raw cashewnut is the major constraint of the cashew industry in the country. The Indian production has to be increased to 10 lakh MT of rawnuts to meet the demand of export and internal consumption. The cashew industry is growing tremendously. Hence our effort will have to be modest to suit the export and internal consumption.

India has considerable competition from other countries in export sphere, particularly from Brazil and Vietnam who are aggressively promoting, processing and exporting cashew. The best approach therefore for India would be take steps to increase the production to bridge the gap of the local industrial demand of 1 million MT only whereby the present level of import can be eliminated besides partially increasing the export and local consumption. To increase the production and productivity the following measures are needed.

a. Replanting of the senile areas, in the context of non availability of areas in the traditional cashew tracts.

The efforts of the Directorate of Cashewnut & Cocoa Development, though has been considerably effective in increasing the area and production of cashew, due to the mushrooming growth of industry, the industry has prevailed upon the import of rawnut in larger quantities. The high yielding varieties have gone into the field only from 8th plan onwards. These varieties have been helpful for an area coverage of a little over 2.00 lakh hectares out of the total area of 8.2 lakh hectares during the last decade. In other words, nearly 5.5 lakh hectares developed earlier to this period have come up with indiscript unknown high yielding types without manifesting higher productivity level. The reduction rate in productivity can be attributed to the high sensility of cashew plantations, because of age and negligence in management. Normally, cashew plantations of 30 years of age and above are reckoned as senile and un economical, with the senility setting in the 25th year of age. The picture of cashew plantation senility is depicted in Table 6.

Replantation/rehabilitation of these areas alone can help

Table 6. Senility situation of cashew plantations in India (Plantations >30 years) 2004-05

Area - 000ha, Production 000MT

Agency	Total Area	Senile Area (>30 yrs)	Total Production	Production from senile areas
Private	675 (82%)	201 (24%)	482 (90%)	62 (16%)
Forest	27 (3%)	17 (1%)	14 (2%)	3 (Neg.)
Corpns.	118 (15%)	84 (10%)	48 (8%)	22 (4%)
Total	820 (100%)	290 (35%)	544 (100%)	62 (20%)

to overcome the situation of senility. Though such a programme was initiated in 8th plan, it gained only a very little momentum due to the inherent resistance on the part of farmers to remove their trees and to replant. Perhaps a better compensation and vigorous promotional activities with necessary input support may help to overcome this problem. Further there is a need to tackle the available large chunk of compact areas under public sector like corporations with interest free loans repayable from 5th year onwards.

b. Establishing cashew zones in the available waste lands in each state of the country with high yielding clones.

   i. It is estimated that nearly 4.7 lakh hectares of cultivable waste land is available in the cashew growing states. This waste land may be identified and high yielding cashew clones may be planted. This can help to increase the area under cashew and thereby boost the production.
   ii. Introduction of farmers participatory demonstration plots with inter cropping of pineapple.
   iii. Cashew apple processing unit as a cottage industry.
   iv. Development of infrastructure for marketing/if necessary for processing.

Reference

Singh H.P., Balasubramanian P.P., and Hubballi V.N.2002. Indian Cashew - Issues and strategies.

CASHEW PROCESSING

C.K. Nair
CEPC Laboratory& Technical Division,
Cashew Export Promotion Council of India, Kollam – 691 001, Kerala
(e-mail : cepclab@cashewindia.org)

Introduction

The commercial activity related to cashew processing had its origin in India and during the last ten decades of its existence, the processing objectives as well as methods underwent several changes in tune with the demands of its customers. The raw material used in the industry is the dried fruit (nut). The main products of the processing are the kernels scooped out of the hard shell protecting the seed and cashewnut shell liquid (CNSL) expelled from the shells of the nut. Cashew kernels find use in the food industry. CNSL is a valuable industrial raw material which finds use in a number of chemical industries such as friction linings, paints and varnishes, laminating resins, rubber compounding resins, cashew cements, polyurethane based polymers, surfactants, expoxy resins and foundry chemicals (Pillai, 2002; Sivasamban, 1977). Other products from the cashew industry such as cashew testa, shell cake etc. also have limited industrial applications.

Cashew kernel

In trade, cashew kernels are best known as cashewnuts, and are grouped under tree nuts. Other prominent members among the group are almonds, walnuts, pecans, filberts, brazilnuts and pistachios (Woodroof, 1967). Cashew nuts are highly favoured of all edible nuts in the world for their unique shape and fascinating flavour. They are high in their nutritive value but less costly to similar nuts.

History

Langley (1962), Russell (1969), Prabhu and Pillai (2001), Musaliar (2001) and Azam Ali and Judge (2001) deal with the origin of commercial activities related to cashew kernel and conclude that the commercial activities initiated at the beginning of the twentieth century, as a few exports to America from India were reported in 1905. The cashew kernels for the trade were bought from the households, dried under the sun, packed in mango wood boxes with newspaper lining and exported. The peeling and grading were not practiced. No doubt, the commodity reached the destination, fully infested. This practice was continued till the General Foods Corporation of America took interest in Indian cashew business. They had the patent for preserving food under the modified atmospheric packaging using carbon dioxide, and they extended this technology for packaging cashew kernels of India (Langley, 1962).

The General Foods Corporation, in association with the R.T. Company of Mangalore began to operate a small factory in early 1920s, for packing cashew kernels in an atmosphere of carbon dioxide. With the establishment of a 'factory', a system of distributing rawnuts to households and getting them roasted and shelled was also initiated. The kernels were further processed (dried, peeled, graded and packed) in the factory. The 'pan roasting' in which rawnuts were thrown into large open pans with miniature furnace under them was the practice used, and shelling was done manually.

Concurrent with the development in Mangalore, the General Foods Corporation extended their interest to Quilon, and the activities at Quilon were pioneered by the India Nut Company established by one W.T. Anderson. One Roch Victoria from Sri Lanka and one Swaminathan from Madras were also involved in this commercial practice (Musaliar, 2001).

In Quilon also, the Cashew nut roasting was done in 'pans', and cashew kernels extracted were sold to the 'factory' where it was blanched (peeled), graded, packed and exported.

Import of raw cashewnuts from Portugese Africa started in the late 1930s. As the processing capacity increased, imports began to grow while domestic production also

increased. By 1940-41, import of raw cashew nuts from Africa was upto 28,000 tonnes, and export of cashew kernels increased to nearly 20,000 tonnes. However, the whole activities came to a standstill during the second world war, as the U.S Government banned import of all non-essential items for want of shipping space. However, in 1943, after a lot of lobbying by the New York agents, the U.S. Government permitted import of cashew kernels on the condition that Indian exporters would supply one metric tonne of CNSL along with ten cartons of cashew kernels. As the processors in Quilon were unable to do the extraction of CNSL, M/s. Pierce Leslie Company Ltd., as a wartime effort, took up cashew processing for CNSL extraction in their Kundara factory (established in 1940), and returned the nuts, after roasting, to the processors for further processing. Cashew Shell Liquid was extracted in the three Hot Oil Plants installed there.

It was in 1932, that Mr.W.Jefferies of M/s. Peirce Leslie and Co. Ltd., produced and installed the 'drum roaster' for cashew nut roasting. This system consists of a long cylinder, tilted and placed over a furnace into which raw nuts are poured at one end, igniting as they pass down the cylinder and collecting for shelling at the other end. This system is being used in many units even today. But the much improved system which has been designed and installed for the extraction of CNSL in 1935, called the 'hot oil bath' has become obsolete in India, because of the unattractive prices for CNSL.

By 1950, the patent rights of General Foods Company over the modified atmospheric packaging with carbon dioxide expired and the system was made commercially available as 'vita pack' system. This gave a bloom to the cashew nut processing industry, and the industry began to grow with a number of new processing units. A new pattern of business began to evolve consisting of processor, exporter, broker / agent, importer / buyer and the end user. Further, with the increased number of processors, the importers began to take speculative positions on the commodity, and the exporters to suffer industry wide loss. A "Cashew Syndicate" was formed to protect the interest of the exporters, but being a voluntary body did not survive long. For providing guidance in marketing and promoting exports, the Cashew Export Promotion Council of India was established under the Ministry of Commerce, Government of India in 1955.

Processing

Generally the processing operation on cashew nuts include (a) Collection and storage of the raw material, (b) Roasting, (c) Shelling, (d) Peeling, (e) Grading and (f) Packing. A number of articles have been published on processing and processing equipments (Woodroof, 1967; Russell, 1969; Shivanna and Govindarajan, 1973; Mathew, 1977; Mathew and Unnikrishnan, 1979; Rajah and Chitrakaran, 1979; Mandal, 1992; Nair, 2002, Prabhu, 2003). Azam Ali and Judge (2001) reviewed the status in Asia and Africa.

1. Raw material collection and storage

The efficiency of processing depends on the recovery of maximum amount of shippable grades which fetch the maximum prices (say first quality, white wholes). Raw material which takes away 70% of the production cost has an important role in deciding the fraction of shippable grades and thereby deciding the profit of the processor (Balasubrahmanian, 2001). In many cases, the prices paid for raw nuts are based on the knowledge of the expected yield.

Cashew nuts are normally purchased on a weight basis. Therefore arrivals at a processing factory have first to be weighed. They are at the same time sampled in order to test the quality of the raw nut to see if it matches up to the specification laid down for quality. The stored rawnuts should be protected from dampness. There should be sufficient head room for allowing manipulation of bags in a stack particularly if large quantities are to be stored, and a space between the wall and the bags stacked to allow passage of a person around in order to determine whether the stack is holding firm.

2. Roasting

The term "roasting" when applied to the raw cashew nut means any process involving the application of heat to the raw nut in order to release liquid in the pericarp, or fix the liquid so that the shell becomes brittle and facilitates the extraction of the kernel (Russell, 1969; Mathew, 1977). The roasting system for cashew nuts has been evolved through a number of stages such as sun drying on rock surface, pan roasting, drum roasting, oil bath roasting and steam roasting (Russell, 1969). Presently, the most preferred method is that of steam roasting, where better control on roasting can be applied.

Other advantages of the steam roasting are the adaptability of steam cooked nuts to the 'cutting' process of decortification and the recovery of the entire CNSL from the shells.

3. Shelling

Shelling is the operation of removal of shells protecting the style of the kernels. The objective is to produce whole kernels, free of cracks. Special care is taken to prevent any contamination from CNSL. The shelling practice utilising the wooden mallets and stones is now being replaced by a "cutting" process, in which specially made leg operated or hand operated cutting machines are utilised, with better labour efficiency (Mathew, 1977)

It should be stressed that once the kernel has been removed from the nut, the subsequent processing must proceed as quickly as possible to the final packing stage where the kernel will be protected. In the interim stages, the kernel is exposed to the hazards of fungal and insect attack. Every endeavour must be made to reduce the time of the interim stages.

4. Drying

Shelled kernels have a moisture content of over 6 percent and are susceptible to fungal attack and insect infestation. It is therefore imperative that the shelled kernels be taken for drying immediately after shelling. Another purpose of drying is to facilitate removal of the testa, to produce the blanched kernels. Drying shrinks the kernel and the loosely adhering testa can be removed by hand. All processors dry the shelled kernel before peeling (Russell, 1969).

Drying programmes are normally organized so that kernels from shelling can go into the drier the evening of the day they are shelled. Drying processes also have undergone changes from the sun drying, through the uses of "Thattu Borma", "Tunnel Borma" and "Electric Borma", versions of what is known as tray driers. Cashew kernels have a surface moisture and internal moisture. Surface moisture can be removed quickly, but removal of internal moisture is a slow process. Air flow at higher velocity is essential for quick drying and the air velocity should be maintained constant throughout the drier. In actual practice, to reduce any risk with higher temperature, kernels are allowed to dry under environment where the relative humidity is allowed to come down only very slowly. Temperature and humidity inside the drier should be monitored and controlled.

The drying operation apart from reducing moisture content sterilizes the kernels and will kill any possible insect infestation. Kernels in the drying operation will be dried down to about three percent moisture.

In the more sophisticated plants the drier trays are built up into nests which can be moved as nests mechanically into a drying room. The room when charged can then be subjected to heat and air movement. The kernels when dry are then removed in the nest of trays for treatment by the next operation.

Another method is to use infra-red heat and in this case the drying time is reduced from hours to minutes or seconds. This application of infra-red is quite new and it is reported to be very successful as the following process of peeling is greatly facilitated.

In the dried condition the kernel is in its most delicate condition. It is brittle and will break easily. It is therefore essential that the kernels be handled carefully. It is estimated that at every transfer of kernels from one place to another or one container to another at least one percent is broken. Careful handling at all stages is imperative if a good outturn is to be obtained. In order to avoid the breakage, the kernel will be kept at room for few hours where the humidity is adjusted to a higher percentage by operating a humidifier.

5. Peeling

This is the process of making "blanched" cashew kernels and essentially involves the removal of the brown cover adhering to the kernel. In India the testa is removed by hand manipulations. One great advantage of this manual peeling process is the grading of cashew kernels taking place simultaneously (Russell, 1969). The mechanical arrangements for peeling involve soft brushing and rubbing with aspiration to remove the peel (Mathew, 1977). So far, commercially exploitable systems under Indian conditions have not been evolved.

6. Grading

From a bulk of peeled cashew nuts, 11 to 33 grades are produced. These are divided into six groups - white wholes, white pieces, scorched wholes, scorched pieces, dessert wholes and dessert pieces.

Grade Specifications

Being a commodity used in food industry, quality requirements of cashew kernels can be visualised broadly under two heads, the commercial requirements and the food regulation requirements. It is a product being traded and it should meet the specifications laid down by the trade in the form of commercial grades, and any deviation would result in a breach of contract and subsequent pecuniary measures. On the other hand, being a food item, the product should comply with the regulatory standards laid down for food items by governments, and any contamination found above the allowed maximum levels would call for regulatory proceedings.

Commercial grades

From the very beginning of industrial production of cashew kernels, India has been enjoying the leading position in the production, processing and export of cashew nuts. In April 1963, the Cashew Export Promotion Council of India took the initiative to introduce compulsory pre-shipment inspection for cashew kernels in order to assure confidence in their overseas buyers regarding quality of cashew kernels exported (Jacob, 1978). Quality standards were established for the various grades of cashew kernels exported. In April 1966, the responsibility for preshipment inspection was taken over by the Export Inspection Agency and quality standards were laid down by the Government of India under the Export (Quality Control and Inspection) Act 1963. In 1975, the Bureau of Indian Standards established specification for cashew kernels vide IS:7750-1975. Similarly, being largest importers, American and European trade organisations also have formulated specifications for cashew kernels (Nair, 2003). An unified specification is being worked out under UN/ECE, and Cashew Export Promotion Council of India has been involved in this as an invited member.

Indian specifications

The Indian specifications prescribe 33 different grades of cashew kernels. Only 26 grades are commercially available and exported. (The illustrated specification chart is given by Singh et al, 2003).

The criteria involved in grading cashew kernels are style, colour, appearance and size. By style, kernels are classified as wholes and brokens. Kernels which retain their characteristic shapes are grouped under wholes. Broken kernels are further grouped as splits, butts and pieces, depending upon the nature of breakage and size of broken pieces. Butts are kernels which have been broken crosswise but the cotyledons are still naturally attached. Splits are kernels split lengthwise naturally. Pieces are kernels which have broken into more than two pieces, and are designated as large pieces (above 4.75mm in size), small pieces (above 2.80mm) and baby bits (above 1.70mm in size).

Based on colour and appearance, cashew kernels are classified as white, scorched and dessert kernels. White kernels are white / pale ivory / light ash in colour, whereas scorched kernels are slightly darkened due to over-heating while processing. The dessert kernels are over scorched, immature, shrivelled, speckled and or discoloured.

Sizing is compulsory in white wholes and there are six size groups namely W180, W210, W240, W320, W450 and W500. The number indicates the count of cashew kernels per pound. Scorched wholes, can be traded either as unassorted, or in various size grades as in white wholes.

In Indian specification for cashew kernels, it is also specified that kernels shall be completely free from infestation, insect damage, mould, rancidity and adhering testa. Moisture content allowed is 5 percent maximum. Admixture in grades is not permitted, but a tolerance of 5 percent for next lower grade and next lower size grade is allowed for white wholes, butts and splits and of 7.5 percent for scorched wholes, butts and splits and also for dessert wholes.

Regulatory requirements

The quality specifications discussed above are strictly followed in trade but the consumers globally expect and demand more stringent quality norms especially with regard to safety aspects. It is in this context, one has to look at the food regulations of the importing countries. The major importers of the cashew kernels are USA and European countries, followed by Japan. The emphasis is on food safety from risks associated with microbiological contamination, natural toxicants, environmental contaminants, pesticide residues, packaging migrants and food additives. Vertical regulation as to the criteria for cashew kernels have not

yet been established for tolerance limits with respect to these parameters and therefore the horizontal regulations on food supply have to be adhered to.

Generally, food safety problems associated with cashew processing are very few. With the right choice of the raw material, processing tools and process technology in combination with rigorous training to labourers, most of the problems associated with commercial quality of the product can be eliminated. To eliminate problems associated with health hazards, one has to follow the good manufacturing practices with particular stress on hygiene and sanitation and employee training.

7. Packaging

The normal pack for cashew kernels for export is two hermetically sealed tins, of 25 pounds each, in one carton or case.

Packaging requirements

In the case of exports of cashew kernels, the pattern of business has so far been restricted to the export of this commodity in bulk. It is inert gas packaged in sturdy tin-plate containers in quantities of 25 lbs (11.4 Kgs) each. Two such tinplate containers, popularly known as the "4 gallon" tins, are bulked in a corrugated box for purposes of exports. The boxes are reinforced using either a rayon or plastic strapping (Narayanan, 1983).

The specifications for the tin plate containers and corrugated boxes are given in IS : 916 – 1975 and IS 2771 (Part 1 and 2) : 1998 respectively.

An inert gas such as carbon dioxide is used to prevent oxidative rancidity and microbial spoilage (Shivasankar, et.al.1979). For effective vacuumisation, the vacuum gauge must be calibrated. The advantages of packing cashew kernels in carbon dioxide are two fold. Firstly carbon dioxide is an inert gas and will not support life. Any infestation that may have been present in the kernels is therefore arrested. Secondly carbon dioxide is soluble in cashew kernel oil and goes into solution as soon as the seals are made. In a short span of time it will be seen that a vacuum has been drawn on the tin and the sides, top and bottom are drawn inwards thus holding the kernels tight in the tin.

Earlier, tin lead mixture was used for soldering, but considering the regulations of importing countries, lead free soldering material are being used now-a-days (Narayanan and Dordi, 2002).

Flexible packaging

The conventional tin packaging system for cashew kernel, is being replaced by a flexible packaging system (Narayanan and Dordi, 2002).

Under the flexible packaging system, cashews are packed in co extruded multi layer double barrier vacuum bags using a compacting station and then vacuumised, gas flushed to form rectangular blocks using a computer controlled double chamber vacuum machine. One of the main problem faced by this system is clumping or blocking of kernels. With excess moisture levels or due to inadequate vacuumisation and gas flushing, the kernels get clumped or blocked and refuse to get disintegrated on unpacking. The problem has been solved by proper vacuumisation and gas flushing. Since flexipakages are highly compact, the drop impact or other stresses in transit will not be directly on the product, so the number of brokens can be minimized.

GMP for cashew kernel industry

Food safety is considered to be the responsibility of the Government, and government agencies implement the regulation by vigil, inspection, survey and monitoring. Import procedures are so regulated that only safe food is imported. But, it has now been realised that truly effective oversight of the food supply by Government is difficult and expensive to achieve. This has led in recent years to a demand for more individual accountability on the part of the food industry in the production, processing, storage and transport of food in an effort to prevent problems from occurring. Good Manufacturing Practices (GMP), specialised monitoring procedures such as HACCP and quality system certification procedures such as ISO 9000, etc. are examples of these preventive approaches to assure food quality and safety.

Indian cashew industry has a proven record of being proactive to consumer expectation. Even prior to the promitigation of Export (Quality Control and Inspection) Act, for the Cashew kernels in 1966, a system of inspection of processing units for compliance with General Hygienic Practice was introduced by the Cashew processing industry itself. Consignments for export were

inspected only after the inspection team was satisfied with the Hygiene and Sanitation conditions. Good Hygienic Practice Requirements include basic requirements for the following: Hygienic design, construction and operation, sanitation of food production premises and equipments, hygiene of operations used in the preparation, processing, storage and use of raw materials and products, the education and training of operators in good personal hygiene and good hygienic practices.

Consequent to the changed policies of the government in light of the WTO agreement, compulsory pre-shipment inspection by government agencies is not in vogue, but the shippers do continue the practice voluntarily by engaging private inspection agencies. Moreover, the industry has set up a modern analytical laboratory with state of the art analytical equipments to test samples for microbiological parameters, aflatoxin, pesticide residues, heavy metals, food additives etc. (Nair, 2001). Many of the processing units have already implemented a quality system conforming to ISO 9001. These units have taken the initiative to implement HACCP, based on the applications of structured hazard analysis and the identification of specific means of control of microbiological, chemical and physical hazards, associated with processing of cashew kernels.

Nutritional and therapeutical characteristics

Modern science evaluates the nutritive and gastronomic quality of food on the basis of their composition in terms of carbohydrates, proteins, fats, vitamins, minerals and other phytochemicals. In case of hypertension and obesity, energy rich fats are normally avoided. Phytochemicals in plants are getting increased attention because of their proven ability to prevent or even heal some of the chromic diseases. With this background, let us look at the composition of cashew kernels, which is a typical treenut, cultivated in India.

The average composition of cashew kernels, is given as,

Fats	-	47 %
Proteins	-	21 %
Carbohydrates	-	25 %
Minerals	-	2 %
Moisture	-	5 %

Because of the high fat content, cashew is considered as 'fatty food' and is listed under foods to be avoided along with meat, fish and poultry. But, there is a lot of difference in the quality of fats present in foods from animal sources and fat from cashew nuts. Fat in animal foods are composed of saturated fatty acids, which in humans help to increase the levels of low density lipoprotein (LDLs) in blood. LDLs are considered as bad cholesterol as they can clog the arteries; hence, the recommendations to avoid fatty food. But, now the research has proved beyond doubt that the 'fat' in cashew is composed mainly of unsaturated fatty acids (nearly 80 percent), which in humans raise the levels of high density lipoproteins (HDLs), which is a good fat and reduce levels of LDLs, thus lowering the risk of heart diseases. Cashew kernels contain polyunsaturated fatty acids, in a 1 : 1 ratio with saturated fatty acids, which also is considered to have potential good health effects.

Cashews contain no cholesterol. Cashews do not contain trans fatty acids. Cashew is a good source of protein, comprising of essential amino acids such as arginine, histidine, lysine, cystine, methionine, valine, phenylamine etc. which have important role in body building; thus are important in prevention and treatment of several chromic diseases. The carbohydrates present in cashew are composed of sugars, starch and dietary fibre. Cashews are rich in potassium (5421 ppm), calcium (248 ppm), magnesium (2536 ppm), iron (60 ppm), phosphorus (8400 ppm) etc. and contain significant levels of copper (22 ppm) and zinc (38 ppm). Content of sodium in cashew kernel is very low (48 ppm). The important vitamins recorded in cashews are Vitamin E (tocopherol), Vitamin A (retinol), Vitamin B_1 (thiamine), Vitamin B_2 (riboflavin) and Vitamin B_6 (niacin).

Cashew Nut Shell Liquid (CNSL)

History

The discovery of CNSL and its industrial uses was quite accidental. The credit of discovery goes to Mr. Mortimer Harvey, who was working at Queen Anne Candy Company, New York. The Company received raw cashew nuts instead of its regular supply of cashew kernel, and as an employee of the Company, Harvey had to decortify the raw nuts. This made him observe the nature of CNSL and after some preliminary work, in 1928, he reported to M/s. Irvington Varnish and Insulator (I.V.I) Company of New York, the potential use of the product in varnishes and paints. The I.V.I sponsored his work, and for the supply of CNSL, the I.V.I. Company approached India through

their brokers in London, and the first consignment of CNSL filled in kerosene oil tins were shipped from Mangalore. Shipment of the product was hazardous as the containers often burst. A cure to this problem was found out by the heat treatment of the product, and this product was found to be quite acceptable to I.V.I Company, and specification for CNSL was laid out based on this treated CNSL (Langley, 1962). The realisation of the potential huge market for CNSL made Mr. Jeffery of Peirce Leslie and Company to find out the means of producing CNSL in large quantity while at the same time avoiding damage to the kernels. The "Hot Oil Plant" was designed and installed in 1935, and the same was the standard equipment for cashew processing, in which the rawnuts were roasted in a bath of cashewnut shell liquid in the process of which further liquid is extracted from the shells of the nuts.

Extraction

There are various processes for the extraction of CNSL, namely, hot oil bath, expeller, and solvent extraction processes (Murthy et.al.1979; Russell, 1969). Commercial preparation of CNSL involve a heat treatment in which the anacardic acid is decarboxylated and a product containing mainly Cardanol and Cardol is obtained (Murthy and Agarwal, 1959).

Commercial uses

Cashewnut shell liquid (CNSL), has always been credited with words such as "versatile raw material" "industrially important material" etc. However, its commercial exploitation has not significantly undergone any drastic changes during the last few decades (Pillai, 2002). Being a structurally versatile material, CNSL has given rise to innumerable patents and a number of reports. (CEPCI 1964; CEPCI, 1977; CEPCI, 1978; Evans and Kaley Saraj, 1993; Gulati and Rao, 1964; Gulati and Rao, 1966; Gulati et.al, 1964; Jain and George, 1972; Murthy et al 1961; Murthy et al 1969; Paramashivappa et.al 2001; Pillai, 2001; Ramalingam et.al, 1970; Shivadasani, 1972; Sivasamban, 1977).

The availability of these patents has encouraged its commercial exploitation. But, the ups and downs of CNSL sale from India over the last three decades indicate that there has been much caution in the commercialization of CNSL products.

Future research needs

1) The most important problem being faced by the cashew processing industry is the shortage of raw cashew nuts. Though production of cashew nuts is outside the scope of this review, the existence of the processing industry depends on the availability of the raw nuts. Presently, half of the requirement of cashew processing industry is being imported, draining out nearly Rs.2000 crores worth of foreign exchange.
2) Though the quality of Indian cashew nuts is generally acceptable to the industry, there is wide variation in the quality of rawnuts available from different markets. There is a need to develop grading and marking systems, so that the farmers will be assured of fair price and the processors, fair quality.
3) The important quality defects noticed in the raw nuts are, immature nuts, voids, infestation by insects and moulds, foreign matters etc. These are caused by improper harvesting and poor post harvest attention. Research efforts should highlight the effects of poor post-harvest handling of the raw nuts.
4) Studies should be done on storage and storage pests.
5) Development of a moisture meter which can determine the moisture of raw cashew nuts in the market place in a necessity.
6) Cashew processing is a labour intensive programme, but in the years to come, there will be shortage of labour in this area, and there is need for improvising labour saving systems in the cashew processing.
7) The packaging system which is followed in the cashew industry need to be critically evaluated to fix controls needed to improve the efficiency of the practices.

References

Azam-Ali, S.H., and Judge, E.C. 2001. Small scale cashew nut processing, ITDC. Schumacher Centre for Technology and Development, Bourton on Dunsmore, Rugby, Warwickshire,U.K.

Balasubramanian, D. 2001. Physical properties of raw cashew nut. J. Agricultural Engineering Research 78(3): 291-297.

CEPCI. 1964. Cashewnut shell liquid patents Vol.I & 2. Cashew Export Promotion Council of India, Cochin-682016, India.

CEPCI. 1977. Production and utilization of cashew nut shell liquid in India. A survey report published by the Cashew

Export Promotion Council of India, Cochin-682016, India.

CEPCI. 1978. A survey of cashew nut shell liquid, patents. Cashew Export Promotion Council of India, Cochin-682016, India.

CEPCI. 2005. Annual Report 2004-2005 : Cashew Export Promotion Council of India, Cochin-682016, India.

Evans, D.A. and Kaleysaraj. 1993. Pharmacological activity of Cardol, the Antifilarial Principle from *A. occidentale*. Cashew Bulletin Vol.XXX April and May, P. 14-15.

Gulati, A.S. and Rao, B.C.S. 1964. Drug analogues from the phenolic constituents of cashew nut shell liquid. Indian.J.Chem.2: 337-338.

Gulati, A.S., and Rao, B.C.S. 1966. New dyes from phenolic components of cashew nut 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 cashew nut shell liquid. Indian. J. Chem.2:114-118.

Jacob, B. 1978. Cashew kernels : Quality Control and Preshipment Inspection. *In* Proceedings of the seminar on Quality Control of Processed Foods, 62-67, Association of Food Scientists and Technologists, Trivandrum.

Jain, R.K., and George, J. 1972. A CNSL based sealant for cracks and joints in buildings Cashew Bull.9(2).4-7.

Langley, W.K.M. 1962 (ed.). Century in Malabar. The History of Peirce Leslie & Co.Ltd.1862-1962. The Madras Advertising Company Pvt. Ltd. Madras. 150 p.

Mandal, R.C. 1992. Cashew production and processing technology. Agro Botanical Publishers India. Bikaner. 195p.

Mathew, A.G. 1977. Cashew processing in India. Proceedings of the seminar on cashew with accent on infestation control. Export Inspection Agency, Cochin.

Mathew, A.G., and Unnikrishnan, M.K. 1979. Harvesting and processing. *In* Nair, M.K., Rao, E.V.V.B. Rao, Nambiar K.K.N. and Nambiar M.C.(eds.). Cashew (*Anacardium occidentale.L*), Central Plantation Crops Research Institute, Kasaragod-670124, Kerala, India. 82-89.

Murthy, B.G.K. and Aggarwal, J.S. 1959. Analysis and upgrading of CNSL, Paint India 9(6):26-29.

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, G.K., Satyavathi, K. and Sivasamban, M.A. 1979. Cashew products. *In* Nair, M.K., Rao, LVVB, Nambiar, K.K.N and Nambiar, M.C (Eds). Cashew (Anacardium occidentale L., Central Plantation Crops Research Institute, Kasaragod – 670 124. 90-104.

Murthy, B.G.K., Sivasamban, M.A., and Aggarwal, J.S. 1969. Process for the production of pale coloured adhesive from cardanol. Indian paint. 119143.

Mussaliar, T.K.S.H. 2001. Evolution of Indian Cashew Industry. Cashew –The Millennium Nut, (Proceedings). The Cashew Export Promotion Council of India, Cochin-682016. India, 93-98.

Nair, C.K. 2001. CEPC Laboratory : Features and Facilities *In* Cashew the Millennium nut (Souvenir) 109-113. Cashew Export Promotion Council of India, Cochin – 682 016, India.

Nair, C.K. 2003. Quality maintenance of cashew kernels. *In* Sing, H.P.,Balasubramanian, P.P., and Hubballi,V.N.,(eds). Indian Cashew Issues and Strategies, 129-132. Directorate of Cashewnut and Cocoa Development, Cochin- 682 011.

Nair, K.G. 2002. Processing and Packaging of Cashewnuts. *In* Sing, H.P., Balasubramanian, P.P., and Hubballi, V.N., (eds). Indian Cashew Industry, 142-147. Directorate of Cashew Nut and Cocoa Development, Cochin - 682 011.

Narayanan, P.V. and Dordi, M.C. 2002. Modern trends in packaging of cashew kernels. *In* Sing, H.P., Balasubramanian, P.P., and Hubballi, V.N., (eds). Indian Cashew Industry, 156-160, Directorate of Cashew Nut and Cocoa Development, Cochi-11.

Narayanan, P.V. 1983. Packaging Quality Control. National Seminar on quality control and Preshipment Inspection. Indian Institute of Foreign Trade, Ashok Bhavan, 93, Nehru place, New Delhi-110019.

Paramashivappa, R., Kumar, P.P., Nithayathi, P.I. and Rao, A.S. 2001. Novel method for isolation of major phenolic constituents from Cashew. (*Anacardium. occidentale.L*). Nut shell liquid. Jour.of Agri. and Food chemistry. 49(5) 2548-2551.

Pillai, C.K.S. 2001. Cashew nut shell liquid : New applications *In* Cashew, The Millenium nut (Souvenir) 117-127. Cashew Export Promotion Council of India, Cochin – 682 016 India, 117-127.

Pillai, C.K.S. 2002. Commercial Exploitation of C.N.S.L. *In* Sing, H.P., Balasubramanian, P.P., and Hubballi,V.N., (eds). Indian Cashew Industry, 161-165. Directorate of Cashew Nut and Cocoa Development, Cochi-11.

Pillai, P.B. 2005. Chairman's speech at the 50th Annual General Meeting of CEPCI, Cashew Export Promotion Council, Cochin – 682 016.

Prabhu, G.G. 2003. Modernisation of Cashew Processing Units in India. *In* Singh, H.P., Balasubramannian, P.P.,and Hubballi, V.N.(eds). Indian Cashew Issues and Strategies, 120-123, Directorate of Cashewnut and Cocoa Development, Cochi – 682 011.

Prabhu, G.G. and Pillai, A.S. 2001. Cashew- The Millennium nut past, present and future. 'Cashew –The Millennium Nut (Souvenir), 25-31. Cashew Export Promotion Council of India, Cochin – 682 016, India.

Rajah, K.K. and Chitrakaran, M. 1979. 'Cashew Nut'. *In* Food Industries. Chemical Engineering Education Department Centre. IIT. Madras. 5.

Ramalingam, T., Murthy, B.G.K., Sivasamban, M.A. and Aggarwal, J.S. 1970. Cashew nut shell liquid distillation

residue-its utilization in coating. Paint India 20(10):29-31.

Rekha Ravindran, Jisha, K.G. and Padma Nambisan. 1997. Effect of Antioxidants on the shelf life of cashew kernels. Cashew Bulletin, October,13-17.

Russell, D.C. 1969. Cashew nut processing. Agricultural Services Bulletin No.6, Food and Agricultural Organization of U.N.

Shivadasani, H.B. 1972. Cashew nut 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.

Singh, H.P., Balasubraminan, P.P. and Venkatesh, N. Hubballi (Eds.). 2003. Indian Cashew. Issues and Strategies. Directorate of Cashewnut and Cocoa Development, Cochin – 682 011. 170p.

Singh, H.P. 2003. Indian Cashew- Present Status and Future Strategies. *In* Sing, H.P., Balasubramanian, P.P., and Hubballi,V.N.,(eds). Indian Cashew in the New Millennium, 1-13. Directorate of Cashew Nut and Cocoa Development , Cochin-11.

Singh, H.P. and Balasubraminan, P.P. 2002. Cashew production and trade. A global prespective: *In* Sing, H.P., Balasubramanian, P.P., and Hubballi,V.N.,(eds). Indian Cashew Industry, Directorate of Cashew Nut and Cocoa Development, Cochin-11.

Sivasamban, M.A. 1977. 'Utilization of by products in cashew industry. *In* Proceedings of seminar on cashew with accent on infestation control. Export Inspection Agency-Cochin.

Woodroof, J.G. 1967. Treenuts-Production, Processing and Products. The AVI Pub.Co. Westport, 221-233.

CASHEW EXPORT SCENARIO

K. Sasi Varma and **K.A. Venkiteswaran**
Cashew Export Promotion Council of India, Cochin - 682 016, Kerala

Cashew is an important agricultural commodity which contributes significantly to India's export earnings. India exported Rs. 2300 crores worth of cashew kernels and cashewnut shell liquid during 2007-08. The cashew producing and processing sector in India employs around six lakh workers, in farms and factories.

India is the largest producer, processor, exporter and second largest consumer of cashew kernels in the world. Our cashew kernels are exported to more than 60 countries in the world, mainly to USA, Netherlands, UK, Germany, Japan, Australia, UAE, etc. In the late 1800's in Kerala raw nuts were roasted in pans at homes and the kernels were extracted and sold by peddlers. Obviously this practice was prevalent all over Western India, where householders took the pleasure of consuming what they produced. Enterprising local converters made this available to the nearby population during the production season.

The first commercial cashew processing unit was set up in Kollam in mid 1920s. However the early exports were not followed up because the cashew kernels were not vacuum-packed but wrapped in newspapers and stuffed in reused tea chests. Intervention of the World War II put a break in any further development of the trade. Export volumes picked up only after the introduction of airtight tins infused with carbon dioxide in the mid 1950s. Soon units came up in Mangalore and Goa also. Thus started India's march to conquer the world with this exotic nut.

Another small but important processing centre is Panruti in South Arcot District of Tamil Nadu.

A major problem facing the Indian cashew industry is the acute shortage of raw cashewnuts within the country. As against the processing requirement of about 12 lakhs MT per annum, the domestic production of raw cashewnuts is only about 6 lakhs MT per annum. Consequently the cashew processing industry has been resorting to import of raw nuts for processing and exports. During the year 2007-08 India imported 6,05,970 MT of raw cashewnuts from different countries. Accompanying charts and tables illustrate the Indian cashew processing industry's dependence on imported sources of raw cashewnuts for meeting its export commitments.

Along with increasing world demand for cashews, Indian consumption is also growing. It is a fair guess to assume that Indian consumption of cashew kernels is as much as its exports. By the year 2020 it is our estimate that the domestic production of raw cashewnuts should be 19 lakhs MT to keep pace with the demand. Government of India is taking steps to increase the domestic production of raw cashewnuts.

India and Brazil were the major suppliers of cashew to the world market till about five years ago. In recent years Vietnam also has emerged as a major supplier, replacing Brazil in the 2nd position.

Though we are exporting to more than 60 countries of the world, over 99.5% of our cashews go in bulk packaging and as plain cashew kernels. In India, we now have different varieties of consumer packs including roasted and salted, sugar coated, spiced and masala fried, etc.

At present USA and West Europe are India's major markets followed by Japan, West Asia and Australia. New emerging markets like Eastern Europe, CIS countries and China have a lot of potential for absorbing more quantities of cashews than at present. Efforts should be made to tap the potential of these markets

At present, cashew is mainly consumed as a snack item. By increasing the awareness about the health advantages of cashews, the benefits can be enjoyed by new segments such as school going children, old people requiring nutritional supplements, pregnant women, etc. Cashew is also finding extensive use in confectionary items.

EXPORT OF CASHEW KERNELS & CNSL FROM INDIA

Year	Cashew Kernels		Cashewnut Shell Liquid (CNSL)		TotalValue
	M.T.	Rs.Crores	M.T.	Rs.Crores	Rs.Crores
2003-04	100828	1804.43	6926	7.03	1811.46
2004-05	126667	2709.24	7474	7.91	2717.15
2005-06	114143	2514.86	6463	7.21	2522.07
2006-07	118540	2455.15	6139	10.29	2465.44
2007-08	114340	2288.90	7813	11.98	2300.88

Source: Director General of Commercial Intelligence & Statistics, Kolkata & Customs figures

IMPORT OF RAW CASHEWNUTS INTO INDIA

Year	Quantity M.T.	Value Rs. Crores
2003-2004	452398	1400.93
2004-2005	578884	2190.94
2005-2006	565400	2162.95
2006-2007	586044	1811.62
2007-2008	605970	1746.80

Source: Director General of Commercial Intelligence & Statistics, Calcutta & Customs Figures

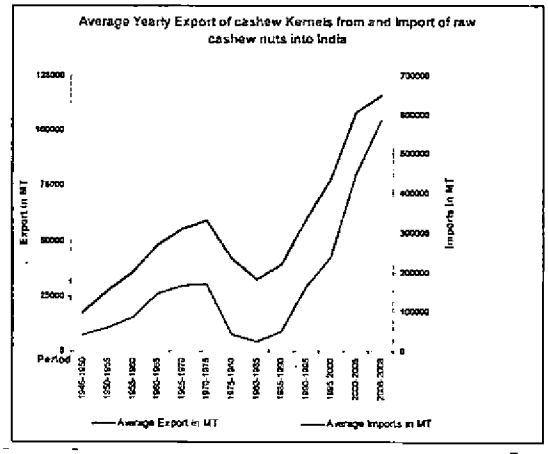
New recipes using cashew are being developed which can easily blend with the traditional cuisine of the various cultures. This will persuade the people to consume more cashews without compromising on their cultural habits.

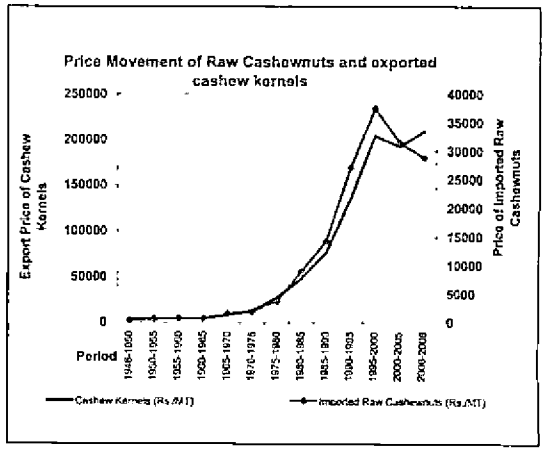
Another area where there is potential for significant growth is export of organically produced cashews. The market for all organic food products is booming especially in the developed countries. Even though it is not officially recognized, it is widely accepted that Indian cashew is predominantly organic as the cashew trees are owned by small farmers who seldom use any synthetic fertilizers to boost the crop nor undertake any kind of crop protection measures. The need of the moment is to introduce organic agricultural practices among the growers and encourage them to get certified by approved agencies. This will fetch them higher returns from the cashew plantations.

Apart from cashew kernels, there are a few other products of the cashew tree such as cashew apple, cashewnut shell liquid, cashew shell and cashew testa which have good market potential.

There are prospects for setting up units for utilization of cashew apple, which is at present mostly wasted. Many preparations like juices, jams, candies, pickles, chutneys and alcoholic beverages can be prepared from cashew apple. The 'Feni' and cashew apple juice are said to have many medicinal values and are very popular in Goa.

Cashew Nut Shell Liquid is a by-product of cashew processing industry. It is a versatile industrial raw material which has applications in polymer based industries such as friction dust, brake linings, paints and varnishes,





laminating resins, cashew cements, polyurethane based polymers, surfactants, epoxy resins, foundry chemicals and intermediates for chemical industry. There are many end users for this product in India and abroad.

Another product of the cashew industry which can be put to profitable use is the cashew shell. The outer shell after removal of the kernel and extraction of shell liquid is now used only as a fuel. This shell can be used for manufacture of particle boards for the packaging industry. Presence of residual CNSL in the shell makes these boards moth and heat resistant. A recent study conducted by the National Institute of Technology, Suratkal, Karnataka, has shown that cashewnut shell waste can be used for removal of pollutants like cadmium from industrial effluents. Thus there is scope for using the waste product of the cashew processing industry in pollution control.

Tannin can also be extracted from the brown skin (testa) of the kernel. It has applications in leather industry. Factories for extraction of tannin from cashew testa also have good scope.

***

CASHEW APPLE – QUALITY ATTRIBUTES AND ITS UTILISATION

M. C. Narayanan Kutty * and A. Augustin
Kerala Agricultural University
(* RARS, Pattambi), Vellanikkara - 680 656, Kerala

Introduction

Cashew apple is a pseudo fruit formed by the swollen receptacle. Ripe cashew apple has bright yellow, red or reddish yellow colour. It is soft and fibrous and has a characteristic flavour. It is a rich source of Vitamin C, often several times more than citrus fruits. Cashew apple juice is known to have anti scorbutic properties and is used as a diuretic. It is also useful for kidney ailments and cholera. Medicinal properties of cashew apple were enumerated by Vijayakumar (1991) and Nair (1995).

In many parts of South America and West Indies, cashew apple was used and the use of nuts was unknown in the early years. The apple contains astringent principles, which gives an unpleasant biting sensation when raw apple is consumed. This in fact limits the utilisation of cashew apple as a fresh fruit as well as a raw material in the fruit processing industry.

Yield of cashew apple is six to eight times that of cashew nut. With the cashew nut production of 5.7 lakh tons per year, an estimated 4.5 million tons of cashew apple is produced in India. In spite of the excellent nutritional qualities, medicinal value and potential as a raw material for conversion to various fruit products and fermented beverages, cashew apple has not gained commercial importance. Except in few production centers like Goa where cashew apple is utilised for making fermented products, the entire quantity of cashew apple available in major cashew producing tracts are wasted at present. Technologies have been developed for the removal of astringent principles and utilisation of cashew apple for manufacture of different types of fruit products [Jose Mathew and Mini (2008); Jose Mathew *et al.* (2008); Mini and Jose Mathew (2007)]. This chapter presents an overall picture of the research especially at Kerala Agricultural University on cashew apple and its utilisation.

Growth pattern of cashew apple

The fruit development in cashew is completed in 52 to 60 days. After fertilization the developing nut become visible by the 5th or 6th day (pea stage) (Damodaran, 1966). At this stage the pedicel length is about 0.6- 0.9 cm. By the time the apple attains maturity, the pedicel length increases 6 to 10 times. The apple circumference increases 12-24 times and weight 650-1500 times during the growth period. The rate of apple growth is slow up to 40 days after fruit set. Peak growth is between 40 and 60 days after fruit set. Enlargement in the later stages of growth is due to increase in carbohydrates and moisture. Specific gravity of young cashew apples ranges from 1.04 to 1.15. Ripe apples have specific gravity less than one (Augustin and Unnithan, 1982; Kutty, 2000).

In the early stages of development the pedicel colour is purple or greenish purple which turns green or light green later. Typical colour of apple appeares at the fully ripe stage. Ripe cashew apples are yellow/golden yellow/ red/ cherry coloured.

Composition of cashew apple

Physico-chemical attributes of high yielding cashew apple varieties of Kerala were evaluated by Vilasachandran and Damodaran (1982, 1985), Aravindakshan *et al.* (1986), Manoj (1992), Narayanankutty (2000), Salam and Joseph (2003) and Suman (2006). Fully-grown cashew apple weighs about 50 to 100 grams. It takes about 55-60 days for the apples to reach ripe stage from fruit set. Ripe cashew apple has 88 to 90 per cent moisture content. Major constituents are carbohydrates (12.3%), Proteins (0.2%), fibre (0.9%)and minerals (0.2%) (CSIR, 1985). The ascorbic acid content ranges from 170-350 mg per 100 g of apple. It has 0.02mg thiamin, 0.5mg riboflavin, 0.4 mg nicotinic acid per 100g and 39 IU of vitamin A (Augustin, 2001).

Cashew apple juice contains 10.7 % sugars and has 0.3% acidity. Ripe apples contain 0.76 to 1.17% pectin. The food value of fresh cashew apple is presented in Table 1.

Soluble carbohydrates and ascorbic acid content increase up to the final stages of maturity in cashew apple. The astringency of fruits is determined by phenolic compounds present in them. In the early stages of growth, level of phenolic substances are very high which decrease sharply as the apples mature. There is a progressive increase in ascorbic acid with the ripening of cashew apple (Augustin and Unnithan, 1982).

Cashew apple is described as one of the most metabolically active material (Tables 2 and 3) with high rate of respiration and shows non-climacteric behaviour (Kutty, 2000).

Anatomy

Cashew apple, which is morphologically the modified peduncle, has typical dicot stem anatomy. Vascular bundles are endarch, collateral and open; arranged in a ring. The cortex is transversed by lysogenously formed resin ducts as in the stem. Epidermis is very thin and the entire cortex and pith develop together to form the succulent apple. Starch grains accumulate in the parenchymatous tissues and are visible at 40 days after fruit set (DAFS) stage. Tannins accumulate in the inter cellular spaces of the cortex.

The cuticular layer is about 6.6μm thick. The epidermal cells are 16 to 50 μm in length and 9.6 to 32.5 μm in width. The cell size is maximum at 30 DAFS stage. The parenchymatous cells of the cortex vary in size at different stages of development. Average length range between 12.8 to 25.6 μm and width range from 12.8 to 22.4μm at 20 DAFS stage. The parenchymatous cells in ripe apples are 56-64 μm in length and 36-56μm in width. Size of lysogenously formed canals also increases from early stages of growth to ripening stage (Kutty, 2000).

Table 1. Food value per 100 g of fresh cashew apple

Moisture	88.8-90.6 g
Protein	0.2 g
Fat	0.05-0.50 g
Carbohydrates	8.96-9.19g
Fiber	0.4-1.0 g
Ash	0.19-0.34 g
Calcium	0.9-5.4 mg
Phosphorus	6.1-21.4 mg
Iron	0.19-0.71 mg
Carotene	0.03-0.742 mg
Thiamine	0.023-0.03 mg
Riboflavin	0.13-0.4 mg
Niacin	0.13-0.539 mg
Ascorbic Acid	195.9-384.8 mg

Table 2. Rate of respiration in (detached) cashew apples at different stages of development

Stage of development (days after fruit set)	Respiration rate ($mgCO_2$ Kg^{-1} hr^{-1})
20	720.38
40	368.9
50	292.3
55	316.2
Ripe	198.6

Table 3. Rate of ethylene release from (detached) cashew apple during different stages of development.

Stage of Development	Ethylene release (μl kg^{-1} hr^{-1})
Immature (40 d)	47.15
Mature green (50 d)	160.17
Turning (52-55 d)	64.92
Ripe	31.57

(Kutty, 2000)

The structural configuration of cashew apple, especially the absence of a protective peel is reflected in the storability of the produce and its susceptibility to physical damage. These factors could also influence shrinkage and shriveling due to moisture loss, physical damage and microbial spoilage when collected and stored in bulk.

Variability in apple characters

In terms of morphological and qualitative characters, cashew apples show a lot of variation. Variability in terms of size of apple, colour, total soluble solids, ascorbic acid, proteins, tannins, acidity, reducing sugar content, specific gravity and juice recovery have been recorded (Chandran and Damodaran, 1985).

Significant variations in apple characters have been observed between varieties/ types of cashew. Average weight of apple was more than 70 g in varieties BRZ-

241, Priyanka, H- 1610, H- 1593, Akshaya, BRZ-242, H-3-17, Kanaka, V-2, V-3 and Sulabha. Juice yield ranges between 66.3 per cent and 75.3 per cent. Most of the varieties have acidity ranging between 0.3 and 0.4 per cent. Ascorbic acid content ranges between 155.3mg $100g^{-1}$ and 352.0 mg $100g^{-1}$. Content of phenolic substances range from 0.25 to 0.79%. Varieties H-1593, H-1600, V-4, K-19-1, Madakkathara-2, Dhana, Kanaka and M 26/2 had desirable attributes with reference to quality parameters (Table 4) (Kutty, 2000).

Acidity ranges from 0.21% in variety *Madakkathara-1* to 0.52% in *H-1610*. Tannin content is lowest in variety *Amrutha* (0.28%) and highest in Kanaka (0.76%). Pectin content is high in Variety *Madakkathara-1* (1.26%). β Carotene levels range between 16.42μg to 52.49 μg per 100g. Variability exists in terms of calcium, magnesium and sodium content also (Suman, 2005).

Post harvest handling and storage

Cashew apple is a highly perishable commodity. It is highly susceptible to physical injury, which leads to microbial spoilage within a very short period after harvest. The storability of cashew apple is thus very poor and complete spoilage can occur within hours after harvest. Ripe apples are also subjected to damage by insect and non- insect pests. The method of collection of nuts from fallen fruits is unsuitable for utilisation of the apple. If cashew apples are to be effectively utilised, the ripe apples are to be harvested carefully and dispatched for processing.

Ripe cashew apples suffer severe damage by insect and non-insect pests as well as pathogens. More than 63 per cent of cashew apple collected at ripe stage have moderate to heavy damage. Cashew apples collected

Table 4. Apple characters of cashew varieties

Variety	Total weight of fruit (g)	Average weight of apple (g)	Weight of nut (g)	Colour of apple	Apple/ Nut ratio	Juice yield (%)	TSS (%)	Acidity (%)	Firmness (kg cm^{-2})	Ascorbic Acid (mg $100g^{-1}$)	Phenols (%)	TSS/ Acid ratio
Ank.1	52.7	46.1	6.6	Yellow	6.98	71.3	11.0	0.36	2.72	234.6	0.48	30.5
Mdk.1	62.2	55.1	7.1	Yellow	7.76	73.7	12.4	0.33	1.50	212.2	0.42	37.9
M44/3	61.1	54.1	7.0	Golden yellow	7.72	73.0	11.0	0.35	1.80	220.7	0.25	31.7
VTH30/4	34.2	28.0	6.2	Deep red	4.51	71.7	11.9	0.34	2.48	212.6	0.41	35.1
H317	80.5	73.2	7.3	Orange red	10.62	67.0	11.6	0.40	1.68	196.2	0.79	29.0
H2/15	91.9	85.6	6.3	Golden yellow	13.58	71.3	11.8	0.33	1.38	199.6	0.64	35.9
Kanaka	81.8	75.6	5.9	Yellow	12.81	70.0	13.4	0.32	1.36	208.1	0.50	43.4
H 1610	93.2	83.9	9.5	Golden yellow	8.83	69.3	14.8	0.33	1.74	200.6	0.62	45.3
H2/16	60.8	53.5	6.5	Yellow	8.23	69.7	11.2	0.25	1.30	238.3	0.36	45.8
V2	78.4	71.9	6.5	Red	11.06	70.7	13.5	0.33	1.10	297.3	0.42	40.9
Dhana	62.3	54.1	8.2	Yellow	6.59	72.3	13.8	0.23	1.50	220.1	0.46	61.3
H59/2	60.0	50.4	8.6	Light Red	5.97	70.3	12.2	0.40	1.26	191.6	0.39	30.8
M26/2	71.5	64.7	7.0	Deep Red	9.24	67.3	12.0	0.28	1.30	194.6	0.37	42.9
Priyanka	105.9	92.8	13.1	Crimson	7.08	67.7	12.6	0.27	1.22	181.1	0.45	46.1
H1593	90.1	81.1	9.0	Golden Yellow	9.01	75.3	13.3	0.38	1.74	221.7	0.61	35.5
V3	79.4	71.1	8.3	Yellow	8.56	70.7	14.8	0.30	2.04	210.1	0.48	50.9
V4	79.4	65.8	8.4	Red	7.83	71.7	13.5	0.33	1.68	164.1	0.49	41.4
H1600	74.7	65.4	9.2	Red	7.10	69.3	13.7	0.35	1.06	202.6	0.46	39.5
Mdk.2	70.7	63.1	6.8	Orange Red	9.27	67.7	14.0	0.22	2.20	166.6	0.50	63.6
Sulabha	80.8	71.6	9.2	Orange Red	7.78	70.3	13.0	0.32	1.88	295.7	0.42	41.7
Anakha	75.4	63.9	9.5	Orange Red	6.72	66.3	11.8	0.32	1.70	155.3	0.50	36.8
Akshaya	93.2	82.6	10.7	Yellow	7.71	68.3	11.5	0.34	1.30	226.1	0.42	34.0
BRZ241	106.7	99.9	6.7	Yellow	14.91	68.3	12.3	0.26	1.32	232.4	0.32	47.5
BRZ242	88.8	81.0	7.7	Yellow	10.51	71.0	11.0	0.32	1.94	352.0	0.36	34.3
K191	55.6	48.1	7.5	Orange Red	6.41	70.7	13.8	0.21	1.14	212.3	0.51	66.9

from fallen fruits suffer heavily due to mechanical damage (Kutty, 2000).

Firm ripe cashew apples of BLA.273, Vengurla 37-3, and M-10-4 dipped in 5% Potassium metabisulphite solution can be stored for 8 days in zero energy cool chamber (Augustin, 2001). Storage of cashew apple under ambient conditions result in 35 to 100 % spoilage by the second day. Storage up to 12-13 days is possible under refrigerated conditions with 15 to 17°C temperature and 85% RH. Apple collected from fallen fruits could be stored for 6-11 days under similar conditions. Packing cashew apple in polythene bags with or without ventilation reduce the storage life. Fungal decay and shrinkage were the main causes of spoilage of cashew apple (Kutty *et.al.*, 2003).

Pre storage treatments with warm water can improve storage life of cashew apple under refrigerated conditions. Pre storage treatment with chemicals such as potassium meta-bisulphite, sodium benzoate or hydrogen peroxide is not effective. Symptoms of chilling injury such as of sunken spots, pitting, water soaked lesions and discolouration appear when apples are stored under freezing temperature (Kutty, 2000).

Utilisation

Removal of components responsible for the astringency is possible by adopting different methods, which include steaming of apple, cooking in brine and clarifying extracted juice with gelatin or polyvinyl pyrrolidone. Technology is also available for conversion of cashew apple and juice after removal of astringent principles, into various products like jam, candies, chutney, pickles, preserves and fruit beverages. Cashew apple is utilised in some production centres for making country liquor after fermentation. Manufacture of country liquor using cashew apple as raw material has developed as a small scale industry in Goa, where 70 per cent of the cashew apple available in the region is utilised for the purpose (Nair, 1974).

Fragmented and scattered nature of cashew plantations also creates problem in collection and utilization of cashew apple. The system of collection of cashew nuts from fallen fruits after considerable delay also limits the availability of quality cashew apple for processing purposes. Harvest of cashew at full ripe stage and separation of the nut with minimum damage to the apple is essential for utilisation of the apples. Extraction of apple juice under hygienic conditions at the production sites itself and transportation of the preserved juice could be a viable alternative to minimise spoilage and reduce transportation costs. When whole fruits are to be preserved and transported before processing, it is necessary to clean the apples and pack them in well-ventilated crates and transport under refrigerated conditions. Packing cashew apples in multiple layer often cause mechanical damage to the apples in the lower layers. It is better to arrange 2-3 layers with proper padding in each pack (Kutty, 2000).

Products

Different types of products can be made using the cashew apple pulp and juice. Whole apples can be canned or candied (Sreeja, 1996) after removal of astringency. Steaming of apple at 5-15lbs pressure for 5-15 minutes can remove astringency. Boiling in 2-4% salt dipping in salt solution or 0.2N sulphuric acid followed by washing is also effective Methods for preparation of cashew apple jam, candy, chutny and pickle have been standardised (Mini *et al.*, 2005 and Augustin, 2001). The technologies developed were suitably modified (Mini & Mathew, 2008) by conducting extensive organoleptic studies at Cashew Research Station, Madakkathara under a project entitled "Transfer, Demonstration and refinement of technologies for cashew apple processing" funded by National Horticulture Mission. Based on crude fibre, tannin and sugar content suitable varieties for making cashew apple candies and tutty fruity are *Amruth*, *Anakkayam-1*, *Dharasree*, *V-5* and *VTH 30/4*. One kilogram of cashew apple on processing gives 745g candies and 715g tutty fruity (Suman, 2005). Cashew apple slices can also be dried (Edassery, 1988).

Ripe cashew apple yields about 60% juice with TSS 9-10%. Juice can be extracted using screw press or hydraulic press. The astringency can be removed by using gelatin @0.5g/kg juice after dissolving it in water. Excess gelatin gives a dis agreeable odour . Poly vinyl pyrrolidone (PVP) @1.4g/kg juice or 125ml/litre of rice gruel twice can also be used. The tannins settle as a sediment which can be removed by decantation. Excess PVP may cause cloudiness in the extracted juice. Cashew apple juice clarified using PVP does not show browning (Augustin, 1982).

Clarified juice can be stored using preservatives. This

juice can be used for making products like squashes, syrups and ready to serve beverages. PVP was replaced by a natural agent sago @ 2g/l of juice (Jayalekshmi & John, 2004) and later the concentration of powdered sago was refixed as 5g/l of juice. The method for preservation of materials like juice, pulp and green mango was also standardised (Mini & Mathew, 2008).

Remyamol (2006) standardised different blended cashew apple RTS beverages to increase the acceptability.

Cashew apple juice on fermentation gives wine with characteristic aroma. This can also be used for distilling good quality alcohol. Kerala Agricultural University has standardised methods for making cashew apple liquor (Augustin *et al* 1982, Patent No. 195/MAS/82). The steps involved are: 1. Collection, washing and extraction of juice 2. Detanning 3. Fermentation 4. Distillation and 5. Ageing

Eight litres of cashew apple juice yield one litre of liquor on distillation. The liquor has a pleasant smell of cashew apple when aged in wooden casks. Liquor with strong or mild cashew flavour, free from cashew flavour or blended flavour can also be made (Augustin, 2001).

Cashew wine can be produced by fermntation for 15-30 days using yeast. Ageing for 6-12 months give good quality wine. Soft, medium, hard and sweet wines can be made from cashew (Patent No. 196/MAS/82; Augustin, 2001). Quality of wine is influenced by clarifying agent. MTCC 180 strain of wine yeast, *Sacchawmyces cerevisiae* produces cashew wine of high alcohol content and low aciditiy. Apples of Madakkathara - 1 and Dhana were found suitable for wine making. Cashew apple wines could be mixed with fresh fruit juices to produce wine coolers of high consumer acceptance (Carvatho, 2001). Cashew vinegar can also be made from the apple juice.

Utilization of apple residue

When bulk quantities of cashew apple is utilised for product preparation, considerable amount of residue is obtained as waste. Apple residue could be effectively utilised for the production of vermicompost having a nutrient composition of 1.69% N, 0.44% P and 0.58% K (Mini *et al.*, 2004).

The cashew apple pourace has been identified as the ideal medium for pectinase enzyme production for *Aspergillus foetidus* 115 through solid state fermentation (Venkatesh, 2003).

Economics of cashew apple processing

Cost of establishment of cashew apple processing unit was worked out by Jayalekshmy and Salam (2000) and Mini *et al.* (2006)

Conclusion

Cashew apple has nutritive value and potential as a raw material for conversion into different kinds of fruit products. Cashew apple products are healthy and refreshing and have to be promoted in the market. Potential also exist to use it as a raw material for manufacture of wine and alcohol. If utilisation of at least a part of the total quantity available could be ensured, it would also generate employment opportunities for the rural poor.

REFERENCES

Aravindakshnan, K., Celine, V.A., Balakrishnan, S. and Veeraraghavan, P.G. 1986. Studies on certain physico-chemical attributes of apple and units of selected types. *Cashew causerie* 8:5-8

Augustin, A. and Unnithan, V.K.G. 1982. An attempt on maturity of cashew apple. *Indian Cashew J. 14* (4): 9-11.

Augustin, A., Vidyadharan, K.K. and Thomas, J.K. 1982. Studies on cashew liquor in Kerala. *Cashew Bull. XIX* (4): 8-11.

Augustin, A. 1982. Studies on the clarification of cashew apple juice for the preparation of cashew syrup. *Indian J. Nutr Dietet.* 19:16 9-172.

Augustin, A. 1987. Unfermented products of cashew apple. *Proceedings of the Ist National Workshop on utilisation of cashew apple. April 29, 1987.* Kerala Agricultural University, Vellanikkara.

Augustin, A. 2001. Utilization of cashew apple. *Souvenir of World Cashew Congress 2001.* The Cashew Export Promotion Council of India, Kochi.

Carvalho, M.G.R. 2001. Standardisation of techniques for cashew apple wine production and development of wine based products. M.Sc. (Hort.) thesis. p. 110

Chandran, T.V. and Damodaran, V.K. 1985. Physico chemical qualities of cashew apples of high yielding types. *Acta Hort. 108*: 165 - 172.

CSIR. 1985. *The Wealth of India. A dictionary of Indian Raw materials and Industrial Products. Raw materials* Vol. I

A. Publication and Information Directorate. CSIR, New Delhi, p : 244.

Damodaran, V.K. 1966. The morphology and biology of the cashew flower (*Anacardium occidentale* L.). II Anthesis, dehiscence and receptivity of stigma, pollination, fruit set and fruit development. *Agric. Res. J. Kerala 4* (2): 78-84.

Edassery, P.M. 1988. Dried fruits from cashew apple. Cashew Bull. 15:11.

Jayalekshmy, V.G. and John, P.S. 2009. Sago-a natural product for cashew apple juice clarificaiton. *J. Trop. Agric.* 42 (1-2(67-68.

Jayalekshmy, V.G. and Salam, M.A. 2002. Cost of establishment of a cashew apple processing unit and production cost of cashew apple syrup. *The Cashew* (April-June): 29-33.

Jose Mathew and Mini, C. 2008. Cashew apple: Economic utilization through value addition. In: Recent initiatives in horticulture (Eds. K.L. Chadha, A.K. Singh and V.B. Patel), Horticultural Society of India, New Delhi, pp. 612-623.

Jose Mathew and Mini, C. 2008. Opportunities for income enhancement from cashew through nut and apple processing. Proc. Nat. Seminar on 'Food Security through innovations in food processign and enterpreneurship development', 29-30 Sept. 2008, KAU, Vellanikkara, pp.36-41.

KAU. 2002. *Package of Practices Recommendations: Crops.* 12th ed. Kerala Agricultural University, Thrissur. 60-62

Kutty, N. M. C. 2000. *Development pattern, storage behaviour and variability in processing characters of cashew apple.* Ph D thesis. Kerala Agricultural University, Thrissur

Kutty, N.M.C., Ramachandran Nair, S. and Jyothi, M.L. 2003. Storage characteristics of cashew apple stored under refrigerated conditions *Proceedings of the 15th Kerala Science congress. 29-31 January, 2003,* Thiruvananthapuram: 764

Manoj, P.S. 1992. Biochemical studies in cashew (*Anacardium occidentale* L.) hybrids. MSc (Hort.) thesis, Kerala Agricultural University, Thrissur, 128 p.

Mini, C., John, P.S. and Sushama, P.K. 2004. Vermicompost preparation from organic wastes of cashew garden. *Proc. First Indian Horticulture Congress.* 6-9 Nov. 2004, New Delhi, p 263

Mini, C., Jose Mathew and Jesy Thomas, K. 2006. Economic potential of cashew apple processing. *Cashew Bulletin* XLIV (6) 5-8.

Mini, C., and Jose Mathew. 2007. Multiuses of cashew apple. Proc. 6th Nat. Seminar on Indian cashew in the next decade - challenges and opportunities, 18-19 May 2007, Raipur, pp. 45-52.

Mini, C. and Mathew, J. 2008. Recipes for cashew apple products. Kerala Agricultural University p.15

Mini, C., Mathew, J. and Augustine, A. 2005. Technologies for cashew apple processing. Kerala Agricultural University, Vellanikkara p. 55

Nair, K.G. 1995. Cashew - a crop of unlimited potential. *The Cashew* 9:14-16.

Nair, K.V. 1974. Utilisation of cashew apple. *Cashew News Teller.* 3 (1-3):6-9

Ohler, J.G. 1979. *Cashew.* Communication 71. Department of Agricultural Research. Kaninklijk Insituut voor de Tropen. Amsterdam. pp. 63-75.

Remyamol, K.K. 2006. Standardisation of blended cashew apple RTS beverages. M.Sc. thesis. Kerala Agricultural University, Thrissur.

Salam, M.A. and Joseph, M.P. 2003. Apple and juice yield potential of cashew varieties. *J. Plant. Crops. 13*(3): 18-22

Sreeja, K.C. 1996. Qualitative changes in cashew apple products in storage with special reference to vitamin C. MSc (Homescience) thesis, Kerala Agricultural University, Thrissur, 112 p.

Suman, K.T. 2005. *Physico chemical and nutritional attributes of cashew apple and its products.* Ph D thesis. Kerala Agricultural University, Thrissur

Venkatesh, M. 2003. Fruit waste utilization for pectinase production through solid state fermentation. MSc (Hort.) thesis, Kerala Agricultural University, p.93.

Vilasachandran, T. Nutritive value of cashew apple.

Vilasachandran, T. and Damodaran, V.K. 1982. Evaluation of cashew apple of high yielding types for alcoholic beverages. *Indian Cashew J.* 13:4-9.

Vilasachandran, T. and Damodaran, V.K. 1985. Physico-chemical qualities of cashew apples of high yielding types. *Acta. Hort.* 108:165-172.

Vijayakumar, P. 1991. Cashew apple utilization - a novel method to enhance the profit. *The Cashew 5:17-21.*

MULTIPLE USES OF CASHEW APPLE AND THE CONTRIBUTIONS OF CASHEW RESAERCH STATION, MADAKKATHARA

Jose Mathew, C. Mini and A. Sobhana
Cashew Research Station, Kerala Agricultural University, Madakkathara -680651, Thrissur, Kerala

1. INTRODUCTION

Cashew is a major commercial horticultural crop of India, ranking second in agricultural export. Cashew now occupies an area of 8.37 lakh ha with a production of 5.73 lakh tones of raw nuts. The crop is now grown for its nut, which is considered as the only economic produce from the crop. Research studies as well as experiences in running India's first cashew apple processing unit at Cashew Research Station, Madakkathara have clearly revealed that the cashew apple, weighing about 8-10 times that of the nut, is an equally valuable produce from the crop, if it is economically exploited. However cashew apple is almost completely wasted in India, without any commercial exploitation, like in many other parts of the world. The production of cashew apple in India is estimated to be around 40 lakh tones per annum. Cashew apple is highly nutritious and comparable with many other tropical fruits. Large number of technologies has been developed by various research station in India, more specifically Cashew Research Station, Madakkathara, for the economic utilization of cashew apple by processing it into various value added products. The Madakkathara Centre has also succeeded in commercializing the cashew apple processing technologies and is profitably running the unit since 1997. In spite of this, it is quite unfortunate that the country is wasting such an excellent fruit causing economic loss both to the farmers and the country. This article presents an over view of the multiple uses of cashew apple and various technologies developed for its processing.

2. COMPOSITION OF CASHEW APPLE

Cashew apple is highly nutritious and is a valuable source of sugars, minerals and vitamins. The chemical composition of cashew apple is : Moisture 87.8%, protein 0.2%, fat 0.1%, carbohydrate 11.6%, crude fibre 0.9%, calcium 10.0 mg/100g, phosphorous 10.0 mg/100g, iron 0.2 mg/100g, vit C 261.0 mg/100g, minerals 200.0 mg/100g, thiamin 0.02 mg/100g, riboflavin 0.5 mg/100g, nicotinic acid 0.4 mg/100g and vitamin A 39.0 IU. Thus cashew apple is comparable with several other fruits in the content of most of the nutrients but superior in vitamin C and riboflavin (Table 1).

The ripe apple is very juicy, spongy, somewhat fibrous, having a unique smell, and has a very thin skin that gets easily bruised. The astringent and acid principles in cashew apple produce a rough, unpleasant and biting sensation on the tongue and throat, which is a major draw back of the fruit. The astringency of cashew apple is determined to a large extent by the tannin content, a phenolic compound, and its content varies from 0.06 to 0.22g per 100 g. The pH of the apples varies between 4.1 and 4.7 and total sugars from 6.7 to 10.5%. Ripe apples contain 0.76 to 1.17% pectin.

3. USES OF CASHEW APPLE

An overview of the multiple uses of cashew apple is given in Fig. 1. The figure depicts the large number of

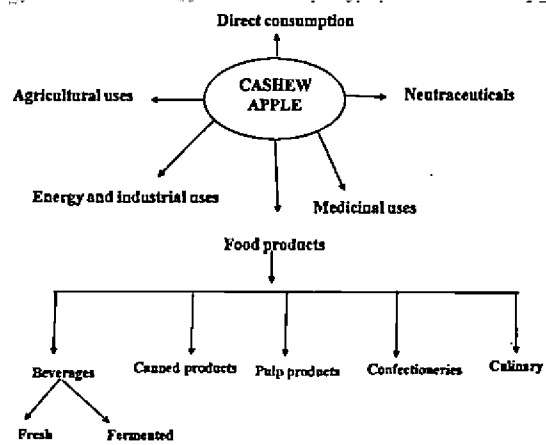


Fig. 1. Multiple uses of cashew apple

Table 1. Comparison of nutritional qualities of cashew apple with that of common tropical fruits

Name of fruit	Moisture (g)	Protein (g)	Fat (g)	Calcium (mg)	Iron (mg)	Carotene (μg)	Vit. C (mg)
Cashew apple	86.3	0.2	0.1	10	0.2	23	180
Apple	84.6	0.0	0.5	10	0.66	0	1
Banana	70.1	1.2	0.3	17	0.36	78	7
Orange	87.6	0.7	0.2	26	0.32	1104	30
Mango	81.0	0.6	0.4	14	1.3	2743	16
Papaya	90.8	0.6	0.1	17	0.5	666	57
Citrus fruit	89.3	0.9	0.6	40	0.6		50

uses of cashew apple unlike other common fruits. Traditionally, several products are prepared from cashew apple, including those with medicinal properties, some of which are still used.

However it is not commercially exploited anywhere in the country except in Goa where it is used for the preparation of cashew feni. However, many institutions in India, particularly Kerala Agricultural University, have developed technologies for the preparation of various nutritious and refreshing products from cashew apple. Cashew Research Station, Madakkathara of Kerala Agricultural University is profitably running a commercial unit for the production of five cashew apple products. This success story is to be replicated elsewhere in major cashew growing areas of the country, which will give additional revenue to farmers and can generate considerable employment for unemployed youth and women. It is a good sign that few cashew apple processing units have started functioning in Kerala during the last two years due to the persistant transfer of technology initiatives of Kerala Agricultural University. This is to be extended to other major cashew growing states of India. The major uses of cashew apple are presented below under six major topics:-

I. Direct consumption

Cashew apple is widely eaten raw as fresh fruit. Either whole apples are consumed or they are cut into small pieces, mixed with table salt and eaten. Quality for fresh consumption is related to low astringency and acidity, sweetness, firmness, size and pear shape. The market requirements for appearance are to be taken into consideration. Cashew apple must be cosmetically perfect without misshaping or physical signs of injury to be sold as fresh fruit. A niche market for cashew apple for direct consumption can be located atleast in major towns. This can be exploited successfully, if constraints like poor storability are overcome.

II. Manufacturing of food products

1. Beverages

a. Fresh apple beverages

Clarified and cloudy juice, juice concentrate, syrup, squash and ready- to- serve are some of the nutritious and refreshing beverages that can be made from the unfermented juice of cashew apple by adding varying concentrations of sugar, citric acid and preservative. The Kerala Agricultural University has standardized the technique for the preparation of juice, syrup and ready to serve drink. The Cashew Research Station, Madakkathara is manufacturing cashew apple syrup and a ready to drink form "Cashew apple drink" on a commercial scale and selling through the sales outlets of the university.

In Brazil, concentrated juice from cashew apple ranks first in sales among the tropical juices. It has contributed to human nutrition, particularly the poor people, by supplying low cost Vitamin C. Vitamin C content in cashew apple juice averages to about 200 mg/100 g juice, which is nearly four times higher than other traditional fruit juices such as orange. Cajuda, cajuuina, cajuvita and cajuaperativo are different cashew drinks in South Brazil. Cashew apple juice can also be blended with other fruit juices like lime, pineapple, orange, grape, watermelon and apple juices to produce mixed or composite beverages with improved consumer acceptance.

b. Fermented beverages

Cashew apple can be utilized for the manufacutre of the

fermented products like wine, vinegar, liquor and alcohol. Cashew apple vinegar can be prepared by alcoholic and subsequent acetic fermentation of juice, which is perhaps the oldest known fermentation product. Cashew liquor is not made by blending of spirits, as done in case of foreign liquor, but distilled exclusively from the pure juice of cashew apple without addition of any extraneous matter. The steps involved in the production of cashew liquor are: 1. Extraction of cashew apple juice and detanning 2. Fermentation 3. Distillation 4. Ageing process on wooden casks and 5. Removal of astringent smell. Use of good ripe apples is very important, as unripe or overripe apples would affect the quality of final product. One litre of 60-62% ethyl alcohol can be obtained from eight litres of cashew apple juice. Kerala Agricultural University has standardized the method of producing four different grades of liquor from cashew apple.

Cashew apples are utilized widely in Goa for the preparation of the liquor, feni, by distillation mostly through crude country methods on cottage industry basis in almost all plantations.

Cashew wine is a product of fermentation of hexose sugar of cashew apple juice by intact yeast cells to form ethyl alcohol and carbon dioxide. Kerala Agricultural University has developed methods for producing four grades of wine such as soft, medium, hard and sweet, based on the alcohol percentage and sweetness. Fermentation, filtration and ageing are done on detanned cashew apple juice. All grades of wine preparation, except soft wine, involve one more step of adding sugar. Sensory evaluation showed that the performance was in the order of sweet, medium, hard and soft wines. Wine can also be distilled to produce brandy.

Cashew apple wine can be mixed with fresh juices of orange, pineapple, tomato, grape and cashew apple as well as tender coconut water to produce wine coolers to serve as good health drink as they contain both wine with its medicinal properties and fruit juices with high amount of nutrients and minerals.

2. Products from cashew apple pulp

Jam is the most important pulp product of cashew. It can be prepared by boiling the cashew fruit pulp with a sufficient quantity of sugar and a pinch of citric acid to a reasonably thick consistency, firm enough to hold fruit tissues in position. Mixed fruit jam can also be prepared by mixing cashew apple pulp with equal quantity of banana pulp or pineapple pulp. The Madakkathara Centre is commercially producing Cashew apple- Mango Mixed jam named *Cashewman*.

Fruit bar having 80^0 brix can be prepared by heating layers of fruit pulp mixed with pectin, sugar, glucose and potassium metabisulphate to 90^0 C and drying to 15% moisture. Different layers of cashew apple paste mixed with 1% citric acid are sun dried and cut into required size after placing one on top of the other to form leather. The layers, after smearing sugar syrup and pressed together, can be eaten like fruit wafers.

3. Confectionery products

Candied fruit is prepared from cashew apple by impregnating with cane sugar with subsequent draining and drying. One kilogram of cashew apple on processing gives 745 g candies. The Madakkathara Centre is commercially producing cashew apple candy .The syrup left over from the candying process can be used for sweetening chutneys, in vinegar making or for candying another batch of fruits. Cashew apple can also be utilized for the preparation of tutty fruity. One kilogram of cashew apple on processing gives 715 g tutty fruity. The whole fruit can also be processed in to nutritious toffee, a feasible dessert item with extended shelf life. Toffee could provide 7.5g of protein and 442 K calories per 100g.

Cashew apple juice can be used for preparing frozen deserts and dairy confectionery items by optimization of juice concentration and spray drying. The only constraint here is the large capital investment required for spray drier equipment.

Dehydrated powder is used to prepare dehydrated cashew apple products. Clarified juice is prepared from steam blanched, sulphur dioxide treated fruits and spray dried for preparation of cashew apple powder with juice. The pulp or the residue of apple can also be dried, powdered and sieved for use as cashew apple powder without juice. 10 to 30% dehydrated cashew apple powder can be used in various value added products like wheat laddu, masala biscuits, sweet and masala doughnuts, sponge cake, steamed kabadu, tomato cashew apple powder soup,

powder koftas, chocolates, sweet and hot bread products and cashew apple blended chocolates. Nutri-Cashew, a ready mix have been prepared using cashew apple powder for the elderly as high fibre fruit (drink) food mix for instant use.

A ready- to- serve beverage mix, fruit–milk/lassi mix has been prepared from clarified juice by homogenization, spray drying and mixing with milk/ lassi powder (Vaidehi, 1994). 10% to 15% clear and cool cashew juice mixed with skim milk powder can be spray dried for the production of cashew milk powder and can be utilized for the preparation of products like milk shakes, ice creams and ice candy.

4. Culinary products

Sliced raw green fruit can be used to prepare pickle using chilli powder, gingelly oil, fenugreek powder, asafoetida, turmeric powder, garlic, mustard powder, a pinch of sodium benzoate and salt to taste. Madakkathara Centre is commercially producing and marketing Cashew Apple Pickle. Chutney can be prepared from sliced cashew apple using sugar, onion, ginger, spices like cumin seed, pepper, cardamom, cinnamon and coriander powder, salt and vinegar. Dried pulp prepared from semi- boiled apples is preserved for off- season and used for culinary uses particularly for the preparation of chutney.

Several traditional culinary preparation are in vogue in cashew growing areas using both unripe and ripe fruits.

5. Canned products

Cashew apple is peeled after treating with boiling NaOH solution followed by subsequent treatment in boiling solution of 0.2 N H2SO4. The treated fruits can be steamed and hot sugar syrup can be poured over the fruits for preparation of canned apple.

Canned curried vegetables from raw green fruit of cashew in combination with potatoes (1:1) or potatoes and tomatoes (2:1) with or without tamarind are also reported.

III. Medicinal properties

Several preparations from cashew apple have been extensively used traditionally for several ailments. Cashew apple is used as a curative against scurvy and stomach ailments like dysentery and diarrhea. It is used as a tonic to mothers in confinement. It is a medicine for women after parturition.

Cashew apple juice, without removal of tannin, is prescribed as a remedy for sore throat and chronic dysentery in Cuba and Brazil. Fresh or distilled, it is a potent diuretic, possessing anti scorbutic properties, and is useful for kidney troubles, and in advanced cases of cholera. It is given for uterine complaints and dropsy. The brandy is applied to relieve the pain of rheumatism and neuralgia (CSIR, 1985). The cashew *feni* is used to cure various aliments of infants and aged.

Cashew apple liquor is used for medicinal purposes for aliments like worms, sickness, cold, body ache, fever or flue, toothache, fresh wounds and cuts, cramps due to chilling weather, muscular pain, irregular movement of bowels, low blood pressure, loss of sleep for aged people and cholera. Cashew apple juice kept in sunlight for a fortnight can be preserved for 2 to 3 years, which would have effect in treating fever and diarrhea of both human beings and domestic animals. It is believed that cashew apple juice induces sleepiness when given along with medicines for patients affected by fever, thus helping in fast recovery.

IV. Neutraceutical products

Ascorbic acid, fibre, carotenoid pigments, minerals and host of other chemicals, which are of significance to human health are contained in cashew apple. Cashew apple powder lipids are rich in unsaturated fatty acids, the major ones detected being palmitoleic and oleic acids. Crude fibre content of dried cashew apple powder has been found to vary from 1.99 to 4.7% (NRCC, 2005). Vitamin C, an anti oxidant present in cashew apple was analyzed and it showed variation from 40.1 to 177.8 mg/ 100g. The cashew apple/ cashew apple residue has the following uses in agricultural/ livestock production.

A valuable by- product that can be obtained from cashew apple waste is pectin. Pectin is used in manufacturing jams, jellies, marmalades, preserves etc. It is useful as thickening, texturising and emulsifying agent and finds numerous applications in pharmaceutical preparations, cosmetics etc. Pectin has been isolated from cashew apple powder, the yield of which varies from 1.6 to 2.03%. The cashew apple pomace or the fruit waste has

been identified as the ideal medium for pectinase enzyme production for *Aspergillus foetidus* 115 through solid state fermentation (Venkatesh, 2003).

V. Agricultural uses

Considerable amount of cashew apple residue is obtained as waste when bulk quantities of cashew apple is utilized for the manufacture of soft drinks or fermented beverages on a commercial scale. Nutrient status of cashew apple residue on dry weight basis is: total ash 1.6%, total tannin 5.2%, ether extractives 4.6%, calcium 20.6 mg/100g, phosphorous 152.7 mg/100g, proteins 8.8%, crude fibre 8.4% and iron 35.0 mg/100g.

1. *Vermi compost*

The cashew apple waste, which is highly perishable and seasonal can be converted to value added products with good manurial value with out creating problems for disposal. Apple residue could be effectively utilized for the production of vermi compost of 1.69% N, 0.44% P and 0.58% K using *Eudrilus euginae*. The pH of the compost from cashew apple is 8.9 and hence could be used as a good ameliorant for acidic soils.

2. *Animal feeds*

The ripened cashew apple or its residue could be utilized for the preparation of cattle feed, pig feed and poultry feed. Cashew apple is a promising feed source for diary cows in Vietnam. Cashew apple or its residue could be preserved for long term use as cow feed by anaerobic ensiling with poultry litter. Cashew peel (7.6% protein, 12.3 % fat and 59.2% carbohydrate) is a good poultry feed. Apples are also dried and preserved as cattle feed for rainy season. Daily feeding of 3-4 kg fresh apples along with normal feed to cow is found useful. However cattle will have stomach problem causing diarrhea, when fed excess quantity.

3. *Pest management*

It is observed that cashew apple extraction is an effective insecticide against red palm weevil (*Rhynchophorus ferruginous* Olive) in coconut (Krishna Kumar *et al*, 2003). Cashew apple and gum extract, in combined form or alone, acts as an effective repellent against leaf feeding pests of vegetables. The cashew apple is dried and powdered into meal which can be used as bait for catching crustaceans.

VI. Energy production and industrial uses

1. *Bio-fuel*

The potentials to utilize cashew apple for production of alcohol to be used as a bio fuel is immense. Fresh cashew apple contains 9.5 to 10 % carbohydrates, in addition to varying quantities of fats, minerals and vitamins. It is estimated that cashew apple can yield 8 to 10 % of ethanol. Every kilogram of raw nut generates apple equivalent to produce 500 to 600 ml of ethanol of about 70% purity. This indicates that there is a huge potential of generating ethanol from cashew apple. As such, the use of cashew apple for ethanol production assumes greater significance.

The residue, after extracting juice for fenni preparation, is used as fuel in liquor industry in Goa.

2. *Biogas*

Ripened fruits can be used as raw material for biogas plant.

3. *Tannin extraction*

Cashew peel can be used for the extraction of tannin which is useful in leather industry (Johnson, 1977).

4. CONTRIBUTIONS OF MADAKKATHARA STATION

i. *Commercial products of Madakkathara Centre*

An FPO licensed cashew apple processing unit has been established at Cashew Research Station, Madakkathara, Thrissur under Kerala Agricultural University during 1997 for the manufacture of unfermented cashew apple products. It is the first ever unit established in India for cashew apple processing. The unit is undertaking commercial production of cashew apple syrup, cashew drink, mixed cashew apple- mango jam, cashew apple pickle and cashew apple candy.

It is a fully fledged commercial unit undertaking production of cashew apple products employing the processing technologies developed by the centre. The participants undergoing various training programme at the centre are familiarized with the working of the unit, equipments used and infrastructural requirements. The licensing and marketing requirements of running a commercial processing unit are exposed to the trainees,

taking Madakkathara unit as the model. The model unit serves to present a comprehensive idea to the trainees and visitors regarding the technical, marketing, economic, infrastructural and licensing requirements for running a commercial unit as well as the response to the cashew apple products. Several entrepreneurs intending to start cashew apple processing units are visiting the model unit and gets convincing idea about the technical and commercial aspects of starting a unit.

The details of commercial cashew apple products from Kerala Agricultural University are given below:-

1. *Cashew Apple Syrup and Drink*

Selected cashew apples are cleaned thoroughly, juice extracted and clarifying agent, preservative and citric acid are added immediately. The clarified juice is siphoned out and this serves as the raw material for the preparation of syrup and drink. Sugar and citric acid are added to the clarified juice in required quantity to produce syrup and drink as per demand.

The nutrients, Vitamin C and riboflavin, which are high in cashew apple, are preserved in these beverages also. Cashew apple syrup contains 276 mg Vitamin C and drink contains 140 mg vitamin C/ 100g. These are natural products and price is fixed comparatively less as compared to other common fruit drinks. Taste is better if served chilled. Syrup has a storage life of one year.

Cashew apple drink is an RTS (Ready – To -Serve) beverage. Drink is marketed both in glass bottles and in attractive food grade pouches. Pasteurized drink in glass bottles has a storage life of three months under ambient storage conditions.

2. *Cashew Apple- Mango Mixed Jam*

The ripe apples are collected from the plantation, selected, cleaned and soaked in salt solution for three days to remove tannin. Apples are again washed in water, cooked, made into pulp and is mixed with equal quantity of mango pulp. Pulp is mixed with sugar and citric acid to prepare jam. Vitamin C content of the product is 18 g/ 100g. It is marketed under the trade name *Cashewman* Mixed Jam.

3. *Cashew Apple Candy*

It is a sweet product and quality apples with good shape are selected for candy preparation. As in jam preparation, tannin is removed from apples, cooked, pierced using fork and dipped in sugar solution. Concentration of sugar solution is gradually increased so as to reach 70^0 brix. After two weeks of soaking, sugar solution is drained out and candy is dried in shade. It takes about 2-3 weeks for making the final product. About 745 g candy can be obtained from one kilogram of cashew apple. Vitamin C content of the product is 28.4 mg/100g.

4. *Cashew Apple Pickle*

Mature but unripe cashew apples are collected directly from plantations carefully without disturbing the flowers and tender nuts. After cleaning, the fruits are cut into small pieces and astringency is removed by immersing in salt water. After removing from salt water, it is again washed and pickle is prepared using oil, chilly powder, fenugreek powder, turmeric powder, ginger and garlic paste.

ii. Progress in the establishment of cashew apple processing units

The constant transfer of technology initiatives by the Madakkathara Centre has resulted in the establishment of several units by private entrepreneurs and Self Help Groups. The first ever cashew apple processing unit in private sector using Madakkathara technology has been established at Iritty, Kannur, Kerala under the trade name "TOMCO PRODUCTS" and they are marketing cashew apple syrup.

Three Self Help Groups have started cashew apple processing units at Payyavoor (Kannur district), Kelakam (Kannur district) and Neendakara (Kollam district) during 2008-09 fruiting season with the technical and financial assistance of Madakkathara Centre under a State Horticulture Mission funded project. At least four private entrepreneurs have started production of various cashew apple products after getting training at Madakkathara Centre, on their own. The Kudumbasree Mission in Kasaragode district is planning to establish several cashew apple processing units during 2008-09 harvesting season and the members have already undergone training at RARS, Pilicode.

The research, development and transfer of technology initiatives of Madakkathara Centre, supported by funding from State Horticulture Mission and Rashtriya Krishi

Vikas Yojana, has started yielding results, with the establishment of several cashew apple processing units. The success of these units largely depends upon the support of the state and central governments. Being a processed product, cashew apple products are also charged Valued Added Tax @ 12.5% at present. This is a major impediment in selling the cashew apple products at attractive prices. Extending financial support for establishing cashew apple processing units under National and State Horticulture Mission and Rashtriya Krishi Vikas Yojana can encourage entrepreneurs to start new units.

***

NHM PROJECT ON TRANSFER, DEMONSTRATION AND REFINEMENT OF TECHNOLOGIES FOR CASHEW APPLE PROCESSING

C. Mini and Jose Mathew
Cashew Research Station, Kerala Agricultural University, Madakkathara -680651, Thrissur, Kerala

The National Horticulture Mission has funded the project "Transfer, demonstration and refinement of technologies for cashew apple processing" for implementation at Cashew Research Station, Madakkathara. The project was implemented at Madakkathara during 1 July 2007 to 30 September 2008.This chapter presents an overview about the project.

The main objective of the project was to demonstrate and transfer the technologies developed by KAU for the utilisation of cashew apple. The major programmes envisaged under the project includes undertaking the product refinement and testing, conducting the training programme for various stake holders and establishment of demonstration units for cashew apple processing in major cashew tracts of the state.

The project was implemented under five major programmes. They were:-

1. Refinement of existing technologies
2. Development of new technologies
3. Transfer of technology
4. Establishment of state- level model cashew apple processing unit and product refinement and testing unit at Madakkathara
5. Establishment of three model cashew apple processing demonstration units in major cashew growing areas

1. REFINEMENT OF EXISTING TECHNOLOGIES

Refinement works have been done for the clarification of cashew apple juice and removal of tannin (de-tanning) from cashew apple, for the purpose of cashew apple processing.

1.1. Clarification of juice

Clarification of juice was tried using different methods and the best method suited for removing the tannin content and having increased storage life were selected. Treatment with powdered and cooked sago @ 5g/ litre with out considering the cooking temperature were found effective for clarification of cashew apple juice. The clarified juice extracted using the selected procedure showed no signs of microbial load even after six months of storage.

1.2. De-tanning of whole ripe cashew apple

Refinement of the existing technology for removal of tannin from the whole ripe cashew apple was tried to improve the acceptability of the product. The tannin content of the pulp was tested after treatment and the method resulting in lowest tannin content was selected. It was seen that dipping in 5 % salt solution for three days, changing water every day, was the best treatment. The efficacy of this method was again compared with continuous dipping in salt solution, in respect of three varieties and three fruit maturity stages. The results indicated that changing the salt solution every day was better and effective in de-tanning compared to continuous dipping in salt solution for three days.

1.3. De- tanning of green cashew apples

When the cut pieces of green cashew apples for pickle preparation was subjected to different de- tanning methods, it was seen that immersing the cut pieces in 8 % salt solution for three days, with the change of salt solution daily, reduces the tannin content to the minimum.

1.4. Storage of raw material for off- season production

Methods were standardized for the effective storage of raw materials for off- season processing.

i. Storage of clarified juice

The extracted juice from cashew apple, after clarification following the recommended procedure involving the addition of 2.5 g Potassium Meta bisulphate, 5.0 g citric acid and 5.0 g sago for every litre, can be stored in well sterilized, air tight, food grade plastic barrels for off season product preparation.

ii. Storage of fruit pulp

De- tanned cashew apple can be stored as pulp for off season production using the following procedure: 1.Steam de-tanned cashew apple for 10-15 minutes in pressure cooker (without putting weight) 2.Remove black spots and parts of pedicel, make into pulp by thorough agitation using mixer/ pulper 3. Mix with 2.5 g Potassium Meta Bi-sulphite and 5 g citric acid with every kg of pulp 4.Store in air tight glass bottles

iii. Storage of raw fruit pieces

The de-tanned fruit pieces can be stored in glass bottles after adding 200 g salt per kg of pieces in alternate layers.

2. DEVELOPMENT OF NEW TECHNOLOGIES

Technologies for the preparation of the blended cashew apple beverages, spiced beverages, mixed jams and cashew apple pickle were newly developed under the project and standardized based on organoleptic studies. Detailed studies were also conducted to know the storage potential of the various products developed. Works were also carried out for the commercial production of cashew apple candy using the refined technology and based on the detailed storage studies.

2.1. Blended Cashew Apple Beverages

Studies were conducted to prepare cashew apple beverages like RTS and squash by blending with other fruit juices to increase the acceptability.

2.1.1. Blended cashew apple squashes

Blended cashew apple squashes were prepared in 50:50; 60:40, 70:30 and 80:20 ratios with orange, lime, mango and pineapple. Based on initial organoleptic studies, the following blended squash samples were selected for further analysis:-

1. Cashew apple + Orange 60:40
2. Cashew apple + Orange 80:20
3. Cashew apple + Lime 70:30
4. Cashew apple + Mango 60:40
5. Cashew apple + Mango 70:30
6. Cashew apple + Pine apple 50:50
7. Cashew apple alone (control)

Acceptability rank of the selected blended squashes were found out by conducting organoleptic evaluation of the selected products using 5 point hedonic scale by a panel of 25 judges and acceptable squash products were selected for further storage study. The two superior blended cashew squashes viz., Cashew + Pineapple 50 : 50 and Cashew + Mango 60 : 40 were further organoleptically scored using 5 point hedonic scale for commercial release of a single product. Blended cashew apple squash with cashew and pineapple in 50: 50 ratio was scored better compared to other sample and selected for commercial release.

Based on organoleptic analysis, the superior two samples, Cashew apple + Mango (60:40) and Cashew apple + Pineapple (50:50) along with the control sample (cashew apple alone) were packed in suitable sterilized glass bottles and were stored at ambient storage temperatures and at low temperature for a period of six months. The quality attributes such as acidity, reducing sugar, TSS, tannin and vitamin C were evaluated initially and at monthly intervals for a period of six months. The products were evaluated for the presence of bacteria, yeast and fungi initially and at monthly intervals. The products were also evaluated for browsing/ colour change.

The ascorbic acid content of the squash samples decreased during storage, both under room and low temperature storage. Acidity was almost same throughout the storage period. Reducing sugar of the samples increased with storage period, irrespective of storage condition. The tannin content of the samples increased till three months after storage at room temperature condition and till two months after storage under refrigerator condition. The values then decreased under both storage conditions.

The microbes were absent at the month of preparation, both under room temperature and at low storage

No bacteria were seen in the samples kept under both storage conditions even after six months of storage. But yeast and fungi were seen in the samples irrespective of storage conditions, but the number was too few to count and hence not reported. The experiment revealed that the blended squash could be stored safely up to five months without any microbial contamination.

2.1.2. Blended cashew apple RTS beverages

Blended cashew apple RTS beverages were prepared using different fruits (lime, ripe mango, green mango, pineapple and mango) in the ratios of 50:50; 60:40, 70:30 and 80:20.Organoleptic assessment of the prepared RTS beverage was done among public using 5 point hedonic scale by a panel of 25 judges and acceptable RTS beverages from each group were selected for further study.

Based on initial organoleptic assessment, the following RTS beverages were selected and again subjected to organoleptic analysis.

1. Cashew + Green Mango 60:40
2. Cashew + Green Mango 70:30
3. Cashew + Lemon 70:30
4. Cashew + Orange 70:30
5. Cashew + Mango 60:40
6. Cashew + Pineapple 60:40

The samples were ranked and the final organoleptic scoring of the top two selected RTS beverages was again done.

Based on the final organoleptic scoring, RTS beverages with cashew and pineapple in 60: 40 ratio was selected as the best and selected for commercial release.

Based on organoleptic analysis, Cashew Apple + Orange (70:30) and Cashew Apple + Pineapple (60:40) along with control were packed in suitable sterilized containers like glass bottles and were stored under ambient storage temperatures and at low temperature for a period of six months. The quality attributes such as acidity, reducing sugar, TSS, tannin and vitamin C were evaluated initially and at monthly intervals during storage period. The products were evaluated for the presence of bacteria, yeast and fungi initially and at monthly intervals.

Very low amount of bacterial count (TFTC) was detected during the storage period of RTS, stored both under ambient and refrigerated conditions. No yeast and fungi were reported during the storage.

2.1.3.. Spiced and blended cashew apple RT'S beverages

Blended RTS beverages prepared using cashew apple juice with pine apple and mango in 50:50 ratios were added with different spice extracts (fresh ginger, cardamom and Naruneendi).Organoleptic assessment of the spiced beverages was done using 5 point hedonic scale by a panel of 25 judges and acceptable products from each group were selected for further study.

As per the results, the spiced beverages were poor in taste and acceptability compared to RTS beverages prepared without spices. So the spiced beverages were not selected for further storage studies.

2.2. Mixed Fruit Jam

Mixed fruit jams were prepared by mixing cashew apple pulp along with pulp of pineapple and mango adopting 50: 50, 60:40 and 70: 30 ratios and certain other combinations. Organoleptic evaluation of the mixed fruit jams was carried out using 5 point hedonic scale by a panel of 25 judges who were above and below 30 years and acceptable products from each group were selected for further study.

Based on the organoleptic testing, mixed fruit jam with cashew and mango in 50: 50 ratios was selected as the best and selected for commercial release.

2.3. Cashew Apple Pickle

Pickle was prepared from mature, but unripe cashew apple using different modified recipes and the samples were organoleptically analyzed among 50 persons and the acceptability score was analyzed.

The cashew apple pickle prepared using ginger-garlic-green chilly paste along with dates was having high acceptability score and selected for commercial release.

2.4. Other Novel Products

Cashew apple fruit bar and cashew apple chutney were prepared from cashew apple pulp.

a. Fruit bar

Fruit bar was prepared from cashew apple pulp. De-tanned ripe cashew apple was made into pulp, mixed with sugar, citric acid and KMS and the mixture is spread in layers and dried. Vitamin C of fruit bar was found as 140 mg/100g.

b. Chutney

Modification of procedure was done by adding dates.

Acceptability of the prepared products was scored using a 5 point hedonic scale.

Cashew Apple Chutney prepared using dates was more acceptable, compared to the product prepared using existing technology.

2.5. Cashew Apple Powder And Dried Apple

Dehydrated powder and dried apple were prepared from cashew apple for the preparation of various value added products.

For the preparation of cashew apple powder, good quality ripe cashew apples were collected, cleaned and dipped in 5% salt solution for 3 days for de- tanning. Salt solution is daily changed and washed after 3 days. Cashew apples are dipped in KMS solution (2g/l) for 2 days, washed, sliced, blanched for minutes in boiling water, drained, dried for one week, powdered and sieved.

Dehydrated powder would serve as a vitamin C rich powder that can be blended with other flours for nutrient enrichment. Preparation of different products was tried using the powder.

Dried apple would serve as a raw material for off season production of cashew apple pickle.

2.6. Confectionaries

a. Biscuits

Biscuits were prepared using cashew apple powder, maida, sugar, ghee, cashew nut and baking powder.

b. Toffee

Toffee was prepared using cashew apple powder by adding maida, milk, sugar, ghee and cardamom powder.

The confectionery products like toffee and biscuits prepared from cashew apple powder were organoleptically scored for acceptance.

Toffee prepared using cashew apple powder was more acceptable compared to cashew apple biscuit.

c. Cashew Apple Halwa

Halwa was prepared from cashew apple pulp and cashew apple powder using ingredients like rice powder, sugar, ghee and coconuts and the samples were subjected to organoleptic analysis.

Halwa was more acceptable when cashew apple pulp is used in the recipe. Cashew apple powder was not suitable for halwa preparation. Sugar was a better ingredient for halwa compared to jaggery.

3. TRANSFER OF TECHNOLOGY

3. a. Launching of new commercial products

The technologies developed under the project were employed for the commercial production of four value added products viz., "Cashew Drink" RTS, "Cashewman" Mixed Jam, Cashew Apple Pickle and Cashew Apple Candy. This was specifically done to demonstrate the commercial viability of the developed technologies and consumer acceptance of the new products; all the products were well received by the consumers. The products were sold through the sales outlets of the KAU spread through the state. The processing unit at Madakkathara, undertaking commercial production of cashew apple products, is functioning as a model processing unit demonstrating the infrastructural requirements of starting a cashew apple processing unit and convincing the new entrepreneurs regarding the profitability and marketability of the products.

3.a.1.Commercial products in the pipeline

The technology for the commercial production of the following products has been standardized:-

1. Blended cashew apple squash with pine apple in 50: 50 ratio
2. Blended cashew apple RTS beverage with pineapple 60: 40 ratio
3. Cashew apple chutney
4. Cashew apple toffee

3. b. Inclusion of newly developed technologies in the state level Package of Practices Recommendation (Crops)

The newly developed technologies are to be incorporated in the state level Package of Practices (POP) Recommendations (Crops) for their official recognition for adoption by the farmers and entrepreneurs. Accordingly, the following ten technologies developed

under the project has been proposed for inclusion in the POP (Crops).

1. Clarification of cashew apple juice with sago
2. De-tanning of whole ripe/ green cashew apples
3. Off- season storage of cashew apple juice, pulp and green pieces
4. Modified procedure for preparation of cashew apple syrup
5. Procedure for preparation of cashew apple RTS beverage
6. Procedure for preparation of cashew apple- pine apple squash
7. Procedure for preparation of cashew apple- pineapple blended RTS
8. Procedure for preparation of cashew apple - mango mixed fruit jam
9. Procedure for preparation of cashew apple pickle
10. Procedure for preparation of cashew apple candy

The proposals have been already approved by the Zonal Research and Extension Advisory Committee of the Central Zone held at Pattambi as well as by the university level Mini Package Workshop held at Vellanikkara. The final approval by the state level workshop is expected shortly.

3. c. Establishment of state level training centre and conduct of training programmes

Conduct of training programmes was a major activity under the project. The trainings were organized under the aegis of the newly established state level training centre on cashew apple processing.

Thirty training programmes of different duration on "cashew apple processing" were conducted from February 2008 onwards for the various stake holders, including farmers, unemployed youth, farm women, members of Kudumbasree units and staff of development departments at Cashew Research Station, Madakkathara for popularization of the technology developed in cashew apple processing.

Aspects such as the importance of cashew apple, its nutritive value and its importance as natural foods were popularized among the general public to increase the consumer acceptance for cashew apple products. The thrust of the training was to give hands-on-training on the preparation of various products so that the participants will acquire the capability to prepare the various products at the end of the training.

The participants of the trainings were selected from all over the state. All the expenses of the training including food and accommodation were met from the training. Wide publicity was given for the training through print and electronic media. The announcement regarding training was also circulated among different development departments such as Department of Agriculture, Kudumbasree Mission and Department of Rural Development. As a result of the wide publicity given for the training, trainees from all the major cashew growing areas of the state could attend the training.

Among the trainings, one each was a one week and 3-day training programme. The three day programme was conducted during 27-29 February, 2008.

The selected trainees from the 1-day and 3-day trainings, who intend to start commercial cashew apple processing units were given one week training in two batches during 14- 19 July 2008.They were given a comprehensive training on all aspects of fruit processing to enable them to process other commonly available fruits in their area to make the units economically more viable.

Fifteen off campus one day training programmes were conducted at different cashew growing tracts of Kerala like Kannur, Kasaragod, Kozhikode and different areas of Thrissur district.

Training programmes were conducted to scientists of different institutes under ICAR/SAUs in Karnataka (NRCC, Puttur; CRS, Ullal), Andhra Pradesh (KVK, Rajamundri), West Bengal (AICRP on Cashew, Jhargram), Kerala (RARS, Pilicode; KVK, IISR, Peruvannamuzhi; KVK, CPCRI) and Tamil Nadu (RARS, Vridhachalam).

Several trainees have started home scale preparation of the products and few ventured into commercial production.

3. d. Starting of commercial production by trainees

Many trainees, after their successful participation in the training, have evinced keen interest in starting new cashew apple processing units. Many are in different stages of establishment of the units such as seeking

financial assistance, applying for licenses from competent bodies, building up infrastructural facilities, procurement of equipments and utensils.

The names and addresses of the trainees who have started commercial production of cashew apple products, along with the items produced, is given below:-

Sl.No.	Name and address	Name of item
1	Sri. Mehboob, Azheekodan House, Ezhom Boat Kadavu, Ezhom, P.O. Pazhayangadi, Kannur Dt. 670 334	Cashew candy
2.	Sree Durga Kudumbasree Unit, Tholur Panchayath, Ponnore, P.O. Parappur, Thrissur	Cashew pickle
3	Thomas, K.J., St. George Printers, St. George Road, Ollukkara P.O., Thrissur 680 655	Cashew apple syrup
4.	Abdul Nassar, Mundallur, Peralassery, Kannur	Cashew apple syrup

3. e. Popularization of new products and technologies

The technologies developed under the project, along with the products, were suitably exhibited in various melas/ exhibitions organized by KAU and other institutions in Thrissur and other districts for popularization of the technologies and products among public. All the commercial products manufactured under the project were displayed and sold through the stalls put up in the various exhibitions. The major exhibitions in which the station participated include Thrissur Pooram Exhibition, South Indian Agricultural Fair, Thrissur Flower Show and State level Agricultural Exhibition organized by College of Horticulture under the RAWE programme at various places. The products received good acceptance from public and were sold out in large numbers. The feedbacks from consumers about the products were very useful in further refinement of the products and development of new products.

3. f. Publications

The results of the studies conducted under the project were published in scientific journals as well as presented in scientific bodies. Publication of books, popular articles and booklets were also undertaken under the project to popularize the technologies as well as to distribute among the trainees as reading material.

The detailed list of publications is presented below:-

1. Research articles

1. Mini C, Jose Mathew and Indira V. 2008. Changes in chemical and microbial quality of mixed cashew apple jams during storage. *J.Plantation crops* 36 (3): 496-499
2. Mini. C and Jose Mathew. 2007. Multi uses of cashew apple. *6th National Cashew Seminar on Indian Cashew in the next decade- challenges and opportunities*, 18th May 2007, Raipur, pp. 45-52.
3. Mini.C. 2007. Utilization of cashew apple and its byproducts. Souvenir and Extended Summaries, *National Seminar on Research, development and marketing of cashew*, 20-21 Nov.2007, ICAR Research Complex, Goa, pp. 92-98
4. Mini. C, Jose Mathew and Indira, V. 2007. Preparation of mixed cashew apple jam for increased acceptance and nutritional quality. *Souvenir and Extended Summaries, National Seminar on Research, development and marketing of cashew*, 20-21 Nov.2007, ICAR Research Complex for Goa, pp. 102-103
5. Mini C, Jose Mathew and S.Krishnan.2008. Refinement and commercialization of technology for the preparation of pickle from cashew apple. *Abstracts, Third Indian Horticulture congress*, 6-9 Nov 2008, Bhubaneswar, Orissa, pp.54.
6. Jose Mathew, Mini,C. and Sobhana, A.2008. Cashew apple: Economic utilization through value addition. Proc. *Third Indian Horticulture Congress on Recent Initiatives in Horticulture*, 6-9 Nov 2008, Bhubaneswar, Orissa, pp.612-623

2. Booklets

1. Mini C and Jose Mathew. 2008. Cashew apple products (In Malayalam), Cashew Research Station,

Madakkathara Kerala Agricultural University, Thrissur, Kerala, 12 p.
Mini C and Jose Mathew. 2008. Recipes for Cashew apple products (In English), Cashew Research Station, Madakkathara Kerala Agricultural University, Thrissur, Kerala, 12 p.

3. Books

1. Jose Mathew and Mini,C (Eds). 2007. Cashew apple and other fruits - processing and enterprises (In Malayalam). Cashew Research Station, Madakkathara, Kerala Agricultural University, Thrissur, Kerala, 115 p.
2. Jose Mathew., Mini.C. and Mareen Abraham (Eds). 2008. Cashew research and development in humid tropics with emphasis on cashew apple processing. Cashew Research Station, Kerala Agricultural University, Madakkathara, 160 p.

4. Popular articles in Malayalam

1	Mini C and Jose Mathew	2007	Cashew apple processing-products and business potentials	*Souvenir, KSCDC Ltd., pp.27-30*
2	Mini C	2008	New products from Madakkathara	*Mathrubhumi, Karshika-rangam*
3	Mini C and Jose Mathew	2008	New products from cashew apple	Karshakan 18(4) : 10-12

4. ESTABLISHMENT OF STATE LEVEL MODEL CASHEW APPLE PROCESSING UNIT AND PRODUCT REFINEMENT AND TESTING UNIT AT MADAKKATHARA

As envisaged under the project, a state level Model Cashew Apple Processing Unit has been established under the project. It is a fully fledged commercial unit undertaking production of cashew apple products employing the processing technologies developed by the centre. Now the unit is undertaking production of cashew apple syrup, cashew apple drink, cashew apple candy and "Cashewman" Mixed fruit jam. Production of more products, for which technologies has already been developed, are in the anvil. The participants undergoing various training programme at the centre are familiarized with the working of the unit, equipments used and infrastructural requirements. The licensing and marketing requirements of running a commercial processing unit are exposed to the trainees, taking Madakkathara unit as the model. The model unit serves to present a comprehensive idea to the trainees and visitors regarding the technical, marketing, economic, infrastructural and licensing requirements for running a commercial unit as well as the response to the cashew apple products. Several entrepreneurs intending to start cashew apple processing units are visiting the model unit and gets convincing idea about the technical and commercial aspects of starting a unit.

The Product Refinement and Testing Unit established under the project undertake refinement and development of products and testing of their quality. It is equipped with all facilities for product refinement, development and testing. The works undertaken at this unit has resulted in the refinement of several technologies for cashew apple processing including the removal of tannin from juice, ripe apple and green apple. Product refinement with regard to cashew apple syrup and cashew apple drink has also been undertaken at this unit. Technologies for the production of new products viz, cashew apple pickle, cashew apple mixed fruit jam and cashew apple candy has been developed at this centre and is commercially employed. The following products have also been developed at the centre, which are in the pipeline for commercial production, viz., Blended cashew apple pineapple squash, blended cashew apple pineapple RTS beverage, cashew apple chutney, and cashew apple toffee. Quality testing of the developed products is also undertaken in the unit. It includes the nutritional qualities of the newly developed products as well as their storage potential.

5. ESTABLISHMENT OF MODEL CASHEW APPLE PROCESSING DEMONSTRATION UNITS

Under the project, three model cashew apple processing demonstration units were established by Self Help Groups in major cashew growing tracts of the state. The units were given technical and financial assistance under the project for their establishment. The units serve as front line demonstration units to encourage cashew farmers and entrepreneurs to start new units. Technology dissemination and product popularization is also intended by the newly established demonstration units.

The selection of SHGs for extending financial and technical assistance was done in a systematic manner. Applications were invited by giving wide publicity in print and electronic media as well as by circulation through development departments like Department of Agriculture, Department of Rural Development and Kudumbasree Mission. Accordingly eleven applications were received in total, of which seven were shortlisted after the scrutiny of the applications. Among the shortlisted applications, one was from Kollam, three from Kannur, two from Thrissur and one from Palakkad.

After inspection of the facilities and locations and getting firsthand knowledge about the working of the applicants, the committee has decided to give financial and technical assistance to the following units under the SHM programme for the establishment of model cashew apple processing demonstration units.

1. Janapriya Purusha Swayam Sahaya sangham, Neendakara, Kollam
2. Malabar Organic Agricultural Society, Payyavoor, Kannur
3. Jaivamithra Farm Club, Kelakam, Kannur

It was ensured that the members of the selected SHGs had undergone training on cashew apple processing at Madakkathara. The following different processing equipments, needed for establishment of cashew processing unit at a cost of Rs. 1,54,746 to each unit were procured and supplied to the units:-Hydraulic press, Juicer, Mixer grinder, Gas stove, Pocket refractometer ($0 - 32^0$, $8-62^0$ & $58-92^0$), Autoclave (Vertical), Crown corking machine, Cap sealing machine, Refrigerator, Electronic balances (2 nos.), Pulper and Sealing machine.

An MOU specifying the terms and conditions to ensure the smooth functioning of the unit according to the technologies developed by KAU was signed between the Registrar, KAU and representatives of the selected units at a function held at Cashew Research Station, Madakkathara held on 25.9.08. It was attended the Registrar, Director of Extension and Director of Research. The handing over of the processing equipments, funded by the project, was also done in the same function.

6. ACHIEVEMENTS OF THE PROJECT IN NUT SHELL

Developed the technologies for the off season storage of cashew apple juice, pulp and pieces of green apple.

Refined the technologies for the clarification of juice and de- tanning of ripe and green cashew apples

Developed the technologies for the production of blended squashes, blended RTS beverages, cashew apple pickle and mixed fruit jam

Developed the technologies for the production f novel products such as fruit bar and chutney and confectionaries such as biscuits, toffee and halwa.

Proposed ten recommendations on cashew apple processing for incorporation in the Package of Practices recommendations (Crops) for state wide adoption.

Launched four commercial cashew apple products viz., Cashew Apple Drink, Cashew Apple Pickle, Cashew Apple Candy and *Cashewman* (Cashew Apple – Mango) Mixed Fruit Jam.

Established state level Model Cashew Apple Processing Unit at Madakkathara

Established Product Refinement and Testing Unit at Madakkathara

Established state level training centre for cashew apple processing at Madakkathara

Conducted 30 training programmes on cashew apple processing including off campus programmes of different duration including one day, three day and one week

Established three model cashew apple processing demonstration units under the project by extending technical and financial assistance to SHGs at Payyavoor (Kannur District), Kelakam (Kannur District) and Neendakara (Kollam District).

Four trainees started commercial production of different cashew apple products on their own.

Published six research papers, two booklets, two books and three popular articles on cashew apple processing for its popularization.

Put up stalls in major exhibitions for popularization of cashew apple processing technologies and cashew apple products.

RECIPES FOR CASHEW APPLE PRODUCTS

C. Mini and Jose Mathew
Cashew Research Station, Kerala Agricultural University
Madakkathara - 680651, Thrissur, Kerala

The Madakkathara centre has developed and fine tuned the technologies for the processing of cashew apple to various value added products. The recipes for the preparation of important products are given in this chapter.

1. Preparation of cashew apple syrup

Ingredients

Clarified cashew juice	:	1 litre
Sugar	:	2 kg
Citric acid	:	15 g
Lemon yellow colour	:	10 mg

Procedure

1. Add sugar @ 2.0 kg/litre into the clarified cashew juice and then heat moderately.
2. Continue heating with continuous stirring till the sugar completely dissolves
3. Add citric acid @ 15 g / litre (dissolved in little quality of syrup) and stir well.
4. Remove the solution from the stove, cool, strain and then add colour (dissolved in little quantity of syrup). Now syrup is ready.
5. To store the syrup for long periods without spoilage, pour it into well sterilised glass bottles/ new food grade pet bottles and cork air- tight (Don't fill completely, leave some air space).
6. Keep in a cool, dry place
7. Dilute the syrup with five times cool water to use as fresh drink

2. Preparation of Ready- To- Serve (RTS) beverage

Ingredients

Clarified cashew juice	:	150 g
Sugar	:	120 g
Water	:	730 g
Citric acid		5 g
Lemon yellow colour	:	1 pinch

Procedure

1. Take required quantity of sugar and citric acid in water and boil.
2. Towards the end, switch off the flame and add cashew apple juice immediately in hot condition itself by stirring.
3. Cool, add colour , strain, bottle it in sterilized glass bottles and seal air tight.
4. Pasteurize by keeping in boiled water for 20 minutes.
5. Packing can also be done in food grade plastic covers using semi automatic liquid packaging machine. But it cannot be pasteurized and hence can be kept only for 2-3 days, unless kept under refrigerated conditions.
6. Cashew apple can be blended with pineapple in 60 : 40 ratio to make blended RTS beverage for increased acceptability.

3. Preparation of cashew apple squash

Ingredients

Clarified cashew apple juice	:	1.0 litre
Water	:	1.4 litre
Sugar	:	1.6 kg
Citric acid	:	2.5 g (as per requirement)
Lemon yellow colour	:	1 pinch (1.25 mg)

Procedure

1. Take required quantity of sugar and citric acid in water and boil
2. Towards the end, switch off the flame and add clarified cashew apple juice immediately in hot condition itself
3. Remove from flame, cool, add colour, strain, bottle in sterilized glass bottles or new food grade pet bottles and seal it air tight

4. Keep in cool dry place
5. Dilute the squash with three times cool water to use as fresh drink

4. Preparation of cashew apple jam

Ingredients

De-tanned cashew apple pulp	:	1 kg
Sugar	:	1 kg
Citric acid	:	2.5 g (based on acidity of pulp)

Procedure

1. Add sugar and citric acid to pulp, keep for half an hour and cork with continuous stirring
2. Confirm end point by conducting sheet test (Dip a spoon into the boiling pulp and let the product run off the sides of the spoon. If on cooling, the product falls off in the form of a sheet instead of flowing readily in a single stream, it means that the end point is reached. Otherwise, continue boiling till the sheet test is satisfactory)
3. When the end point is reached, transfer hot jam into sterilized glass bottles
4. While bottling, bottle must be kept on an insulating material like thick cloth or a wooden board to prevent breakage
5. Close the bottles well. Jam can be stored for long periods without spoilage
6. De-tanned cashew apple pulp and mango pulp can be mixed in 50 : 50 ratio to make mixed cashew jam

5. Preparation of cashew apple pickle

Ingredients

Raw green apples (de- tanned)	:	1 kg
Chilly powder	:	50 g
Gingelly oil	:	100 ml
Fenugreek powder	:	20 g
Asafoetida	:	10 g
Turmeric powder	:	5 g
Garlic (made into thin, long pieces)	:	10 g
Mustard powder	:	15 g
Sodium benzoate	:	a pinch
Vinegar	:	100 ml
Salt to taste		

Procedure

1. Boil gingelly oil in steel vessels
2. Fry ginger, garlic and green chilli pastes in boiling gingelly oil, till they are brown.
3. Turmeric powder, fenugreek powder, chilly powder, asafoeitida powder and mustard powder are added to it and stir
4. When the colour of chilly powder changes, add sliced de-tanned raw green apple, citric acid (dissolved in hot water), sodium benzoate and vinegar and stir well
5. Add required quantity of water and salt (if necessary) by thorough stirring
6. Cover the vessel well and allow to cool.
7. Transfer into clean dry glass jar, pour half tea spoon gingelly oil over it and seal it
8. Use the product after keeping for one week.

6. Preparation of cashew apple chutney

Ingredients

De-tanned ripe cashew apple	:	1 kg
Sugar	:	750 g
Coriander powder	:	1 teaspoon
Cumin powder (Jeerakam)	:	1 teaspoon
Cinnamon powder	:	1 teaspoon
Clove powder	:	1 teaspoon
Cardamom powder	:	1 teaspoon
Pepper powder	:	1 teaspoon
Large onion	:	1 No.
Ginger	:	30 g
Vinegar	:	20 ml

Procedure

1. Remove black spots and parts of pedicel from de-tanned cashew apple by steel knife and slice them into small pieces
2. Make a sugar syrup by adding equal quantity of water and boil
3. Add sliced cashew apple, chopped onion, grated ginger and vinegar into sugar solution and stir well
4. Tie all powdered spices (coriander, cumin, cinnamon, clove, cardamom and pepper) in a cloth bag and drop it into the syrup just a little before the final stage of boiling and stir well
5. Boil the mixture until it is sufficiently thickened
6. Remove from the stove and allow to cool
7. Store in clean and dry sterilized jars

7. Preparation of cashew apple candy

Ingredients

De-tanned ripe cashew apple	:	1 kg
Sugar	:	1 kg
Citric acid	:	1 g
Potassium meta bisulphate	:	4 pinches

Preparation of cashew apple

1. De-tanned ripe cashew apples are kept it in a solution of potassium meta bisulphate (two pinches) for 2- 3 days
2. Thoroughly wash the apples in water
3. Remove black spots and parts of pedicel. Keep in perforated crate of stainless steel and steam for 10-20 minutes without overcooking at 0.35 kg pressure
4. Make deep holes in the apple using bamboo sticks or steel forks

Preparation of sugar syrup

Dissolve 250 g sugar in one litre of water and heat well. Dissolve citric acid and potassium meta bisulphate (2 pinches) in this solution

Preparation of candy

1. Drop the pre- prepared apples in to the boiling sugar syrup so that the apples are completely immersed.
2. Switch off the flame, cover the container with lid and keep it as such for one day
3. Take out the fruits on the 2nd day, add 125 g sugar, and drop the apple while heating
4. Repeat (1) for 5 days (i.e.1-1-5)
5. On 8th day, volume of sugar syrup will be reduced to one- third
6. Keep the apples as such for 8-10 days
7. Remove the apples from the syrup solution, drain for 30 minutes and dry it slowly in open area by spreading in a polythene sheet
8. Keep it in clean, dry screw capped glass jars in a cool, dry place.

8. Preparation of cashew apple frutty

Ingredients

De-tanned ripe cashew apple	-	1 kg
Sugar	-	1 kg
Citric acid	-	1 g
Potassium meta bisulphate	-	4 pinches

Procedure

1. Initial procedures are same as that of apple candy
2. Apples are removed from the syrup after immersing for seven days in sugar syrup
3. Drain off the syrup completely
4. The apples are cut in to small cubes and again immerse in the already available syrup for 2-3 days
5. Remove the cubes from the syrup and dry in shade.
6. It can be packed in 200 guage polythene covers and stored under ambient storage conditions for a period of 6 months
7. One kg cashew apple on processing roughly gives 715 g tutty fruity.

***