Lecture Notes Series 24

E-Manual on

Advances in
Cashew Production Technology

ಐ.ಸಿ.ಎ.ಆರ್. – ಗೇರು ಸಂಶೋಧನಾ ನಿರ್ದೇಶನಾಲಯ
भाकृअनुप - काजू अनुसंधान निदेशालय
ICAR - DIRECTORATE OF CASHEW RESEARCH
Darbe P.O., Puttur - 574 202, Dakshina Kannada, Karnataka

Advances in
CASHEW PRODUCTION TECHNOLOGY

21– 23 May 2015

Lecture Notes Series 24
(For circulation to participants of training programme)

ಐ.ಸಿ.ಎ.ಆರ್. – ಗೇರು ಸಂಶೋಧನಾ ನಿರ್ದೇಶನಾಲಯ
भाकृअनुप - काजू अनुसंधान निदेशालय
ICAR - DIRECTORATE OF CASHEW RESEARCH
Darbe P.O., Puttur - 574 202, Dakshina Kannada, Karnataka

May 2015 **Lecture Notes Series 24**

Published by

Prof. P.L. Saroj
Director
ICAR-Directorate of Cashew Research
Puttur - 574 202, Karnataka
Tel No : 08251-231530 (O), 230992(R)
EPABX : 08251-230902, 236490
Fax : 08251-234350
E-mail : director.dcr@icar.org.in
Website: http://www.cashew.res.in

Training Sponsored by

Sh. Venkatesh. N. Hubballi
Director
Directorate of Cashewnut & Cocoa Development,
Cochin - 682 011, Kerala
Tel No : 0484-2377151 (O), 0484-2293268(R)
Fax : 0484-2377239
E-mail : dccd@nic.in
Website: http://dccd.gov.in

Compilation and Editing

M.G. Nayak, Principal Scientist (Hort.)
Sajeev, M.V., Scientist (Agril. Extension)

Design & Layout

R. Muthuraju
Technical Officer

Lecture notes circulated to the participants of the National Training Programme on 'Advances in Cashew Production Technology'.

Prof. P.L. SAROJ
Director

ICAR - DIRECTORATE OF CASHEW RESEARCH
PUTTUR – 574 202, DK, KARNATAKA
Phone : 08251 – 231530, 9483509653, Fax : 08251 – 234350

FOREWORD

India is the first country to exploit cashew as a commercial crop though five centuries after its introduction to India by Portuguese. Directorate of Cashew Research is the nodal agency for cashew research in the country. The research on cashew was initiated in the early 1950s and initially, Indian Council of Agricultural Research (ICAR) sanctioned *Ad-hoc* schemes in research centres of Kerala, Karnataka, Andhra Pradesh, Assam and Maharastra. This was followed by sanctioning of All India Coordinated Spices and Cashew Improvement Project at CPCRI, Kasaragod and establishment of National Research Centre for Cashew at Puttur in 1986. This centre was further upgraded to Directorate of Cashew Research (DCR) in 2009.

Considering the growing demand for cashew at both global and national levels, it is imperative to increase production and productivity of raw cashewnut, besides enhancing production of cashew apple which can be utilized for preparation of value added products. Towards achieving this, it is essential to know the current status of research and development in cashew in the country. I am pleased that Directorate of Cashew Research, Puttur in collaboration with Directorate of Cashewnut & Cocoa Development, Kochi is organizing a National Level Training Programme on "Advances in Cashew Production Technology" with special emphasis on the latest concepts, methodologies, approaches and practices in the field of cashew research for the benefit of stakeholders.

I congratulate the editors and all scientists involved in bringing out this publication and I hope it will be immensely useful to researchers, policy makers and other stakeholders who are engaged in research and development of cashew in the country.

[**P.L. SAROJ**]

CONTENTS

Sl. No.	Topic	Resource person	Pages
1.	Cashew cultivation in India – Issues and Challenges	P.L. Saroj	1 - 9
2	Biodiversity, varietal wealth and molecular applications in cashew	A.R. Desai	10 - 27
3	Soil and water conservation in cashew	S. Jeeva	28 - 31
4	Propagation and nursery management in cashew	M.G. Nayak	32 - 40
5	Establishment and management of cashew orchards	J.D. Adiga	41 - 46
6	Organic farming in cashew	N. Yadukumar	47 - 57
7	Rejuvenation of senile cashew orchards	M.G. Nayak	58 - 65
8	Cashew based cropping systems	P.L. Saroj	66 - 72
9	Nutrient Management in cashew	T.R. Rupa	73 - 77
10	Irrigation and fertigation in cashew	N. Yadukumar	78 - 81
11	High density planting and canopy management in cashew	M.G. Nayak	82 - 87
12	Management of tea mosquito bug in cashew	P.S. Bhat	88 - 92
13	Management of cashew stem and root borer	T.N. Raviprasad	93 - 95
14	Transfer and impact of cashew production technologies	M.V. Sajeev	96 - 108
15	Cashew apple processing	P.B. Pushpalatha	109 - 116
16	Cashew nut processing	D. Balasubramanian	117 - 121

CASHEW CULTIVATION IN INDIA: ISSUES AND CHALLENGES

Prof. P.L. Saroj, ARS
Director
ICAR-Directorate of Cashew Research, Puttur
pl.saroj@icar.gov.in

Introduction

Though, cashew (*Anacardium occidentale* L.), is an exotic horticultural crop brought to India by Portuguese travellers in 16th Century but now adapted well in Indian conditions. It is grown along the coastal regions of Maharashtra, Goa, Karnataka and Kerala in the West Coast and Tamil Nadu, Andhra Pradesh, Odisha and West Bengal in the East Coast. It is spreading in non-traditional areas such as Bastar region of Chhattisgarh and Plain regions of Karnataka, Gujarat, Jharkhand and in NEH region. Due to its high nutritional value and increasing affordability by the consumers, demand for cashew continues to increase both in India and in foreign countries. During 2012-13, total production of cashew in the country was 7.28 lakh tonnes from 9.82 lakh ha of land with a productivity of 772 kg/ha (Fig. 1). Moreover, the productivity of cashew nut in India is very. There is a wide gap between potential productivity and present productivity. The major factors for low productivity are: the large plantations under seedling origin, poor orchard management practices and severe incidence of tea mosquito bug (TMB) and cashew stem and root borer (CSRB).

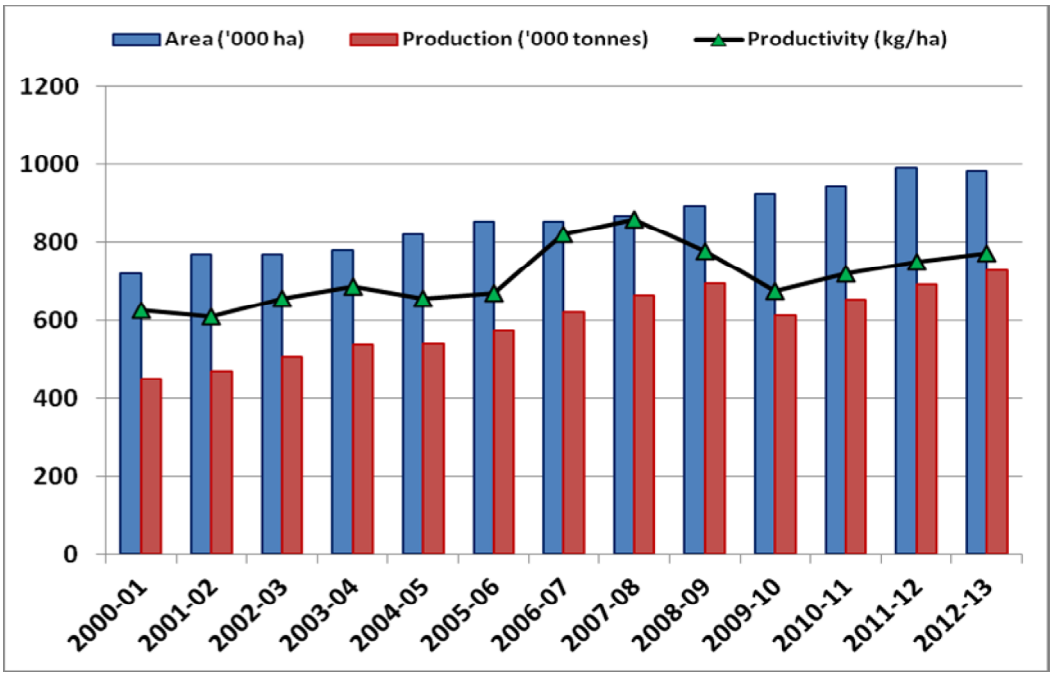

Fig. 1. Area, production and productivity of raw cashew nut (2000-01 to 2012-13)

Production system management

(i) Establishment of cashew orchard

Though, cashew is grown in almost all types of soils, it performs better in well drained, brown forest soils, red sandy loam and light coastal soil with a high water holding capacity and rich in organic matter. Cashew is a deep-rooted crop with its active roots concentrated in the first 1 m depth of the soil and 2 m radius around the trunk of the tree. Therefore, soil should be minimum 1.5 m deep without any hard pan which obstructs root growth. While selecting land for cashew, soils with salinity/ alkalinity or water logging should be avoided. The selected land should be cleared of shrubs/ vegetation before digging pits. The pits of 60 cm x 60 cm x 60 cm are to be opened at a spacing of 7.5m x 7.5m or 8m x 8m for cashew which gives a tree density of 175 and 156 trees/ha, respectively. High density planting at 4m x 4m giving a tree density of 625 trees/ha in the initial years and subsequently thinning in stages to reach a final spacing of 8m x 8m is also practiced in some areas. High density planting of cashew is more suitable in less fertile areas. The size of pits can be increased upto 1m x 1m x 1m in soils with hard pan or hard laterite substratum. Opening the pits along the contour line is preferred in slopy areas. The pits have to be filled with mixture of top soil, compost (10 kg) or poultry manure (2 kg) and rock phosphate (200 g). A small channel above the pit is opened to divert water to the sides during rainy season in slopy lands. The runoff water should not accumulate in the pit which causes water stagnation during rainy season.

Planting of grafted plants is usually carried out during the monsoon season (July-September). The polythene bag (containing graft) covering the root and soil is to be removed carefully and the graft with ball of earth intact is to be separated. The graft is to be placed gently in the centre of the pit where soil is scooped out and cover with soil and press gently. The graft is to be planted in such a way that the graft union is above the soil level. Sprouts if any below the graft union may be removed with the help of sharp knife. Plastic ribbon covering the union is removed if not done already. Mulching should be done at the base around the plant to conserve soil moisture and also to suppress weed growth. Frequent watering is required during post monsoon phase.

(ii) Selection of varieties

With the concerted efforts of DCR, Centres of AICRP-Cashew and SAUs, a total of 42 cashew varieties (29 selections and 13 hybrids) have been developed and released in the country for cultivation.The varieties released by DCR *viz*., NRCC Selection-2 and Bhaskara are medium nut types with high yield and recommended for cultivation in Karnataka. These varieties exhibited better yield performance in other cashew growing regions of the country as well. Twenty-one varieties have kernels with export grade (W 180 to W 240). The varieties recommended for adoption in different cashew growing states are given below:

State	Recommended varieties
Andhra Pradesh	BPP-4, BPP-6 and BPP-8
Goa	Goa-1, Goa-2, Vengurla-1, Vengurla-4, Vengurla-6 and Vengurla-7.
Karnataka	NRCC Sel-2, Bhaskara, Ullal-l, Ullal-3, Ullal-4, Vengurla-4, Vengurla-7, Madakkathara-2, Chintamani-1 and Chintamani-2.
Kerala	Madakkathara-I, Madakkathara-2, K-22-I, Kanaka, Dhana, Priyanka, Amrutha and VRI-3.
Maharashtra	Vengurla-l Vengurla-3, Vengurla-4, Vengurla-6, Vengurla-7 and Vengurla-8.
Odisha	Bhubaneswar-I, BPP-8 and Dhana.
Tamil Nadu	VRI-1, VRI-3 and VRI H-1
West Bengal	Jhargram-I, Bidhan Jhargram-2 and BPP-8
North Eastern States	Ullal-3, Ullal-4, Vengurla-1 and Vengurla-4

(iii) Production of Quality planting material

Being a cross pollinated crop, the seedlings raised orchards show variation with respect to yield, nut size, apple colour and several other characters. Hence, vegetative propagation is adopted in cashew as vegetatively propagated clonal progenies are genetically identical to the mother plant and give relatively more uniform yield and come to fruiting earlier. Of the different methods of vegetative propagation, softwood grafting was found to be the best for vegetative propagation of cashew. Production of planting material of high yielding varieties through softwood grafting technique has been a great success story in cashew and has made tremendous impact in improving cashew productivity. There are over 100 Regional Cashew Nurseries, which are coming under both public and private sector. Farmers are always advised to procure planting materials from accredited nurseries of recommended varieties and standard. Framers can himself produce planting materials after taking necessary training from the Directorate of Cashew research, Puttur.

(iv) Management of plant canopy architecture

Canopy management in cashew has direct impact on vigour of plants which eventually influencing yield and quality of nuts. Therefore, proper training should be done from the beginning in order to develop ideal frame work. Sprouts emerging from the rootstock are to be removed at regular intervals as and when seen. The graft should be allowed to grow by maintaining single stem up to 0.75 to 1 m height by removing sprouts or side shoots not only below the graft union (stock portion) but also above it. The flower panicles emerging later in the season need to be removed during the first two years of growth of the graft to facilitate proper vegetative growth and thereby achieving proper height and good canopy. The plants are to be allowed to flower and fruit from third year onwards. The well spaced branches (4-6) should be allowed in all directions. For better fruiting regular pruning is important based variety and vigour of plant.

(v) Rejuvenation of senile cashew orchards

In older cashew plantations, removal of dried or dead wood, criss-cross branches, water shoots etc. should be done at least once in 2-3 years. Redevelopment of canopy is possible by heading back of existing senile trees which have exhausted canopies and erratic growth resulting in reduced yield. Heading back if done at 1.0-1.5 m height of the trees new flushes will emerge from dormant buds on remaining trunk and develops into a vigorous new canopy. By and large old cashew plantations are of seedling origin and have become senile. Such trees can be rejuvenated by grafting with scion sticks of improved and high yielding varieties on new shoots arising on beheaded stumps. May-June is the right time for beheading and July-August is for grafting. However, preventative measures need to be taken to monitor each plant for the attack of cashew stem and root borer on the top worked trees.

(vi) High density planting

High density planting technique in cashew has provided higher yield and better economic returns per unit area in the initial years, but also helped more efficient use of inputs. Further, high density planting reduces the weed growth by early canopy coverage, reduces soil temperature thereby increasing the soil moisture content especially during peak summer season and provides mulching effect. In high density planting, closer spacing [6.5 m × 4 m (384 plant density/ha), 5 m × 5 m (400 plant density/ha) and 5 m × 4m (500 plant density /ha)] has given two times more yield than normal spacing. Cashew nut yield can be increased to four folds up to 6 years and 2.27 folds up to 12 years in high density planting system. High density planting system however needs suitable dwarf and / or compact cashew varieties so that overlapping of canopy is kept at minimum. High density planting with dwarf and compact canopy varieties shall be the best breeding strategy for increasing productivity of cashew per unit area. Limb pruning and diagonal thinning can also be evaluated for their effectiveness in high density planting systems.

(vii) Soil and water conservation techniques

Cashew is generally grown on degraded lands and experiences severe moisture stress from January to May, which adversely affects flowering and fruit set. In order to harvest the rainwater and to make it available to the cashew plant during critical period, *in situ* soil and water conservation techniques are very important. Studies conducted at DCR, Puttur have indicated that coconut husks buried in trenches of 1 m width 0.5 m depth and 3.5 m length per plant opened across the slope between two rows of cashew helps in better soil and water conservation. Generally three to four layers of coconut husks are buried one above the other. The first layer is laid with the convex surface of the husk touching the ground. After spreading a layer of soil on the husks, the second layer of husks is laid in the same position. The last layer should be covered with soil upto 10 cm thickness. About 100 coconut husks are needed to bury in a trench of 3.5 m length. The coconut husk buried will enhance moisture retention of soil and make the same available to the plants during flowering and fruiting, thereby reducing fruit drop. Soil moisture content was considerably higher in soil and water conservation plots as compared to control plots (without soil and water conservation measures). With proper soil and water conservation, the soil loss can be minimized;

the runoff water from post-monsoon and pre-monsoon rainfall can be harvested and made available to the plant during the critical period.

(viii) Nutrient management

In India, cashew is mainly grown on laterite, red and coastal sands. It is also grown on black soils in Tamil Nadu and Andhra Pradesh to a limited extent. Though it is grown in almost all types of soils, it performs better in well drained, brown forest soils, red sandy loam and light coastal soil with a high water holding capacity and rich in organic matter. A large portion of cashew growing soils is reported to be acidic. Some of the major constraints to cashew production on acid soils are: Low soil pH brings associated problems, including Al, and Mn toxicity, low base saturation percentage, low available P and high P fixation capacity, low concentrations of exchangeable Ca, Mg, and K, reduced Zn, Mo and B availability and low microbial activity (nitrification), sensitivity to erosion, low water holding capacity, low permeability to air, water, and roots, slow water infiltration rate *etc.*

The major nutrient requirement of cashew plant demands more liberal application of N followed by K, while P is needed in comparatively lesser quantity. Nitrogen and P are most important nutrients during the pre-bearing stage, but at the bearing stage, K together with N is also important. Studies conducted at DCR, Puttur indicated that application of 500 g N and 125 g each of P and K and 10 kg poultry manure per tree per year under normal density planting system (200 trees/ha) and 250 g N and 50 g each of P and K and 10 kg poultry manure per tree per year under high density planting system (625 trees/ha) is found superior in terms of higher nut yield for rainfed cashew. The recommended dose of fertilizers for cashew for major producing states is given in the Table 1. The recommended dose of fertilizers during first year after planting is 1/5th of the full dose, 2nd year after planting is 2/5th, 3rd year after planting is 3/5th, 4th year after planting is 4/5th and 5th year onwards is full dose. In order to enhance the efficiency, fertilizers should be applied in a circular trench of 10 cm depth at a distance of 0.5 m, 0.75 m and 1.5 m away from the centre of the trunk in the first, second and third year onwards, respectively and covered with soil. Foliar sprays of nutrients (urea 2 to 4%; DAP 1%; orthophosphoric acid; $ZnSO_4$ 4%; Cu 0.3 to 0.6%) at the emergence of the flush, panicle initiation and fruit set stages ensure better fruit set and also enhance nut yield in cashew.

Table 1. Recommended dose of Fertilizers to Cashew for different states

State	Nutrient dose for mature cashew plantations (5th year of planting) (g/tree/year)		
	N	P	K
Kerala	500 750	125 325	125 750
Karnataka	500 500	250 125	250 125
Tamil Nadu	500	200	300
Andhra Pradesh	500 1000	125 125	125 125
Maharashtra	1000	250	250
Odisha	500	250	250
West Bengal	1000	250	250

Water soluble fertilizers such as urea, DAP, and MOP were suggested for fertigation through drip once in a week from December to March. With fertigation, the quantity of nutrients (through fertilizers and organic manure) to be applied can be reduced to half the quantity of recommended nutrients. It has been reported that an increase of 100 per cent and 226 per cent in yield in treatment receiving half of recommended dose of NPK in inorganic form (Recommended dose: 500 g N, 125 g each of P_2O_5 and K_2O/tree/year) of nutrients through fertigation and balance half applied in organic form through castor cake as compared to the above dose applied through soil and irrigated separately and, absolute control (without manure and irrigation) respectively indicating better nutrient use efficiency.

Majority of the cashew growing farmers do not apply fertilizers / pesticides / fungicides due to which the productivity of cashew is moderate. Hence, there is very vast potential of bringing the areas like NEH region under organic farming to take advantage of great demand globally for organically produced cashew. Organic production of cashew offers immense potential. Cashew plantations produce huge cashew biomass which can be recycled for supply of nutrients. About 5.5 t of cashew leaf litter and cashew apple (Recyclable cashew biomass) available per ha can be converted into 3.5 t of compost or vermicompost which contributes 50 per cent of the total nutrient requirement of cashew. Growing green manure crops such as glyricidia, sesbania, sunhemp and cover crops between two rows of cashew resulted in considerable improvement in soil moisture content and soil quality. The dry matter production of green biomass was about 7.65, 5.75 2.25 and 1.63 t/ha/year from *glyricidia*, sesbania, sunhemp and cover crop, respectively. The nutrient addition to soil was about 186 kg N, 23.6 kg P and 126.2 kg K and 141 kg N, 17.9 kg P and 162.3 kg K /ha through *glyricidia* and sesbania, respectively.

(ix) Water management

Generally, Cashew is grown as a rainfed crop, but the yield can be doubled if irrigated. The largest area under cashew cultivation is along the steep hillocks of West Coast region of India where the mean annual rainfall ranges from 3000 to 3500 mm with 80% of its contribution during June to September. Due to the non-uniform distribution of rainfall, cashew experiences severe moisture stress from January to May which adversely affects its flowering and fruit set, resulting in immature nut drop and lower productivity of cashew gardens. During fruiting season of cashew (February to May), a mean rainfall of around 67 to 415 mm is received. The water deficit is highest during March to May (112 to 183 mm). Cashew yields can be enhanced by providing protective irrigation with 200 L of water per tree once in 15 days from January to March during the summer season. Irrigation can be started after the commencement of flowering for better nut set, filling and yield. It has been reported that fertigation saved 50% in the fertilizer requirement and doubled the cashew yield.

(x) Cashew based cropping systems

During the initial age (upto first 3-5 yrs), several intercrops can be taken up between two rows of cashew plants to get more returns as well as utilize the solar energy and soil resources efficiently. Pineapple can be grown as a intercrop between two rows of cashew for the first seven years. The spacing to be maintained for cashew is 8m x 8m

(156 trees/ha) or 7.5 m x 7.5 m (175 trees/ha) or 10 m x 5 m (200 trees/ha). Growing pineapple in trenches across the slope between two rows of cashew helped to conserve the soil moisture, which in turn increased the yield of cashew (main crop) by 1.5 times compared to cashew alone. Pineapple can be grown as a profitable intercrop under irrigated as well as rainfed conditions in west coast region. Other suitable intercrops are tapioca, turmeric, ginger, cucurbits, colocasia and elephant foot yam.

(xi) Pest management

A large number of insect and pests have been reported in cashew but tea mosquito bug and cashew stem and root borer are the major pests of cashew. The tea mosquito bug (TMB), *Helopeltis antonii* Sign. (Heteroptera : Miridae) is the most serious foliage and fruit pest of cashew in India. Integrated pest management involving resistance and adopting spraying of insecticide is a good package to manage TMB. Mid season variety like Bhaskara is able to escape from the severity of the pest to certain extent. As the TMB incidence coincides with critical period of flushing, flowering and fruit set, need based spray as given below has been recommended.

Flushing	-	Lambda cyhalothrin (0.003%)
Flowering	-	Carbaryl (0.1%) or lambda cyhalothrin (0.003%)
Fruiting	-	Carbaryl (0.1%)

Cashew Stem and Root Borer (*Plocaederus ferrugineus* L.) (Coleoptera: Cerambycidae) is another important pest infesting cashew in all parts of India. Integrated pest management involving phytosanitation measures is found very effective in managing CSRB. The trunk portion is to be examined at least once during fruiting season (February - May) for initial symptoms of cashew stem and root borer infestation and grubs should be removed by carefully chiseling out the bark taking care not to damage more than half of bark circumference. Swabbing the pest infested portion after removal of different stages of pest occurring internally and drenching the root zone with chlorophyriphos (0.2%) as post extraction prophylaxis (PEP). Dead trees and those beyond recovery should be uprooted and removed before and after monsoon as they serve as natural inoculum repositories for further spread of this pest. The newly planted grafts should be trained to have branching at a height of 0.75 to 1.00 m from ground level for better inspection and management operations.

(xii) Harvesting of nuts and apples

Bearing commences after the third year of planting and the trees will be in full production by the tenth year whilst the economic life of a tree is about 20 years. The main harvesting season is from February to May. Most farmers harvest their crop before they drop to prevent pilferage. This very often results in poor quality of the kernels. The optimum stage of harvest is when nuts drop to the ground. High quality nuts are obtained when freshly fallen nuts are separated from the cashew apples and sun dried for 2-3 days to bring down the moisture percentage from about 25 per cent to below 9 per cent. It is very essential to dry the nuts in order to prevent spoilage during storage. The drying process helps to retain flavor and quality of the kernels. When cashew apples are used for processing, harvesting has to be carried out before they drop. A simple test of maturity is to float nuts in water when mature nuts will sink

while the immature and unfilled nuts will float. Nuts are usually gathered every week during the harvest season. Ripe cashew apples for the fresh fruit should be harvested daily before they drop of on ground.

MAJOR ISSUES AND CHALLENGES

Researchable issues

Genetic Resource Management:

i) Narrow genetic base.
ii) Introduction of germplasm with desired traits.
iii) Cryo-preservation of germplasm.

Crop Improvement:

i) Development of dwarf genotypes with high yield potential suitable for high density planting.
ii) Varieties for cold tolerance, variable CNSL content, cashew apple, early maturing varieties. for NEH region and nutrient efficient varieties with synchronized flowering and fruiting.
iii) Development of SSR markers.
iv) Linkage mapping to identify markers linked to economic traits.
v) Introgression of genes from wild species.

Crop Management:

i) GIS based delineation of cashew area.
ii) Variety and location specific management.
iii) Development of nutrient diagnostic norms.
iv) Input use efficiency.
v) Foliar feeding and use of growth regulators.
vi) Management of canopy architecture.
vii) Identification of rootstock.
viii) Cashew based cropping systems.
ix) Better understanding of crop phenology.
x) Farm mechanization.

Crop Protection:

i) Development of pheromone and kairomone traps.
ii) Utilization of entomopathogenic nematode (EPN) for management of cashew stem and root borers (CSRB) and fungal pathogens for tea mosquito bug (TMB).
iii) Development of pest forecasting models.
iv) Evaluation of new and safer molecules for management of pests.
v) Economic threshold level for foliage pests.
vi) Monitoring pests and disease dynamics in the scenario of climate change.

Post – Harvest Technology:

i) Efficient mechanization of cashew processing.
ii) Development of standards for raw cashewnuts.
iii) By-product utilization.
iv) Product diversification.
v) Non-thermal processing of cashew (cold).

Transfer of Technology and HRD:

i) Constraint analysis in technology adoption.
ii) ICT based TOT.
iii) Crop advisory system.
iv) Human Resource Development.

Policy Issues:

i) Poor coordination between research and development agencies.
ii) Reliable data base.
iii) Crop insurance.
iv) Minimum support price.

CHALLENGES

Genetic Resources:

i) *In vitro* clonal regeneration.

Crop Improvement:

i) Development of varieties resistant to CSRB and TMB.
ii) Breaking the yield barrier.

Crop Management:

i) Enhancement of cashew productivity.
ii) Expansion of area under moderate cold climate.
iii) Organic production of cashew.
iv) Sustained supply of raw cashew nuts to industries.

Crop Protection:

i) Eco-friendly and cost effective management of CSRB and TMB.
ii) Early detection of CSRB infestation.

Post-Harvest Technology:

i) Automation of cashew processing.
ii) Commercialization of cashew apple based value products.

BIODIVERSITY, VARIETAL WEALTH AND MOLECULAR APPLICATIONS IN CASHEW

AR Desai and NP Singh
Sr. Scientist (Hort) & Director
ICAR-Central Coastal Agricultural Research Institute
desaiavars@gmail.com

Introduction

Biodiversity is the universal phenomenon and is essential for existence of life on earth. This forms the fundamental link between the need for conservation and utilization of genetic resources, and sustainable production programmes or strategies. Increasing awareness about the importance of crop diversity and its conservation world wide for posterity has led to formulate the strategy for global food security. In this context, Cashew is being viewed as one of the most potential tropical nut tree that caters to the needs of the nutritional security as well as economic security in the global scenario in general and for the cashew growing countries in particular considering all the global stakeholders involved in the global cashew platform. Therefore, cashew genetic resources assume greater significance especially in the current context when there increasing demand for cashew nuts at national and international level. The cashew tree occupies an important position among the tropical nut and fruit bearingtrees on account of the growing commercialization of its main economic products: the nut, the cashew 'apple' and cashew nut shell liquid (CNSL). This crop with its inherent potential features to support the man's needs for the long future. Cashew has abundant diversity of unique kind which deserves to be conserved diligently. After realizing its economic potential and nutritional importance, all cashew growing countries have initiated several research programmes on cashew including the studies on diversity and its utilization cashew crop improvement for evolving new varieties or genotypes with due focus on climate change factor. Several new varieties have been already developed and yet the crop improvement is continued to address the new challenges of biotic and abiotic nature. Novel approaches like molecular breeding strategies are being integrated in identifying, selecting and enhancing and exploring the genetic potential of this crop. Some aspects in this direction are summarized here under just to recapitulate the status of the crop improvement in cashew utilizing its genetic resources.

Diversity in cashew

The greatest diversity is reported to exist in the Various coastal ecosystems comprising of beach and dune vegetation and the restinga in northeastern Brazil. However, with spread of this nut to the Asian and African continents and the subsequent realization of economic value of cashew kernels in the new world, commercial plantations were taken up, though primitive in nature, in the early part of 20th century. As usual, seed nuts selected from better yielding trees led to the establishment of Easter year's commercial plantations of seedling progeny. Due to high heterozygosity coupled with allogamous nature of cashew species, the above, preliminary plantations had segregated seedling progeny with enormous variability with respect to yield, nut size and quality , apple size and quality, growth habit, etc. As a result, there existed some natural recombinants having some desired high yielding traits in them which were picked up or identified as plus trees. Thus, development of high yielding

varieties initially started with identification of superior genotypes from among the existing seedling population. Initially selection of high yielding elite trees among the seedling progeny was irrespective of nut quality. The elite selections having high yielding traits were released as varieties, vegetatively propagated (by layering, budding or grafting) and supplied for commercial planting.

Cashew Germplasm

The main goals of the cashew germplasm bank is to document and conserve plant material, which can then be used to enrich the available genetic variation in the species, serve as a basis for agronomic and morphological characterizations of accessions, and support breeding programs.

Castro (2011) reports that the cashew germplasm bank located in Pacajus, Ceará State, Brazil, holds 621 accessions, most of which belong to *Anacardium occidentale*. The accessions are characterized with morphological, agronomic and molecular descriptors. The genetic variability contained in the collection has allowed development of early dwarf cashew clones, recommended for commercial planting in northeastern Brazil. The genetic basis of early dwarf cashew has been expanded by natural and artificial hybridization with regular cashew genotypes from the germplasm bank, to increase the weight and size of nut and kernel. Interspecific hybrids of *A. occidentale* × *A. othonianum* and *A. occidentale* × *A. microcarpum* have been produced in order to transfer anthracnose resistance alleles and desired quality traits to table cashew.

Recapitulated objectives for crop improvement in cashew

The breeding objectives broadly aimed at developing new high yielding commercial varieties with such characters as desired tree size (dwarf / semi dwarf canopy/ vigorous), bold nut size (>8g) with higher shelling percentage(>28%) and higher kernel grade (180-210W), bigger and juicy apple, resistance / tolerance to biotic (Cashew stem and root borer and Tea mosquito bug; Powdery mildew disease.) and abiotic stress (moisture stress and climate changes), besides considering the specific problems or needs (Bhaskara Rao, 1998., Bhaskara Rao *et al*., 1998 and Harries, *et al*., 1998).

Global crop improvement efforts in major cashew countries were reoriented keeping in view the global requirement and the constraints being faced by the respective countries, the results and achievements of which are summarized here under.

Crop improvement in India

Initially selection of high yielding elite trees among the seedling progeny was irrespective of nut quality. Redefined objectives of crop improvement in cashew to include nut quality, tree size, coupled with reaction to biotic and abiotic stress, besides higher yields, aptly hinted the importance of germplasm, variability and its eventual utility in synthesizing new varieties. (Gunjate and Deshpande, 1994; Bhaskara Rao, 1998). As genetic resources of cashew are considered as an important asset for the future, further studies on genetic divergence were undertaken in cashew (Lenka *et. al*., 1999; Sankaranarayanan and Ahmad Shah,1999; Rao *et al*., 2002). Classification of cashew germplasm accessions based on the morphological

characteristics of trees was attempted to understand the strength of genetic base of this local germplasm of Goa (Desai *et al.*, 2000).

Cashew genetic resources are conserved in field gene banks established at different centres in India. At National Cashew Field Gene Bank (NCFGB), Directorate of Cashew Research, Puttur, Karnataka, 527 cashew germplasm collections are being conserved (DCR, 2013-14), while a total of 1307 germplasm collections are being maintained at different Regional Cashew Field Gene Banks (RCFGBs) with 132 accessions at Bapatla, 100 at Bhubaneshwar, 120 at Jhargram, 208 at Vridhachalam on East Coast; 132 at Madakkathara, 43 at Pilicode, 302 at Vengurla, 75 at ICAR Goa on West Coast and 128 at Chintamani, 67 at Jagadalpur in Maidan (Plain) tracts (AICRP, 2013-14). The germplasm collections maintained at ICAR Complex for Goa include 38 bold nut types, 12 medium nut and high yielders, 20 high yielders with cluster bearing and 3 dwarf canopy types.

There are 49 cashew varieties developed in India, comprising of 30 developed through direct selection and evaluation of plus trees and 19 varieties developed through hybridization and selection, at various cashew research stations. Specialty genotypes such as dwarf types viz. TBP-1 and GB-2; Mridula (PTR-1), KGN-1 have also been identified from the among the genetic resources, which are useful in future breeding programmes.

Table 1. Characteristic features of cashew varieties developed through direct selection selections

Sl. No	Variety	Pedigree	Institute		Year	Nut yield (kg/tree)	Nut wt. (g)	Kernel wt(g)	Shelling (%)	Export grade	Apple wt. (g)	Apple colour	Juice %	Juice TSS (B^{o})	Season
1	ANK-1	T.No. 139 Bapatla	C.R.S, Anakkayam, KAU		1982	12.0	5.95	1.67	27.99	W280		Pinkis yellow	71		Early
2	MDK-1	T.No. 39 Bapatla	C.R.S, Madakkathara, KAU		1990	13.8	6.2	1.64	26.8	W280		Yellow	72		Early
3	Sulabha	K 10-2 Seln	,, ,,		1996	21.9	9.8	2.88	29.4	W210		Pinkish yellow	70		Mid season
4	MDK-2	NDR-2-1, Neduvellur	,, ,,		1990	17.0	7.25	1.88	26.00	W210		Red	68		Late
5	K 22-1	Kottarakkar 22	,, ,,		1987	13.2	6.20	1.60	26.50	W280		Red	67.5		Mid season
6	Vengurla-1	Ansur-1	RFRS, Vengural, Dr.BSKKV, Dapoli		1974	19.0	6.20	1.39	31.00	W240		Yellow	65		Early
7	Vengurla-2	WBDC-VI (V.37/3)	,, ,,		1979	24.0	4.30	1.00	32.00	W320		Red	45		Early
8	BPP-3	3/3 Simhachalam	CRS, DR YRS APHU, Bapatla		1980	11.0	4.80	1.34	28.10	W400		Yellow	67		Late
9	BPP-4	9/8 Epurpalam	,, ,,		1980	10.5	6.00	1.15	23.00	W400		Yellow	64		Late
10	BPP-5	T.No.1	,, ,,		1980	11.0	5.20	1.25	24.00	W400		Yellow	64		Early
11	BPP-6	T.No.56	,, ,,		1980	10.5	5.2	1.44	24.00	W400		Yellow	74		Early-mid season
12	VRI-1 (M10/4)	Vazhisodanipalyam local	RRS, Vridhchalam, TNAU		1981	7.20	5.00	1.40	28.00	W320		Yellow	74		Mid-late
13	VRI-2 (M 44/3)	T1668 Kattrapalli	,, ,,		1985	7.4	5.10	1.45	28.30	W320		Yellow	82		Mid-late
14	VRI-3 (M26/2)	EDayanchavadi	,, ,,		1991	11.68	7.18	2.16	29.10	W210		Red	72		Mid-late
15	Ulla-1	Taliparamba			1984	16.0	6.70	2.05	30.70	W210		Yellow	64.2		Mid-late
16	Ullal-2	36/67 Gumtur	,, ,,		1984	9.00	6.00	1.83	30.50	W320		Red	64		Mid season
17	Ullal-3	5/37 Manchery	,, ,,		1993	14.70	7.00	2.10	30.00	W210		Dark Red	66		Mid season
18	Ullal-4	2/27 Tuni-AP	,, ,,		1994	9.50	7.20	2.15	31.00	W210		Yellow	65.4		Early-Mid season
19	Chintamani-1	8/46 Taliparamba	,, ,,		1993	7.20	6.90	2.10	31.00	W210		Yellowish red	65.4		Mid-late
20	UN-50	2/27 Nileshwar	,, ,,		1995	10.50	9.00	2.24	32.80	W180		Yellow	65.2		Mid-late
21	NRCC-1	3/28 Simhachalam			1989	10.00	7.60	2.10	28.80	W210		Yellow			Late

22	NRCC-2	2/9 Dicherla	,, ,,		1989	9.00	9.20	2.15	28.60	W210		Pink			Mid season
23	Bhaskara	Goa 11/6	,, ,,		2006	10.7	7.38	2.20	30.60	W240					Mid season
24	Jhargram-1	T 16 Bapatla	BCKV, Kalyani		1989	8.50	5.00	1.50	30.00	W320		Yellow	63.5		Late
25	Bidhan Jhargram-2	H-2/15	,, ,,		2013	8.0	9.2	2.85	32.0	W180		Yellow			
26	Bhubaneshwar-1	WBDC-5 (V36/3)	OUAT, Bhubaneshwar		1989	10.00	4.60	1.47	302.00	W320		Reddish yellow			Late
27	Jangannatha	BH-6	,,			10.5	8.6			32.5					Mid
28	Balabhadra	BH-85	,,			10.0	7.4			30.0					Early
29	Goa-1	Balli-2 Accession	ICAR Complex, Goa		1999	10.00	7.60	2.20	30.00	W210	70.0	Yellow	68	11.2	Mid season
30	Goa Cashew -2	Tiswadi-3	,,		2007	7.5	9.8	2.6	29.6	W180	110	Yellowish orange	69.5	108	Early

Table 2 . Characteristic features of cashew varieties developed through hybridization.

Sl. No	Variety	Pedigree	Institute		Year	Nut yield (kg/tree)	Nut wt. (g)	Kernel wt(g)	Shelling (%)	Export grade	Apple wt. (g)	Apple colour	Juice %	Juice TSS (B^o)	Season
1	Dharasree (H 3-17)	T-30 x Brazil 18	CRS, KAU.		1996	15.02	7.80	2.40	30.50	W240		Yellowish pink	67		Mid season
2	Anagha (H 8-1)	T-20 x K-30-1	,, ,,		1998	13.73	10.00	2.90	29.00	W180		Orange red	66		Mid season
3	Priyanka (H 1591)	BLA 139-1 x K-30-1	,, ,,		1995	17.03	10.80	2.87	26.57	W180		Yellowish red	67		Mid season
4	Vengurla-3	Ansur-1 x Vettore 56	RFRS, Vengurla,		1981	14.40	9.10	2.09	27.00	W210		Yellow	77		Mid season
5	Vengurla-4	Midnapur red x Vettore 56	,, ,,		1981	17.20	7.70	1.91	31.00	W210		Red	76		Early
6	Vengurla-5	Anasur early x Mysore Kotekar1/61	,, ,,		1984	16.60	4.50	1.00	30.00	W400		Yellow	86		Mid season
7	Vengurla-6	Vettore 56 x Anasur-1	,, ,,		1991	13.80	8.00	1.91	28.00	W210		Yellow	85		Mid season
8	Vengurla-7	Vengural-3 x VRI-1	,, ,,		1997	18.50	10.00	2.90	30.50	W180		Yellow	86		Mid season
9	Vengurla-8	Vengurla-4 x (VRI-1)	,, ,,		2001	15.75	11.50	2.80	28.0	W180		Red			Mid season
10	BPP-1	T 1 x T 273	CRS, Bapatla,		1980	10.00	5.00	1.75	27.50	W400		Yellow	68		Late
11	BPP-2	T 1 x T 273	,, ,,		1980	11.00	4.00	1.04	25.70	W450		Yellow	67		Late
12	BPP-8	T 1 x T 39	,, ,,		1993	14.50	8.200	1.89	29.00	W210		Yellow	64		Early
13	Kanaka (H 1598)	BLA 139-1 x H 3-13	,, ,,		1993	12.80	6.80	2.08	30.58	W280		Yellow	70		Mid season
14	Dhana (H 1608)	ALGD-1 x K 30-1	,, ,,		1993	10.66	8.20	2.44	29.80	W210		Yellow	72		Mid season
15	Amrutha (H1597)	BLA 139-1 x H 3-13	,, ,,		1998	18.35	7.18	2.24	31.58	W210		Yellow	72.2		Mid season
16	Akshaya (H 7-6)	H-4-7 x K 30-1	,, ,,		1998	11.78	11.00	3.12	28.36	W180		Yellow	68		Mid season
17	Raghava (H 1610)	ALGD-1 x K 30-1	,, ,,		2002	14.65	9.20	2.27	26.60	W210		Yellow	68		Mid season
18	Damodara (H-1600)	BLA 139-1 x H 3-13	,, ,,		2002	13.65	8.20	2.00	27.27	W240		Red	68		Mid season
19	Poornima	BLA 139-1 x K30-1	,, ,,		2006	14.08	7.80	2.60	31.00	W210			75.3	13.3	Mid season

Comparative analysis of varieties developed in different countries reveals that research programmes are taken up with divers objectives, considering the local constraints and needs, however, with common major emphasis on nut yield and quality. Comparative information present in Table 3. It is observed that, varieties with extremely high yielding ability are developed elsewhere in different countries, particularly in Tanzania.

Table 3. Comparison of varieties of major cashew growing countries

	India	Brazil	Tanzania	Vietnam
Nut yield (Kg/tree)	Var:7.2(Vri-1) - 24(Veng-2) Hyb:10(BPP1 – 18.5 (Veng-7)	Normal : 1 -180 Hyb. 25 (Emb.50)	Var: 50- 92 (18 yrs)* Hyb:115-140 (18yrs)	7.4-10.2 (at 3 yrs age)
Nut size (g)	Var.:4.3 (Veng3) - 9.0 (UN-50) Hyb:4.5(Veng-5) - 11.5(V-8)	4.8 – 12.2	6.1 (Ac 6) - 10 (AC4)	6.21 – 7.14
No. nuts/kg	Var: 230 – 110 Hyb: 220 - 90	220 - 85	100 - 164	161 - 140
Kernel out turn (%)	Var:26.0(Mdk-2 – 32.8(UN-50) Hyb:25.7(BPP-2)-31.8(Amruta)	26-32	27 - 33	28.8 – 31.4
Resistance / tolerance to disease / insect	Few Mod. Tolerant to TMB Susceptible for CSRB No screening for diseases	Resistant to Gumosis Anthracnose	Tol. to PM, Anhrac, Die back Res. to	Need protection from TMB & Anthracnose

Crop improvement results at Goa Centre.

Besides Goa-1 (Balli-2) cashew variety developed through selection and clonal evaluation, a long-term evaluation trial of local bold nut accessions resulted in the selection of three more promising genotypes namely, Tiswadi-3, Ganje-2 and KN 2/98. Tiswadi-3 is already approved for releasing under the name Goa-2. It is a jumbo nut (9.2-10.6g) selection with bigger apple (101-110g) and higher juice contents. This selection is early and yields about 10kg of nuts per tree

Table-4. Characteristic features of Tiswadi-3 (Goa-2)

	Growth and flowering	
1.	Tree Height (at 10th year)	5.8 m
2	No. fl. laterals/ M^2 canopy	18.86
3	Sex ratio (male to female)	11.54 : 1
4	Season of flowering	Dec – Mid February
5	Duration of flowering	70 – 80 days
6	Season of Harvest Nut yield	Mid Feb. – April 10.02 kg/tree
	Nut Characteristics	
7	Nut Weight.	9.2 - 10.6 g
8	Number of Nuts / kg	105 – 110
9	Shelling Percentage	29.25 to 29.55 %
10	Average Kernel weight	2.26 - 2.52 g
11	Whole Kernel Counts per lb	W 180 – W 210
	Apple Characteristics	
12	Apple Colour	Yellowish orange
13	Apple Shape	Cylindrical
14	Weight of apple	100.5 – 110 g
15	Juice Contents	68.2 – 72.0 %
16	TSS contents	10.8 – 12.2 ^{O} B

Figure 4. Apple, nut and kernels of Tis-3 selection

Promising New Selections:

Ganje-2 (GCC 94/2) and KN-2/98 (G-CS-7-7) are the other two promising selections from the local germplasm, which are in the pipeline for releasing for commercial cultivation in the state of Goa (Desai et al., 2010). Both are selected for their bunch bearing habit with higher nut yield of 12-14kg/tree. Ganj-2 has the vigorous tree growth with spreading growth habit. Nuts are bold (7.8-8.2g) and recorded a higher kernel recovery of 29.8 %. Round yellow apples are big (85-92.5g) with higher juice contents of 75-78 %. Trees flower during December –January with 70-80 days of flowering duration. The flowering intensity is very high (80.23 %).

Figure 5. Fruit bunch, apples and nuts of Selection Ganje-2

On the other hand, KN-2/98 has the semi-vigorous growth habit with upright and compact canopy. It is a mid season variety with flowering intensity of 80.23%. This selection bears bold nuts (8.0-8.3g) in bunch. Nuts yield kernel recovery of 29.59 % having kernel grades of W210-W240 counts. Pyriform apples are red and big (120g) with higher apple to nut ratio of 15.

Figure 6. Apple, nut and kernels of Selection KN-2/98

Brazil

The variability in Brazilian cashew is mainly viewed into two major types, the common type with a vigourous growth habit with tree height of 8-15 m, canopy diameter reaching 20 m and with a vast yield range of 1-180 kg/tree of raw nut; the dwarf type is characterized by precocious nature (flowering between 6 - 18 months after planting) short stature of tree with tree height up to 4 m, having a homogeneous canopy, with stem diameter and canopy diameter smaller than the common type. Diallel analysis to evaluate inter-populational cashew hybrids was studied by Cavalcanti, et al. (2000), The dwarf group of clones (CCP06, CCP76, CCP09, and CCP1001) and common cashew genotypes (CP07, CP12, CP77, CP96 and BTON) were used in the study. It was observed that parent effects and heterosis were components of the means of the population for important traits studied. Hybrid combinations CCP76 x CP07, CCP09 x BTON, and CCP09 x CP77 were considered as the most promising, enabling establishment of base populations for breeding programmes of cashew. This intergroup population may also useful in molecular analysis and molecular breeding.

Genetic parameters were estimated using in an interpopulation hybrids of cashew using REML/BLUP methods for vegetative, yield and nut quality traits. The study indicated that plant height, canopy diameter, kernel weight and nut weight were under strong additive genetic control thereby not expressing heterosis. The heritability of nut number and yield were higher in the broad than in the narrow sense. This indicated dominance and heterosis of these traits could be adequately exploited in cashew breeding programs. Therefore, the best-suited breeding strategy to exploit heterosis is reciprocal recurrent selection using individual crosses between parents with high mean genotypic performance and high specific combining ability. (Cavalcanti, et al.,2007).

Cashew dwarf clones, in Brazil, like CPC 06, CPC 09, CPC 76 and CPC 1001 are the phenotypic selections from natural populations of the Brazilian Northeast coastal region. Use of these in different breeding procedures such as the poly-cross method, selection between and within progenies and inter and intra-specific hybridization, resulted in the development of dwarf cashew clones Embrapa 50, Embrapa 51, BRS 189, BRS 226 and 265. Further, Embrapa Tropical Agro industry launched two new clones: BRS 274, the first clone of common cashew for commercial planting, and BRS 275, the first hybrid cashew clone, obtained from a cross between common cashew and dwarf cashew clone (CPC 1001). BRS 274 was obtained through phenotypic selection of a mother plant of common (giant) cashew in a segregating population, followed by cloning. On the other hand, BRS 275 was obtained through phenotypic individual selection within a controlled pollination progeny from a cross between a dwarf early cashew clone CCP1001 and a common (giant) clone CP 12 (Oliveira, 2008).

East and West African countries

The commercial cultivation actually started in 1950s at Iwo in Nigeria. Attempts by Cocoa Research Institute of Nigeria (CRIN) on Cashew Germplasm collections in Nigeria were initiated from 1972 based on the biotypes / land races originated from the initial introductions by Portuguese during 16th century (Sanwo, et al, 1972, Sanwo, 1973 and Hammed, *et al*.,2008). CRIN ha its field gene banks located at Ibadan (Western Nigeria), Uhonmora (Mid-Eastern Nigeria) and Ochaja (North Central Nigeria) whose collection was later found to be of narrow genetic base (Aliyu, and Awopetu, , 2007a and Aliyu, and

Awopetu, 2007b) and efforts were initiated to introduce the genetic material during 1978-1980 from India, Tanzania, and Mozambique which formed the second collection of germplasm in Nigeria. From this, twenty five half sib genotypes with high yielding potential (>1000 kg/ha) were released as G-series improved varieties by CRIN (Akinwale and Esan, 1989) . The third set of germplasm comprised of the material with characteristic bold nuts and high grade kernels, introduced directly from Brazil (by a private Company)during latter part of 1980.

Nigerian cashew plantations are comprised of six biotypes viz. Jumbo (16g), Extra large (12-15g), large (8-11g), medium (6-7g), small (2-5g) and madras (2g) with nut yield of jumbo nut types in the range of 8-10kg/tree, while the nut yield from equally matured tree of Medium and madras types in the range of 30 kg/tree to 250 kg/tree. Considering the low pricing in the international market for Medium nut size yielding kernels of W320-W280 grades, these types need to be replaced with high priced Brazilian cashew biotypes (W180-W210). About 59 accessions (11 from old land races, 23 from Indian source and 25 from Brazilian introductions are being extensively studied and used in recurrent breeding programmes in Nigeria to improve low nut yield of jumbo nut types (Hammed, *et al*.,2008). CRIN has developed an improved variety of cashew called “Brazilian Jumbo”, which has precocious bearing compared to the local varieties which mature after 5 years, besides, the higher in quality of CNSL oil.

Tanzania cashew breeding programme

The abandoned cashew farms were the inoculums source for insect pests and diseases, which resulted into an outbreak of cashew powdery mildew disease (PMD) and sucking pests (Topper *et al.* 1998)in Tanzania. The PMD is currently the main constrain in cashew production. Cashew Production Improvement Pilot Project (CPIPP) and later Cashew Improvement Programme (CIP) steadily recovered production levels from 1990s onwards. The Cashew Research Program (CRP) receives its funds from Cashew Levy (1% FOB) through Cashew Board of Tanzania/Cashew Industry Development Trust Fund, the Government of Tanzania and as well as from other sources. Under this programme, studies on genetic divergence were undertaken in cashew in Tanzania. Screening of cashew clones for reaction to *Helopeltis* was undertaken as a part of crop improvement (Millanzi,1998) Cashew breeding department at Naliendele Agricultural Research Institute in Mtwara, Tanzania has come out with several high yielding hybrids with yield potential of 24 - 100kg/tree at the age of six years without irrigation (Masawe , 1998, Masawe *et. al*., 1999 and Masawe, 2006). Following are the major tasks of cashew breeding (CIP).

- Import of additional exotic cashew germplasm from Brazil, Mozambique, Zambia, Malawi, Senegal, Cook Island.
- Release of 20 improved cashew clones, which are being distributed to farmers.
- Establishment of the controlled hand pollination techniques.
- Develop over 100 cashew hybrids, have improved cashew genetic pool.
- Develop and establishment of additional selection criteria in cashew (i.e. yield per canopy ground cover area, precocity, short duration of nut picking etc.)
- Develop and establishment of detailed flowering biology of a cashew tree.
- Establishment of existence of Genotype Environment Interaction in cashew.
- Establishment of presence of maternal effects in cashew suggesting the choice of parents to be punt into consideration.

- Establishment of the presence of clonal resistance/tolerance to sucking pests (*Helopeltis* spp). Investigation into the percentage out-crossing in cashew which has led to an establishment of the first polyclonal seed orchard in Africa.
- Identification of resistance aspects of cashew against PMD.
- Develop an effective field and laboratory based screening techniques of cashew against PMD.

Table 5. Raw nut production trend (Kg/tree) of selected cashew clones of Tanzania under CIP, under no irrigation or no fertilizer application conditions

Cashew Clone	Age of tree (Years)															Reaction to diseases & pest
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
AC 1	9	10	25	24	32	34	36	33	37	36	35	32				Partially resistant to Powdery mildew (*Oidium anacardii),* Anthracnose (*Colletotrichum gloeosporioides*), Die back (*Phomopsis) and Susceptible to* leaf and nut blight disease (*Cryptosporiopsis spp*)
AC 4	11	9	27	22	43	37	67	61	61	65	69	50				
AC 6	9	19	20	28	30	41	48	53	59	42	55	58				
AC 10	4	8	13	10	25	20	42	42	52	34	42	40				
AC 10/129									14	25	47	50	67	81	92	
AC 10/220									26	29	40	51	56	58	62	
AC 22	9	8	16	19	29	39	28	36	33	36	39	40				
AC 28	8	10	21	27	31	40	39	30	37	39	42	42				
AC 34							30	40	44	42	44	46	48	50	55	
AC 43	8	18	13	25	24	33	31	56	63	66	68	67				
AC10/14									26	29	30	39	42	48	55	
AZA 2	5	13	20	15	32	49	41	45	54	50	52	51				Resistan to leaf and nut blight disease (*Cryptosporiopsis spp*) besides above partial resistance
AZA 17/158	4	9	12	13	14	15										
AZA 17/79	4	7	10	14	16	17										

Planted at 12m x 12m or 12m x 15m spacing

Under Cashew Research Programme, Naliendele Agricultural Research Institute has developed more 20 cashew varieties of high nut yield potential coupled with partially resistance / tolerance to pest and diseases (Masawe, 2006**).** Nut yield record of a few selected clones is presented in table 5. These selected cashew clones were developed by adopting the strategy of poly clonal seed gardens

The Cashew Research Programme has been collaborating with various institutes overseas including KARI (Kenya), IIAM and INCAJU (Mozambique), NaFORRI (Uganda), FOFIFA Madagascar, OCFCU (Ethiopia), CNRA (Ivory Coast), Burkina Faso and CATAS (China).Selection of elite cashew genetic material in Mozambique was also initiated. With objective of developing dwarf, high yielding , bold nut genotypes coupled with resistance to powdery mildew and TMB, Prasad et al (2000) studied / evaluated the segregating seed progenies of the three Brazilian dwarf cashew varieties namely CP9, CP76 and CP1001and another Brazilian genotype of unknown origin. From this progeny, 32 trees were selected and further their clonal performance was evaluated. The clones of CP 1001 – V.12, AD-IV.1,

CP 76 – II.3 and CP9 – XII.8 showed high level of resistance to tolerance with very low incidence of disease coupled with higher nut yield.

Specifically dwarf and common cashew genotypes were screened separately for resistance against anthracnose (*Colletotrichum gloeosporioides*) with a view to utilize the resistant / tolerant source in cashew breeding programmes in Mozambique (Uaciquete,et al., 2013) . Not a single clone with a high level of resistance was identified out of 229 entries. However, the clones namely, 1.12PA, 12.8PA and 1.18PA were reported as tolerant types and 11.9PA and 2.3BG as susceptible types among the dwarfs. Among the common genotypes, clones NA7, MB77, 1.5R and MCH-2 ranked tolerant and IM1 and MU3 susceptible. Tolerant clones were therefore recommended to be used in the national cashew breeding program for further development of cashew cultivars with durable resistance to anthracnose.

There are two main varieties of cashew in Guinea-Bissau, the red (local) and yellow (Mozambican type. Thus, cashew industry of Guinea-Bissau till 2004 had a very small nut size types(average nut weight of 4.84g or 207 nuts per kg) with low yields, no germplasm collections due to weak applied research capacity and poor extensions capacity, public or private. But, Guinean cashew have the reputation of being sweet in flavour and having a high kernel:shell ratio, i.e. out turn rate(Lynn and Jaeger, 2004).

Vietnam

In Vietnam, high yielding clones namely DDH 66-14, DDH 67-15, B01, PN1, KP11 and BD 01 were released initially for commercial cultivation. Further, PN-1, LG-1, MH 5/4, MH 4/5 and TL-2/11 (Table 5) are the improved hybrids currently available for commercial cultivation in Vietnam (Sasi Varma, 2007).

Table 6 . Salient features of improved cashew hybrid cultivars of Vietnam (at 3 years of age)

Cultivar	Nut yield (Kg/tree)	Number of nuts./kg	Nut size (g)	Kernel out turn (%)
TL 2/11	10.2	140.0	7.14	28.8
MH 4/5	9.7	153.3	6.52	30.2
MH 5/4	8.1	135.3	7.39	30.3
PN-1	7.4	150.0	6.67	31.4
LG-1	9.1	136.7	7.31	29.1
CH-1	9.9	161.0	6.21	28.9
Mean performance	9.06	146.05	6.84	29.78

Constraints in cashew in Vietnam

Pests and diseases: Anthracnose (*Colletotrichum gloeosporioides*) is a common and serious disease of cashew. Water-soaked lesion develops on affected shoots, inflorescence and fruits, resulting in dieback and finally death of the whole tree. Fungicide sprays can be used as a control. Major insect pests include an East African weevil (*Mecocorynus loripes*) the larvae of which make extensive tunnels in the trees, an Indian weevil (*Plocaederus ferrugineus*) with wood-boring grubs, and a Brazilian butterfly (*Anthustarcha binocularis*) with larvae boring into young twigs and inflorescence. General control measures include plant and plantation sanitation and the use of insect repellents and insecticides.

Shoot borer (*Zeuzera coffeae*) is the most serious pest of cashew trees. Control measures applied for pests and diseases were practiced only in 2.17% of orchards.

In Sri Lanka, Six promising accessions namely, WUCC 05, WUCC 08, WUCC 09, WUCC 13, WUCC 19 and WUCC 21 were identified for their nut yield potential of over 15 kg/tree/year. These accessions showed high yielding ability at early stages of life cycle with high quality nut and kernel characters (Jayasekera, et al., 2009 ; Attanayaka and Jayasekera, 2011).

Resistance breeding

Screening for Anthracnose disease

In a study, 229 dwarf and common cashew (*Anacardium occidentale*) genotypes were screened for resistance against anthracnose (*Colletotrichum gloeosporioides*) in Mozambique (Uaciquete, et al, 2013). Hierarchically clonal sensitivity ranked clones 1.12PA, 12.8PA and 1.18PA as tolerant and 11.9PA and 2.3BG as susceptible among the dwarfs. Among the common genotypes, clones NA7, MB77, 1.5R and MCH-2 ranked tolerant and IM1 and MU3 susceptible. Tolerant clones were therefore recommended for using in the national cashew breeding program for further development of cashew cultivars with durable resistance to anthracnose. Clones such as 2.5VM, 1EM, MB75 and others that revealed incidence consistency over seasons can be used as susceptibility or tolerance standards in screening trials.

Molecular Markers in cashew

DNA markers are fundamental links between plant breeding and plant biology. Hither to, approaches for crop improvement were mostly accomplished in the total absence of basic knowledge of plant biology. Still many important biological phenomena like heterosis, epistasis, host-pest interactions, response to abiotic stress, *etc*, very often used in plant breeding programmes, are described in abstract concepts. But there is a need to generate precise and firm data for complete understanding of genetic gains in perennial crops like cashew. Knowledge on basic biology, therefore, will be the source for much new information about genomes, genes, pathways and interactions of direct relevance to crop improvement. In many instances, DNA markers will be the vital and fundamental link between plant biology and main stream plant breeding. Several reports are available depicting the efforts to generate molecular data base in cashew to understand the diversity, selection of parental combinations for hybridization for constructing desired recombinants, marker assisted selection and QTL mapping, etc., in order to enhance the precision and pace of crop improvement in cashew.

For the first time, RAPD markers were used in cashew to distinguish four dwarf cashew seedlings (Neto *et al*., 1995) in Brazil. The genomic DNA was extracted from seedlings of 4 dwarf cashew clones (CP 06, CP09, CP76 and CP1001).The amplification products were generated by using six 10-mer arbitrary primers. Similarity coefficients revealed that there was a high genetic similarity between the seedlings CP-06 and CP-76 (0.778) which was confirmed with the fact that the clones CP-06 and CP-76 had common genetic origin. The seedling CP09 was observed to be the most genetically divergent in relation to the other seedlings.

Later, polymorphic profiles of RAPD markers were observed between cashew populations of diverse geographic locations viz.Brazil, Mozambique, Guinea Bissau, India and

Tanzania((Mneney *et al*., 2001)). Accessions from India, Mozambique and Tanzania showed closest relationship, while those from Brazil being the most distinct from other provenances. The relatively uniform RAPD profiles of Tanzanian cashew lines, however, indicated a high level of similarity among themselves which attributed to the fact that majority Tanzanian clones had their ancestry in Sri Lanka. The study indicated that the diversity within the germplasm of Tanzania was inadequate for breeding programmes and needed to widen genetic base. During these studies, it was felt that the dedicated (non random) PCR-based, yet more robust DNA markers like 'Sequence tagged sites' (STS) and 'Expressed sequence tag' (EST), developed from cloned genomic or cDNA libraries would be more useful practically in identifying a large number of mapped locations in the genome that corresponds to genes. Such a novel approach would precisely facilitate breeding for economically important characters and systematic exploitation of heterosis in cashew.

In India, application of molecular markers in cashew began only in the year 2000. Karihaloo and Archak (2000) used molecular markers in cashew as an aid to agro-biodiversity management. It was reported that cashew, despite being an introduced plant, exhibits high molecular diversity among its Indian cultivars. This was attributed mainly to the combined effect of its breeding system and continuous seed propagation, that together led to high level of heterozygosity and ensured the availability of multiple alleles. The observed variation in molecular markers, while reflecting the extent of genetic diversity in cashew grown in India, underscored the need to collect and screen the local germplasm for the important economic traits including pest and disease resistance and adaptability to diverse agro-climates.

Dhanaraj *et al*. (2002), in India used the RAPDs to estimate the diversity among 90 accessions from the National Cashew gene Bank (National Research Centre for Cashew , Puttur, Karnataka, India), which represented different cashew growing states and exotic collections. The accessions from different geographical regions were observed to be grouped together, probably due to continuous germplasm exchange between various research centers practiced for their evaluation in other parts of the country. The results indicated a moderate to high diversity in Indian cashew collections. Further, the core collection consisting of 54 out of 90 accessions including three *Anacardium* sp., the purple mutant plant, Mozambique introductions, CNSL free accession, 40 other accessions and 8 of 10 released varieties was reported to overcome the redundancy in germplasm bank.

At the same time, Rout *et al*. (2002) developed an efficient protocol for DNA extraction and purification from fresh leaves of different varieties of cashew for RAPD analysis at Orissa University of Agriculture and Technology, which could be useful for other woody species. In the same laboratory, similar studies by Samal *et al*. (2002) on genetic relatedness in 20 cashew germplasm collections determined by randomly amplified polymorphic DNA showed the highest similarity index of 87 per cent between Ullal-3 and H-1608. It was observed that Vengurla-2 and Vengurla-3 were not grouped into a single cluster, but Vengurla-4 had 82 per cent similarity with Vengurla-3, which in turn had a close similarity (85%) with VRI-3, a variety from altogether a different geographical location. The analysis of genetic relationships in cashew using morphological traits and RAPD banding data can be useful for plant improvement, descriptions of new varieties and also for assessment of variety purity in plant certification programmes (Samal *et al*., 2003 and Desai, 2008).

Molecular profiles of 35 cashew varieties of India (24 selections and 11 hybrids) were developed by using a combination of five RAPD and four ISSR primers pre selected for maximum discrimination and repeatability (Archak, *et al*., 2003a). Primer-wise and technique wise results revealed that five selected random primers generated 56 bands of

which 78.6 per cent were polymorphic which was observed to be was high enough to enable discrimination of all the varieties. Correspondingly, analysis of molecular variance (AMOVA) within a breeding centre was observed to be only 3.6 per cent and was attributed to the frequent exchange of genetic material among different breeding centers while developing the present day varieties as has been reported earlier by Dhanaraj *et al*. (2002). Further, a comparative assessment was carried out between varieties developed through selection and those obtained by hybridization indicating the need and scope for identification of more parental lines in enhancing the effectiveness of hybridization programmes in the country. These results also led to the development of the fingerprint pattern of the varieties in the form of bar code diagram. Subsequently, in a comparative studies comprising 50 random primers, 12 ISSR primers and 6 AFLP primer pairs (Archak *et al*., 2003b), AFLP exhibited maximum discrimination efficiency with a genotype index of 1. The utility of each molecular marker technique, expressed as marker index, was observed to be more than 10 times higher in AFLP than in RAPD and ISSR. Comparison of Similarity matrices, determined based on the data generated by molecular and morphometric analyses displayed no correspondence of AFLP with RAPD and ISSR. Correlation between ISSR and RAPD similarity matrices was observed to be low but significant. However, the similarity matrix based on morphometric markers exhibited no correlation with any of the molecular markers. AFLP, with its superior marker utility, was concluded to be the marker of choice for cashew genetic analysis.

Subsequently, Croxford *et al*. (2006) used an automated, high throughput system to isolate cashew microsatellites from a non enriched genomic library blotted on to membranes at high density for screening. Twenty one out of 65 sequences containing a microsatellite array, showed polymorphism among the closely related seed garden population of 49 cashew genotypes. Further, 12 markers were observed to be suitable for multiplex analysis, of which only 10 amplified in *A. microcarpum, A. pumilum and A. nanum.* These markers would provide a valuable resource for further hastening breeding programmes through map-based applications in cashew.

For the first time in cashew, two genetic maps comprising of 205 genetic markers (194 AFLP and 11 SSR markers) were developed by using F1 mapping populations of 85 individuals derived from a cross between CP 1001 (dwarf commercial clone) and CP 96 (a giant type) of Brazil (Cavalcanti and Wilkinson, 2007). The female map (CP 1001) contained 122 markers over 19 linkage groups, while the male map (CP 96) had 120 markers assembled over 23 linkage groups. Around 68 per cent genome coverage was observed in the female map in a total map distance of 1050.7 cM, whereas the corresponding values were 64 per cent and 944.7 cM in the male map. Homology between the two maps was established between 13 and 14 linkage groups of female and male maps respectively, using 46 bridging markers including 11 SSRs. These maps can be useful in identifying loci controlling economically important traits in cashew.

QTL mapping

This tool, once validated and applied practically, will be effective in bringing about the rapid crop improvement in cashew to address at higher pace the new challenges ahead.

Eighteen QTL associated with cashew apple quality were identified : three for oligomeric phenolics, five for total soluble solids, six for total acidity and four for vitamin C. These QTLs

are reported to be promising for marker-assisted selection since they have the greatest phenotypic effects and contribution to phenotypic variation (Santos, et al., 2011).

The methods of interval mapping and multiple QTL mapping were applied to evaluate 71 F1 genotypes. and subsequently, eleven QTLs (three for nut weight, four for male flowers and four for hermaphrodite Flowers) were detected . The QTL accounted for 3.79 to 12.98 % of the total phenotypic variance and had phenotypic effects of -31.81 to 34.25 %. The potential for marker-assisted selection of the QTL hf-2f and hf-3m appeared to be great and the phenotypic effects and percentage of phenotypic variation higher than of the others (Cavalcanti, et al, 2012).

Thimmappaiah, et al, (2009) studied diversity and genetic relationship in 100 cashew germplasm accessions by using RAPD and ISSR markers. Sixty bands were generated by using 10 selected RAPD primers, of which 51 bands were polymorphic (85%), and with 10 selected ISSR primers 67 amplified bands were observed with 58 polymorphic bands (86.6%). Though both kinds of markers discriminated the accessions effectively, analysis of combined data of markers (RAPD + ISSR) resulted in better distinction of accessions. By combining markers, a total of 127 bands were detected, of which 109 bands (85.8%) were polymorphic and produced on an average of 5.45 polymorphic bands per primer. Primers with high polymorphic information content and marker index were identified for discriminating accessions. High percentage of polymorphism (>85%) observed with different markers indicated high level of genetic variation existing among the accessions. Genetic relationship estimated using similarity co-efficient (Jaccard's) values between different pair of accessions varied from 0.43 to 0.94 in RAPD, 0.38 to 0.89 in ISSR and 0.43 to 0.87 with combined markers suggested a diversity (dissimilarity) ranging from 6 to 57%, 11 to 62% and 13 to 57% respectively and the diversity skewed around 50% indicated moderate diversity. The cluster analysis with UPGMA method separated the accessions broadly into 13 clusters and in that three into smaller clusters. Some correspondence between the molecular groupings and the morphological clusters were observed. Among the accessions, NRC-142 and NRC-12 were highly divergent and NRC-231 and NRC-232 were genetically similar.

The efficiency of the breeding and selection process can be assessed in many different ways including the ultimate success of the varieties released and the frequency with which new varieties are produced. A major cost and logistical issue in cashew breeding are the actual number of lines that need to be carried through the evaluation and selection phases of a program. Large breeding programs for crops like may carry hundreds of thousands of lines to produce a new variety after considerable long period of time and hence field trials can be expensive and evaluation of some traits, such as quality and yield stability can be technically and genetically complex requiring large batches of material. Molecular markers have proved to be a powerful tool in replacing bioassays and there are now many examples available to show the efficacy of such markers. The use of molecular markers to track loci and genome regions in crop plants is now applied in many breeding programs. The location of major loci is known for many disease resistance genes, tolerances to abiotic stresses and quality traits. Improvements in marker screening techniques have also been important in facilitating the tracking of genes. For markers to be effective they must be closely linked to the target locus and be able to detect polymorphisms in material likely to be used in a breeding program. The prime applications of markers in most breeding programs has been in backcross breeding where loci are tracked to eliminate specific genetic defects in elite germplasm, for the introgression of recessive traits and in the selection of lines with a genome make-up close to the recurrent parent. In progeny breeding, markers have proved valuable in building crucial parents and in enriching F1s from complex crosses. Markers have also improved the

strategies for gene deployment and enhanced the understanding of the genetic control of complex traits such as components of quality and broad adaptation (Peter Langridge, 2005)
Limitations in adoption of Marker assisted selection (MAS)

Although the identification of marker trait associations is now rapid for simply inherited traits and for many QTL, adoption rates within breeding programs has been slow. The key issues identified are:

- Lack of useful marker trait associations. Many breeders feel that the loci targeted for marker development have been selected by molecular biologists rather than the breeders.
- Poor polymorphism rates in "real" breeding material. Many marker development programs have been based around highly diverse germplasm, selected for ease of detecting polymorphism rather than value to breeding programs.
- Closeness of linkage. The closer the linkage the greater the reliability of the markers. Not surprisingly breeders would like diagnostic markers.
- Lack of resources for marker screening. Breeders are reluctant to redirect their current resources to marker screening and in many cases such redirection is not feasible. The most successful implementation programs have been funded separately from the core breeding programs. This applies to both public and private sector breeding operations.
- The long lead time for breeding means high risks to a breeding program if it modifies its breeding strategies. The real value of markers appears to lie in the development of new breeding strategies. The crosses, population size and screening methods using in traditional breeding and marker based breeding programs are not necessarily compatible.

Relevance of developments to other crops

Although the most detailed marker information is available for the major cereal crops, genetic linkage maps based around molecular markers are now available for most crop species. For some species, such as strong out breeders, long generation perennials and clonally propagated species, it may be slow and complex to develop useful marker trait association. This is the case for most tree crops. However, even for these crops, many maps are available. Usually, the maps have been constructed from populations segregating for traits of relevance to improvement programs although the germplasm may not be the most recent. For example, molecular mapping studies in cassava have identified loci and associated markers for productivity, plant architecture, and resistance to cassava mosaic disease. Therefore, in many respects the technology is sufficiently well developed to be applicable to most crop improvement programs and the examples of using MAS in cereal breeding should have direct relevance to other breeding programs. Although the breeding strategies may vary between crop species, there is sound reason to believe molecular markers could offer significant benefits to all breeding programs and could lead to increases in the speed of breeding and the sophistication of breeding programs.

References

Akinwale, S A and Esan, E B, 1989. Advances in cashew breeding in Nigeria. In: Progress in tree crop Research. 2nd Edition. Cocoa Research Institute of Nigeria, Ibadan, Nigeria. 166-174.

Aliyu, O Mand Awopetu, J A , 2007a. Multivariate analysis of cashew germplasm in Nigeria. Silvae Genetica. 56 (3-4):170-179

Aliyu, O Mand Awopetu, J A , 2007b. Assessment of genetic diversityin three populations of cashew using protein isozymes electrophoretic analysis. Genetic Resources and Crop evolution, 54:1489-1497.

Archak, S., Gaikwad, A.B., Diksha Gautam, Bhaskara Rao, E.V.V., Swamy, K.R.M. and Karihaloo, J.L., 2003a, DNA Finger printing of Indian cashew (*Anacardium occidentale* L.) varieties using RAPD and ISSR techniques. Euphytica, **230**: 397 – 404.

Archak, S., Gaikwad, A.B., Diksha Gautam, Bhaskara Rao, E.V.V., Swamy, K.R.M. and Karihaloo, J.L., 2003b, Comparative assessment of DNA fingerprinting techniques (RAPD, ISSR and AFLP) for genetic analysis of cashew (*Anacardium occidentale* L.) accessions of India. Genome, **46**: 362–369.

Attanayaka, DPSTG and Jayasekera, SJBA, 2011. **Recent Developments in Cashew Research.** Proceedings of the Cashew Research Workshop held on 20th November 2009 at the Faculty of Agriculture and Plantation Management of the Wayamba University of Sri Lanka.

Bhaskara Rao, E.V.V., 1998, Cashew crop improvement programmes in India. *Proceedings of the Int. Cashew and Coconut Conference*, Dar es Salam, Tanzania, 108 – 115.

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

Castro, A.C.R, Bordallo, P.N, Cavacanti J.J.V and Barros, L.M.2011. Brazilian Cashew Germplasm Bank. Acta Hort. 918 :857-861

Cavalcanti1 J J V, Pinto C A B P, Crisostomo, J R and Danial Furtado. 2000. Diallel analysis to evaluate interpopulational cashew hybrids. *Pesquisa Agropecuaria Brasilira.* Vol **35**(8): 1567-1575.

Cavalcanti1 J J V, Santos F H C, Silva F P and Pinheiro, Cássia Renata, 2012. QTL detection of yield-related traits of cashew Crop Breeding and Applied Biotechnology **12**: 60-66, 2012

Cavalcanti, J. J. V. and Wilkinson, M. J., 2007, The first genetic maps of cashew. Euphytica, **157** : 131-143.

Croxford, A. E., Robson, M. and Wilkinson, M. J., 2006, Characterization and PCR multiplexing of polymorphic microsatellite loci in cashew (*Anacardium occidentale* L.) and their cross-species utilization. Molecular Biology Notes, **6** : 249-251.

Desai, A. R., Dhandar, D. G., Leebu Babu and Dalvi, R. B., 2000, Classificatory analysis of some cashew germplasm accessions of Goa. PLACROSYM XIV, Hyderabad, 12-15 December, 2000.

Desai, A R, 2008. Molecular diversity and phenotyping of selected cashew genotypes of Goa, and physiological response of cv. goa-1 to *in situ* moisture conservation. Ph.D thesis submitted to University of Agricultural Sciences, Dharwad, Krnataka, India.

Dhanaraj, A.L., Bhaskara Rao, E.V.V., Swamy K.R.M., Bhat, M.G., Teertha Prasad, D. and Sondur, S.N., 2002, Using RAPDs to assess the diversity in Indian cashew (*Anacardium occidentale* L.) germplasm. J. Hortic. Sci. and Biotech. **77**: 41 – 47.

Gunjate, R.T and Deshpande , S. B, 1994, Improvement of cashew. In : *Advances in Horticulture **Vol.9** - Plantation and Spice crops. Part-1*. Eds. K.L. Chadha and P. Rethinam. Malhotra Publishing House, New Delhi, India. pp. 281-292.

Hammed, L.A,. Anikwe J.C and Adedeji A.R. 2008 Cashew Nuts and Production Development in Nigeria. American-Eurasian Journal of Scientific Research 3 (1): 54-61

Harries, H. C., Kusolwa, P. M., Millanzi, K. J. and Masawe, P. A. L., 1998, A cashew breeding programme for Tanzania. *Proc. Int. cashew and coconut conference : trees for life – the key to development*, Dar Es Salam, Tanzani, 17-21 February1997 : 128-123.

Karihaloo, J L., and Archak, S., 2000, Molecular markers as aid to agro-biodiversity management: some Indian cashew studies. Extended Summary, Vol. 2. Voluntary papers. *International Conference on Managing Natural Resources for sustainable agricultural Production in 21st Century*, 14-18, Feb. 2000, New Delhi.

Latha A and M. A. Salam, 2001. Cashew (Anacardium occidentale L.) varieties tolerant to K-deficient soils. *Journal of Plantation Crops.*29(1): 16-21

Lenka, P.C., Mishra, N and Mohapatra, K.C., 1999, Genetic divergence in cashew nut(*A. occidentale* L.). J. Plantation Crops **27** (3) :193-195.

Lenka, P.C., Samal, S., Mohapatra, K.C. and Dash, D. K, 1999, Studies on genetic variability and correlation studies in cashew. Orissa J. Hortic. **27** (1) : 92-96.

Lynn, Steev and Jaeger, Peter, 2004. Guinea-Bissau Cashew Sector Development Study. P 86. www.hubrural.org/IMG/pdf/bissau_cashew_rap-04.pdf

Masawe, P.A. L. , Cundall, E. P., and Caligari, P. D. S., 1998, Performance in South Eastern Tanzania of local cashew germplasm and selected clones. *Proceedings of the Int. Cashew and Coconut Conference*, Dares Salam, Tanzania, 146 – 150.

Millanzi, K.J.K., 1998, Screening cashew clones for reaction to *Helopeltis*. *Proc. Int. Cashew and Coconut Conference*, Dar es Salam, Tanzania, 117 – 120.

Mneney, E.E., Mantell, S.H. and Mark Bennet., 2001, Use of random amplified polymorphic DNA (RAPD) markers to reveal genetic diversity within and between populations of cashew (*Anacardium occidentale* L.). *J. Hortic. Sci.Biotech.* **76** : 375 – 383.

Neto, Silva, S. P., Maruta, I., Takaiwa, F., Oono, K. and Matsumuto, K., 1995, Identification of cashew (*Anacardium occidentalei* L.) seedlings with RAPD markers. Acta Horticulturae, **370** : 21-26.

Prasad, M. V. R., Langa, A. and ConsoloJ. P., 2002, Selection of elite cashew genetic material in Mozambique. The Cashew, **14** (1) : 8-23.

Potty, V.P, 2007. Cashew scenario in india and Vietnam : a comparative study. A paper presented in National Seminar Research , Development and marketing of Cashew , held on 22-23 Nov. 2007 at Goa.

Rao, A. V. V. D., Ravishankar, C and Reddy, M. L. N, 2002, Correlation between nut yield and plant charactersin cashew nut. J. Res. – ANGRAU, **30** (1) : 98-100.

Rout, G. R, Samal, S., Nayak, S., Rashmi, M. Nanda., Lenka, P. C, and. Das, P., 2002, An alternative method of plant DNA extraction of cashew for randomly amplified polymorphic DNA (RAPD) analysis. Gartenwissenschaft **67** (3) :1-4.

Samal, S., Lenka, P. C., Nanda, R. M., Nayak, S., Rout, G. R. and. Das, P., 2002, Genetic relatedness in cashew (*Anacardium occidentale* L) germplasm collections as determined by randomly amplified by polymorphic DNA. Genetic Resources and Crop Evolution, 1

Samal, S., Rout, G. R. and Lenka, P. C., 2003, Analysis of genetic relationships between populations of cashew (*Anacardium occidentale* L) by using morphological characterization and RAPD markers. Plant Soil Environment. **49** (4) : 176-182.

Sankaranarayanan, R and Ahmad Shah, H., 1999, Genetic divergence and path analysis in cashew. The Cashew **13** : 28 – 39.

Santos, Francisco Herbeth Costa dos, José Jaime Vasconcelos Cavalcanti; Fanuel Pereira da Silva. 2011. QTL detection for physicochemical characteristics of cashew apple. Crop Breed. Appl. Biotechnol. (Online) vol.11 no.1 Viçosa Mar. 2011

Sanwo, J.O., B.O. Kuti and Osundolire, 1972. Cashew Germplasm collections. The Annual Report of Cocoa Research Institute of Nigeria, 1972/73, pp: 100-110.

Thimmappaiah,, Santhosh, W.G. . Shobha, D,. Melwyn, G.S,2009. Assessment of genetic diversity in cashew germplasm using RAPD and ISSR markers. Scientia Horticulturae. 120(3): 411–417

Uaciquete A , Korsten, L and Van der Waals J.E, 2013. A search for anthracnose resistant cashew cultivars in Mozambique. Crop Protection Volume 50, August 2013, Pages 6–11.

Zhang Zhongrun,Liang Lihong,Huang Weijian,Wang Jinhui,Huang Haijie,2011. Evaluation of the resistance of five cashew clones to the cashew long-horned beetle. *Plant Protection*, 2001-04

SOIL AND WATER CONSERVATION IN CASHEW

Dr. S. Jeeva,
Professor (Horticulture)
Horticulture College and Research Institute for Women, TNAU
Tiruchirapalli, Tamil Nadu.
jeedharan@gmail.com

Cashew is the prominent perennial horticultural crop, which has been contributing to the Indian economy significantly. Though India ranks first in area and production productivity is very low. One of the main constraints for low productivity is lack of *In-situ* moisture conservation measures and subsequent moisture stress during the summer. It is generally grown as a rainfed crop along steep slopes of hills or on neglected land unsuitable for any other crop. In India, cashew experiences severe moisture stress from January to May, adversely affects its flowering and fruit set.

One of the short-term strategies to achieve 10.00 lakh MT that can be absorbed by 1100 processing units established in the country is to increase per unit area productivity in the country. The best option available is to go for high density planting with suitable in-situ soil and water conservation measures instead of conventional cultivation method.

in-situ soil and water conservation

In situ retention of rain water in the field itself is the most efficient method to recharge and store moisture in the root zone for better plant growth. This can be achieved by suitable agronomic measures such as crop geometry, crop combinations, mulching etc., and also by promoting moisture retention by mechanical measures such as trenching, bunding, terracing, basin making or micro catchment, contour furrow etc., of which trenching being the most appropriate method.

Types of trenches

Continuous contour trench (CCT) : It is the trench which is made for the entire field length continuously along the contour at certain vertical interval.

Graded Trench (GT) : is the trench, which is made for entire field length continuously in different grades.

Staggered contour trench (SCT) : Has to be excavated for the length of 2 m, top width of 0.45 m, bottom width of 0.30 m and depth of 0.45 m in staggered manner of an aligned contour.

Semi elliptical trench (SET) : The trench with the length of 2 m, top width of 0.45 m, bottom width of 0.30 m and depth of 0.45 m prepared in respect to each plant in a semi elliptical manner on the upstream side of the plant is called Semi elliptical trench

Crescent shaped trench (CST) : The trench that will be taken up in crescent shape is called Crescent Shaped trench.

Bio Engineering measures: The trenches or terraces supported with live barriers are called bio engineering measures. Vegetative barriers such as *Vetivaria zizanoides, Stylosanthes scabra* and *Glyricidia maculata* can be planted as hedge crops on the bunds of trenches.

Individual tree terracing with crescent bund is the best soil conservation measure in slopy lands. Soil and water conservation techniques like modified crescent bund or staggered trenches with coconut husk burial helps in conserving moisture, reducing the annual runoff / soil loss and increasing the nut yield. Terracing taken up around each plant by cutting soil from the upper portion of the slope and filling the lower portion has been recommended. Catch pits around the plant not only helps in harvesting, retaining and making the water available to the plant for a prolonged period but also cuts the velocity of running water on the slopes thereby arresting soil erosion. Top soil eroded from the exposed portion of the hillocks also gets trapped in the catch pit. Thus, it plays triple role in preventing soil erosion, rain water harvesting and insitu moisture conservation.

Coconut husks are buried in trenches of 1 m width, 0.5 m depth and 3.5 m length/ plant opened across the slope between two rows of Cashew. Generally 3-4 layers of coconut husks are buried one above the other with convex side of the first layer of the husks touching the ground. After spreading a layer of soil on the first layer of the husks, second layer of husks is laid in the same fashion as that of the first layer. The last layer of the husks should be inverted so that convex side is facing the upper side. Thick layer of soil upto 10 cm thickness should be spread over this.

Modified crescent bund and coconut husk burial reduced the annual runoff (22.3 and 20.4% of the annual rainfall compared to 36.9% of the annual rainfall in control), soil loss (47 and 49% of control) and nutrient loss. Also it increased the mean soil moisture content, growth of plants, yield of cashew (6.45 and 6.60t/ha respectively compared to 4.88t/ha in control for the first 5 harvests) and net profit from cashew garden (40% more than control). In addition to this, the groundwater level in nearby wells and ponds increased. Hence, the barren land even in steep slopes with proper soil and water conservation measures can be effectively utilized for cashew cultivation. (DCR, Puttur).

Soil and water conservation measures In the case of slopy lands terracing should be taken up around each plant during the second and third year. Terraces should be of 1.8 to 2.0 m radius with a catch pit (1.5m x 45 cm x 30 cm) on the upper side of the terrace. The soil around the plant should be mulched with organic materials which will help to avoid direct exposure there by conserving soil moisture. Mulching The soil around the plant should be mulched with dried leaves or green leaves for conservation of moisture. (Cashew cultivation practices, KVK, CPCRI, Kasargod)

Studies were conducted at ICAR Research Complex for Goa, Old Goa on soil and water conservation measures for cashew by adopting different *In-situ* soil and water conservation measures. The continuous contour trenches with vegetative barriers was the best as compared to all other treatments for runoff, soil loss and nutrient loss reduction. Staggered contour trenches with *Stylosanthes seabra* and *Vetiveria zizanioides* was the alternative measure for reduction of runoff and soil loss for cashew land use. Additional income could be generated from the vegetative barriers, which can be used as either fodder or biomass for mulching during the initial period of cashew plantation by adapting the bio-engineering measures. Continuous contour trenches with vegetative barriers and staggered contour trenches with vegetative barriers were found economically viable and these technologies are recommended for adoption in the cashew plantations in hilly terrain.

Continuous contour trenches with *Stylosanthes scabra* and *Vetiveria zizanioides* and staggered contour trenches with *Stylosanthes scabra* and *Vetiveria zizanioides* reduced the runoff by 44.5 and 34.6 per cent, respectively under spacing of 4 m X 4 m cashew plantations. Similarly, continuous contour trenches with vegetative barrier of *Stylosanthes scabra* + *Gliricidia maculata,* staggered contour trenches with *Stylosanthes scabra* and *Gliricidia maculata* and crescent shape trenches with *Stylosanthes scabra* and *Gliricidia maculata* recorded runoff reduction of 46.3, 35 and 29.0 per cent, respectively in the field where cashew was planted at 6 m x 6m spacing.

Continuous contour trenches with *Stylosanthes scabra* and *Vetiveria zizanioides* and staggered contour trenches with *Stylosanthes seabra* and *Vetiveria zizanioides* reduced the soil loss by 11.3 and 8.1 t ha-1 yr1 in 4 m x 4 m cashew field. Similarly, continuous contour trenches with vegetative barrier of *Stylosanthes seabra* + *Glirieidia maeulata* significantly reduced average soil loss (6.5 t ha-1) followed by staggered contour trenches with *Stylosanthes seabra* and *Glirieidia maeulata* (5.6 t ha-1) and crescent shape trenches + *Stylosanthes seabra* and *Glirieidia maeulata* (5.7 t ha-1) in the plot where the cashew was planted at 6 m x 6 m spacing. Continuous contour trenches with vegetative barriers was the best when compared to all other treatments as far as nutrient loss reduction was concerned.

Highest soil and water conservation efficiency was observed in continuous contour trenches with *Stylosanthes seabra* and *Vetiveria zizanioides* (49.5 per cent) followed by staggered contour trenches with *Stylosanthes seabra* and *Vetiveria zizanioides* (37.1 per cent) under 4 m X 4 m cashew plantations. Similarly, maximum soil and water conservation efficiency was observed in continuous contour trenches with *Stylosanthes seabra* + *Glirieidia maeulata* (62.9 per cent) followed by staggered contour trenches with *Stylosanthes seabra* + *Gliricidia maeulata* (51.3 per cent) in the plot where cashew was planted at 6 m x 6 m spacing.

All the conservation measures significantly increased the growth and yield of cashew.Continuous contour trenches and staggered contour trenches with vegetative barriers recorded the maximum plant growth and yield. Total cashew nut yield of7.72, 14.21 and 18.1 q ha-1 were recorded in treatment comprising of continuous contour trenches with *Stylosanthes scabra* and *Vetiveria zizanioides* during fourth, fifth and sixth years, respectively under 4 m X 4 m cashew plantations. The total cashew nut yield of 6.80, 3.50 and 5.20 q ha-1 were recorded in treatment comprising of continuous contour trenches with *Stylosanthes scabra* + *Gliricidia maculata* during fourth, fifth and sixth years, respectively under 6 m X 6 m plantations. Maximum NPW of Rs. 4, 61,820 per ha was obtained under cashew cultivation with continuous contour trenches with *Stylosanthes seabra* and *Vetiveria zizanioides* followed by Rs. 4,08, 090 per ha under cashew cultivation with staggered contour trenches *Stylosanthes seabra* and *Vetiveria zizanioides.* Maximum NPW of Rs. 1, 64, 900 per ha was obtained under cashew cultivation with continuous contour trencFles with *Stylosanthes seabra* + *Glirieidia maeulata* followed by Rs. 1,27,190 per ha under cashew cultivation with staggered contour trenches *Stylosanthes seabra* + *Glirieidia maeulata.* Higher benefit cost ratio and Internal rate of return were obtained under the continuous contour trenches with *Stylosanthes seabra* and *Vetiveria zizanioides* (6.87 and 20 per cent, respectively) followed by staggered contour trenches with *Stylosanthes seabra* and *Vetiveria zizanioides* (6.82 and 18 per cent, respectively) under 4 x 4 m cashew plantation. Similarly, BCR and IRR were higher under the continuous contour trenches with *Stylosanthes seabra* and *Glyrieidia maeulata* (5.07 and 13 per cent, respectively) followed by the staggered contour trenches with *Stylosanthes seabra* and *Glirieidia maeulata* (4.64 and 12.5 per cent, respectively) under 6 m X 6 m cashew plantations.

Green Manuring:

Green manures can improve the soil by increasing organic matter, earthworms and beneficial micro organisms, increasing the soil's available nitrogen and moisture retention, stabilizing the soil to prevent erosion etc., Growing cover crops like *Mimosa invisa, Pueraria javanica, Calapagonium muconoid*es and *Centrosemja pubescens* enrich the soil with the plant nutrients and organic matter, prevents soil erosion and conserve moisture. Higher soil moisture content was observed in cashew orchard with green manure crops such as glyricidia (17.0 – 18.6% dry basis) and sesbania(15.5-18.3% dry basis)

Mulching

Mulching the tree basins will help in conservation of soil moisture and prevents soil erosion. The basin area of Cashew plants can be mulched either with green leaves, dry leaves or weeds soon after planting. Mulching with organic matter or residues inhibits weed growth and reduces surface evaporation during summer and also regulates the soil temperature. Black polythene mulch was helpful to conserve soil moisture. Using coconut coir pith as soil mulch in cashew plantations resulted in 14.15% more water retention and suppression of weeds to an extent of 73.52.

PROPAGATION AND NURSERY MANAGEMENT IN CASHEW

MG Nayak
Principal Scientist (Hort)
ICAR-Directorate of Cashew Research, Puttur
gangadhara.nayakm@icar.gov.in

1. INTRODUCTION

Cashew is a cross pollinated and therefore, the seedling progenies are heterogenous due to segregation. Whereas the clonal progenies are true-to-true of the mother plant and give relatively more uniform yield and come to fruiting earlier than the seedling progenies. Different methods of vegetative propagation, namely layering, grafting and budding have been tried in cashew both at National Research Centre for Cashew (NRCC) and different Cashew Research Stations in the country. Studies conducted at NRC Cashew, Puttur and All India Coordinated Research Project (AICRP) on Cashew Centres, have indicated the superiority of “Softwood grafting” technique over other methods and hence, this technique has been standardized and recommended for taking up of commercial multiplication of cashew varieties.

In case of softwood grafting about two month old root stocks of cashew and 3-5 month old scions are utilized for grafting by adopting “cleft or wedge” method of grafting. Since softwood portion of the rootstock is utilized for making cleft and the scion is mended into wedge shape, this method is know as softwood grafting technique.

Softwood grafts can be prepared almost throughout the year with a mean graft success of 65-70 per cent saleable grafts. However, the best season for grafting would be June to November under Dakshina Kannada weather conditions. The cost of production is comparatively cheaper and field establishment of softwood grafts is very high.

2. TERMINOLOGIES

Grafting	:	Grafting is joining of two plant parts.
Root stock	:	Rootstock is the lower portion of the graft which has the root system of the grafted plant
Scion	:	Dormant buds is a short piece of detached shoot (lateral shoot) containing several dormant buds, which when united with root stock results in the upper portion (canopy) of the grafted plant.
Wood / sap wood (xylem)	:	Through wood the sap is drawn up from the roots and translocated to leaves.

Bark (phloem)	:	The carbohydrates synthesized in the leaves will be distributed / transported to roots via phloem. Protecting the phloem there is an outer skin called the bark.
Cambium layer	:	It is one celled thick strip around the outer side of sap wood (xylem) and inner side of bark (phloem). It manufactures new growth by rapid multiplication of cells. Cambium layer is important in healing of graft joint and establishing the connection between root stock and scion.

3. SCIONS FOR GRAFTING

a) Production of scion sticks

Scion bank for the recommended cashew varieties should be established by adopting a closer spacing of 4m x 4m and it should be maintained properly for getting continuous supply of scion sticks for commercial multiplication.

b) Selection of scion sticks and precuring

- Non flowered lateral shoots of current season's growth (3-5 month old) are to be selected.
- The selected shoots should be 10-12 cm long, straight, uniform round with brown coloration and of pencil thickness.
- The leaves are to be removed using a secateur (precuring or defoliation) 10 days in advance of grafting.

c) Collection of scion sticks

- The precured scion sticks should be collected from the mother trees before the terminal buds sprout.
- The scion sticks should be separated from the mother tree preferably during morning hours.
- The detached scion sticks may be dipped in cold water and then placed in a polythene bag of 100 gauge thickness and brought to the grafting shed and utilized for grafting.

4. ROOT STOCK SEEDLINGS FOR GRAFTING

a) Selection of cashew seeds for sowing

- Cashew seeds should be collected during the peak period of harvest (February-April).
- Collected from a single variety block.
- The seeds should be sun dried for 2-3 days.
- Medium sized (6-7g) and dense seeds should be selected.
- The seeds gradually loose viability after 8-10 months of storage.

b) Preparation of potting mixture and filling of polythene bags

- The potting mixture should be prepared in the proportion of 1:1:1 (red soil; coarse river sand: compost) in heavy rainfall areas and 1:1 (red soil: Compost) in low rainfall areas. Rock Phosphate @ 5g/kg of potting mixture may also be added for getting good root growth of seedlings.
- Polythene bags of 25 cm x 15 cm size and 300 gauge thickness should be used for filling potting mixture.
- In heavy rainfall areas, 30-40 drainage holes of 0.5 cm diameter may be punched uniformly on the polythene bags. In low rainfall areas, the number of drainage holes can be few.
- Potting mixture should be filled upto the brim level.
- The filled bags should be arranged in beds of 1000 number each (100x10).

c) Sowing of seeds

- The cashew seeds should be soaked in water for 12-24 hours before sowing. Seeds need not be presoaked during rainy season.
- The seeds should be dibbled in the centre of the polythene bags, stalk-end upwards and covered with little soil.
- The depth of sowing should be not more than 2.5 cm.
- Immediately after sowing and every day after sowing the seed beds should be watered depending upon the weather conditions.

- During rainy days, if water stagnation is observed, excess water should be removed by pressing the sides of bags.
- During dry months seedbeds may be mulched with paddy straw till the germination takes place. Agro shade nets may also be used for this purpose.
- The seeds will germinate 10-15 days after sowing depending on the weather condition.
- Seeds should be sown at regular intervals (weekly/fortnightly) to get continuous supply of desired root stock seedlings for grafting depending upon the number of grafters available.

d) Maintenance of seedlings in the nursery

- The seedlings should be watered daily depending upon the weather conditions.
- During monsoon season, if water stagnation is observed, the polythene bags may be pressed from sides, so that the excess water drains out of the bags. This reduces the incidence of collar rot/damping off of seedlings.
- During rainy season, the seedlings should be sprayed with Bordeaux mixture (1%) at 10 days interval to control collar rot/damping off of seedlings.
- The seedlings may be sprayed with systemic insecticides such as monocrotophos (1.5 ml/litre) to control tea mosquito and other pests at regular intervals.
- The side shoots arising from the axils of leaves should be removed frequently in order to get vigorous seedlings with single main stem.

5. SOFTWOOD GRAFTING TECHNIQUE

a) Preparing the root stock seedling for grafting

- The grafting operation should be carried out under the shade either in a grafting shed or makeshift shelters.
- About two month old seedlings (of 25-30 cm height) are selected as root stocks. The girth of the seedling should be about 1cm at the place of grafting.
- On selected root stock seedling, two pairs of bottom leaves are retained and the other leaves are removed with a sharp grafting knife.

- Then the terminal shoot is decapitated at a height of 15 cm (where soft wood portion is available for grafting).
- A cleft of 6-7 cm deep is made on the decapitated stem.
- From the inner sides of the cleft a little portion of wood is removed at the tip.

b) Preparing the scion stick for grafting

- If the scion stick is longer, then it should be reduced to a length of 10-12 cm by cutting off the excess portion at the bottom. Very short scion sticks should be discarded.
- The scion stick should be carefully mended into a wedge shape of 6-7 cm long. However, care must be taken to retain the bark on either side of the wedge. The cut surface should be smooth and it should not be soiled at the time of preparing the wedge.

c) Grafting operation

- The wedge of the scion is inserted carefully into the cleft of the root stock. If the scion is thicker in girth, then care must be taken to match the cambial layers of both root stock and scion at least on one side with the help of finger.
- Then the graft joint is secured firmly with a polythene strip (2.0 cm wide, 30 cm long and 100 gauge thickness).
- Then a long and narrow white polythene cap (20 cm x 4 cm size and 200 gauge thickness) is inserted on the grafted plant.
- After 3 weeks, the polythene caps are removed gently and the grafts are shifted to open area in the nursery.
- At the time of removing the caps, about 70-80 per cent of the grafts show sprouting.

6. SEASON OF GRAFTING

Monsoon season (June-November) is the best season for grafting under the weather conditions of Dakshina Kannada (West Coast) and a graft success of over 80 per cent can be obtained due to favorable weather conditions and availability of proper mature scion sticks. During other season the graft success varies from 50-60 per cent due to non availability of proper mature scion sticks in sufficient numbers and less favorable weather conditions. However, soft wood grafts can be produced

almost throughout the year with a mean graft success of 65-70 per cent. Grafting may be suspended during Dec-Jan as there will be poor graft success in winter.

7. MANAGEMENT OF GRAFTS IN THE NUSERY

Generally the cashew grafts produced during monsoon season (June- November) are to be maintained in the nursery till the next planting season (July-August). Therefore, the following points should be considered:

- In the nursery, the grafts should be arranged in beds after spreading black polythene sheet on the ground to prevent the grafts from striking their roots into the ground. Otherwise, frequent shifting of grafts from one place to another place is required which involves labour.
- The grafts should be watered daily depending upon the weather conditions.
- During heavy rainy season, if water stagnation is observed in the bags, then the excess water may be removed by pressing the sides of the bags.
- During summer, the grafts should be provided with partial shade by erecting pandal and covering with agro shade nets (35-50% shading). As soon as the monsoon starts, the shade should be removed. Complete shading should be avoided as it results in lanky and weak growth of grafts. Laminated shade nets (35% shading) may also be used.
- During rainy season, the grafts may be sprayed with bordeaux mixture (1%) at 10-15 days interval. Spraying should be done when the weather is clear.
- The grafts may be sprayed with systemic insecticides such as monocrotophos (1.5 ml/litre) to control insect pests such as tea mosquito, leaf minor, leaf eating caterpillars etc.
- The side shoots arising from root stock portion of the grafts should be removed frequently.
- During November/December, the flower panicles coming from the grafts in the nursery should be removed frequently.
- After 4-5 months of grafting, the polythene strip should be removed from the graft joint. Otherwise, there will be girdling at the graft joint. However, the polythene strip should be removed before selling the grafts.
- After three-four months of grafting, the bottom leaves on the root stock portion of the graft should be removed.

8. COST OF GRAFT PRODUCTION

On an average 65-70 per cent saleable grafts can be realised on commercial scale. The estimated cost of production per graft varies from Rs.13/- to Rs.14/- depending upon the cost of inputs (cost of materials and labour).

9. GRAFT PRODUCTION UNDER LOW COST POLYHOUSES

By employing low cost polyhouses, softwood grafts can be produced almost throughout the year. Low cost polyhouses prepared from casuarina poles/areaca reapers etc. and covered with Silpaulin brand plastic film (natural colour) of convenient dimensions (preferably 11 m long and 6 m wide sheets with eyelets at regular distance) may be utilized for grafts production. The height of polyhouse in the centre should be 2.0-2.25 m and the height in the sides should be 1.0 m. Depending upon the cost of material (Silpaulin sheet, poles, GI wire etc.) and labour, each polyhouse may cost about Rs. 3000/-. Each polyhouse may accommodate about 4000 filled bags of 25 cm x 15 cm size and about 6000 filled bags of 20 cm x 12.5 cm size. Raising of rootstock seedlings, grafting of rootstocks and further maintenance of grafts can be done inside the polyhouses. This will save the labour required for supplying root stock seedlings from nursery area to grafting shed and shifting of grafts from grafting shed to nursery area. The polyhouses will also give protection to the seedlings and grafts during heavy rainy season and reduce the mortality due to fungal diseases. The plants may be watered using hose pipe fitted with a fine rose. Misting units may also be fitted at suitable points and switched on for about 5-10 min at an interval of 2 hours from 10 AM to 6 PM during summer months. This reduces the temperature build up inside the polyhouses. During summer months the Silpaulin sheet has to be removed and shade net (35-50% shade) is to be used.

10. GENERATION OF CASHEW PLANTING MATERIAL

Government of India, realizing the viability of the softwood grafting technology, has come forward during the VIII Five year plan to establish Regional Nurseries in different cashew growing States. Today we have 83 units of Regional Nurseries in the country supported by Directorate of Cashewnut and Cocoa Development (DCCD), Ministry of Agriculture, Cochin. These nurseries have the production potential of over 80 lakh grafts annually. From 1992-93 to 2000-2001, these Regional Nurseries could produce and supply about 3.77 crores of quality planting material to the farmers and development agencies, covering an area of about 1.70 lakh ha. With the area expansion taking place with high yielding clones, we will be able to achieve the requirement of one million tons of rawnuts for processing in India.

11. IMPORTANT DO'S AND DONT'S

- The length of scion should be 10-12 cm with pencil thickness.
- Very short scions and very thin scions should not be collected for grafting.
- For raising uniform and vigorous root stocks, always collect seeds from a single variety block and use graded seeds (mediums size and dense seeds).
- Application of good quality compost / cattle manure is a must to raise healthy and vigorous seedlings with proper stem girth.
- Pre-soaking of seeds for 12-24 hours helps in quicker and good germination.
- Seeds should be sown at weekly/fortnightly intervals to get continuous supply of desired root stock seedlings.
- To control the collar rot incidence in the germinating seeds and young seedlings of less than one month old, spraying of Bordeaux mixture (1%) during rainy season at 10-15 days interval is to be done.
- At the time of grafting two pairs of bottom leaves should be retained on the root stock and a cleft of 6-7 cm deep is to be made at a height of 15-20 cm.
- The scion should be mended into a wedge shape of 6-7 cm length.
- The cut surfaces of the wedge should be smooth and they should not be soiled or disturbed by touching with fingers.
- At the time of grafting, the cambial layers of both rootstock and scion should be aligned atleast on one side with the help of finger.
- The graft joint should be secured firmly with a polythene strip of 2.0 cm width and 30 cm length and 100 gauge thickness. Thicker gauge strips should not be used, as this results in loose tying and failure of graft joint to heal. Moisture may also enter through the graft joint resulting in rotting at graft joint.
- The grafted plants should not be allowed to strike their roots into the ground. In order to overcome this problem, arrange the grafts on black polythene sheet (300 gauge thickness) in the nursery.
- During summer months the grafts should be provided with partial shade (< 50% shade) using agro shade nets / coconut fronds. Complete shading should be avoided. Shade nets should be removed when once the monsoon sets in.
- The suckers arising from rootstock portion of the graft, and flower panicles arising from scion should be removed.
- The polythene strip from the graft joint should be removed after five months of grafting, before girdling takes place at the graft joint.

- Before sale, the grafts in the nursery are to be hardened by withholding water or watering on alternate days.

- Low cost polyhouses may also be used for graft production. Raising of root stock seedlings, grafting and maintenance of grafts etc. can be done inside the polyhouses. This will save labour required for shifting of plants. The polyhouses will also give protection from rains and incidence of collar rot will be minimum.

References

Swamy, K.R.M. 1994. Vegetative Propagation in Cashew. In: **Advances in Horticulture Vol.10 - Plantation and Spice Crops Part-2** (Eds. KL Chadha and P Rethinam). Malhotra Publishing House, New Delhi. pp 671-688.

Swamy, K.R.M. 1997. Technology for planting material multiplication in cashew. **The Cashew**. **11**(1):23-32.

Swamy, K.R.M., Nayak, M.G. and Nagaraja, B. 1998. Soft wood grafting and nursery management in cashew. **NRCC Tech. Bull.** No.6. 18pp. National Research Centre for Cashew, Puttur (Revised and reprinted).

ESTABLISHMENT AND MANAGMEENT OF CASHEW ORCHARDS

J. Dinakara Adiga
Senior Scientist (Horticulture-Fruit Science)
ICAR-Directorate of Cashew Research, Puttur
jd.adiga@icar.gov.in

A) Selection of site and soil management

Great harm has been done to cashew cultivation by notions like "cashew is very modest in its soil requirements and can adopt itself to varying soil conditions without impairing productivity". As a result, the worst soils have always been selected for cashew, where no other crop could give an economic return. As a matter of fact, cashew performs much better on good than on poor soils, but its yield potential has never been tried out on good soils, using the best available plant varieties, fertilizers and pesticides such as those used for other crops to which cashew is compared.

To get fairly economical return from cashew it is always preferable to select proper land suitable for cultivation. It is well known fact that cashew is fairly deep-rooted crop with its active roots concentrated in the first 1 m depth of the soil and 2 m radius around the trunk of the tree. So, soil should be minimum 1.5m deep without any hard laterite substratum or granite or any other hard pan which obstructs root growth.

The best soils for cashew are deep, friable, well drained sandy loam soils without a hard pan as explained above. Presence of water table at 5 to 20 m deep is quite congenial for this crop. Deep red laterite soils are also very much suitable for this crop.

The land should be exposed to sunlight all round the day. The crop comes up well even in the very slopy land also provided proper soil conservation measures are followed.

Soil management

In general the crop received minimum attention by the farmers. The crop is mostly raised in poor soil which require proper management to enrich fertility level.

In the case of slopy land, particularly in Kerala and Dakshina Kannada district of Karnataka the soil is very poor. Owing to frequent exposure to weather conditions, particularly heavy rainfall the top soil is almost completely eroded and the subsoil with poor nutrient reserve is exposed in the elevated and slopy lands. If the crop is planted in such soil the yield/tree is generally poor provided, proper soil management is not followed. The following soil conservation measures can be taken up to improve the soil fertility subsequently.

(i) Filling of natural gullies

The natural gullies formed during the rainy seasons have to be filled up at lower level at regular distances with, boulders and soil and planting of grasses which bind the soil very quickly and reduces erosion of fertile soil. In due course of time the gullies are filled up with soil settled at depressions. If the gully checks, as discussed above, are constructed at regular distances, erosion of fertile soil can be arrested.

(ii) Contour bunding

Depending upon the slope of the land the contour bunds of 60 cm height and 2m width at regular distances can be formed to check soil erosion during rainy season and to conserve moisture during pre-monsoon and post monsoon showers. The distance from one bund to another bund will depend upon the degree of slope. If the slope is more than 25%, the spacing from one contour bund to another is around 8m. The crop can be planted at 8m distance along the contour line to further check soil erosion.

(iii) Terracing

By second or third year of planting terracing of 1.8m radius around the trunk of the plant has to be done by cutting across the slope and spreading below. So that the water received through rain drop, runoff or seepage is absorbed directly to the soil within 1.8m radius around the trunk of the plant to make it available to the root zone. This minimises soil erosion, nutrient loss through runoff etc. A catch pit across the slope at the periphery end of terrace is to be provided for withholding water during pre-monsoon and post-monsoon showers in the slopy area. A small channel sidewise connecting the catchpit is to be provided to drain out excess water during rainy season. If the terracing is done after 3 years the roots of the crop get damaged while levelling. As a result the crop suffers. In the levelled land the base of the plant is raised by applying soil all around wherever there is likelihood of water stagnation during rainy season.

(iv) Growing cover crop

The cover crop seeds like Peuraria phasioloides, Calapagonia muconoides, Mimosa invisa @ 7.5 kg seeds/ha on the contour bunds and also in the interspaces of the main crop at 3 to 4 m distance are to be sown by loosening top soil enriched with farm yard manure with the onset of monsoon. The cuttings of Mucuna bracteata can also be planted at 3 to 4 m distance.

Depending upon the fertility and moisture holding capacity and rainfall the cover crops spread and cover the entire ground within two to three seasons. Excess growth of the cover crop can be cut and the cut materials can be spread at the base of the plant as mulch. The cover crop not only conserves moisture, by checking evaporation and reducing soil temperature but also

improves the soil fertility level by adding organic matter to the soil in the process of recycling. It also fixes atmospheric nitrogen and make available this nutrient to the crop steadily. The cover crop even checks growth of noxious weeds like Eupatorium odoratum and Pennisetum polystechyon by its smothering effect and competition. For the early establishment of cover crop in the beginning, the uprooting of noxious weeds and other jungle growth should be done.

B) Recommended Agro techniques

Till recently cashew plantation received very little attention. An analysis of production figures in India shows that the increase in production has not been proportionate to the increase in area under cashew. Cashew plantations are raised in marginal land where no other crop can give an economic return.

The reason for the low production can be attributed to a large proportion of the plantations consisting of seed sown seedlings under poor management, conceivably the production potential of these plantations is very low.

Cashew can grow on poor or stony soil mainly due to its extensive root development and thereby, increasing greatly the available volume of soil from which it can draw nutrients and water. Reasonable yields are obtained as long as there is sufficient soil between the stones to allow the roots to penetrate and specially if deeper, more favourable soil layers can be reached. Crops with less extensive root system might perish on such soils. Scientific management of cashew orchards has become imperative to increase the production of cashewnuts to the maximum extent possible within the shortest time.

Land preparation, manuring, irrigation, drainage, cultural operations, weeding, mulching, cover cropping, pruning, high density planting and intercropping are some of the important aspects to be considered for improving the production potentials of the cashew orchards.

Land preparation and sowing of cover crop seeds

With the onset of monsoon the land must be cleared of all bushy growth and noxious weeds. Soon after the receipt of pre-monsoon showers the stumps of bushy growth should be uprooted and the noxious weeds are also uprooted when the soil is soft with moisture. Soon after that with the onset of actual monsoon season the cover crop seeds like Calapagonia muconoides or Mimosa invisa or Peuraria phasioloides should be sown @ 7.5 kg seeds per hectare on the contour bunds if the land is slopy and also in the interspaces of the rows of main crop proposed to be planted. The seeds are sown by loosening top soil enriched with farm yard manure.

The pits of 60 cm x 60 cm x 60 cm (lbd) are opened at 7 to 8 metre distance either following square or triangular method. Hedge row system of planting can also be adopted (the distance between rows 10m and between plants within row 5m). The size of pits is upto 1m x 1m x 1m in soils with hard pan or hard laterite substratum. Opening the pits along the contour line is preferred in slopy area. The pits have to be

filled with mixture of top soil, compost (5 kg) or poultry manure (2 kg) and rock phosphate (200 g). A small channel above the pit is opened to divert water to the sides during rainy season in slopy lands. The run off water should not accumulate in the pit which causes water stagnation during rainy season.

Planting

Planting is done preferably during the first week of June with the onset of monsoon. The soil in the centre of the filled up pit is scooped out. The polythene bag (containing graft) covering the root and soil is removed carefully and the graft with ball of earth intact is separated. The graft is placed gently in the centre of the pit where soil was scooped out and covered with soil and pressed gently. The graft is planted in such a away that the graft union is above the soil level. Sprouts, if any, below the graft union on the root stock are removed with the help off sharp knife. Plastic ribbon covering the union is removed if not done already. Later mulch is provided at the base around the plant to prevent soil disturbance during rainy season and also to suppress weed growth and conserve moisture in the soil. The plant is then staked by erecting. 1 m stick and loosely tied with coir or plastic string.

After care

Sprouts emerging from the rootstock are removed at regular intervals as and when seen. The graft should be allowed to grow by maintaining single stem upto 0.75 to 1 m height by removing sprouts or side shoots not only below the graft union (stock portion) but also above it (only side shoots on the scion portion are removed allowing apical bud to grow). Staking the plant in the second year also by replacing the spoiled and weak support fixed in the first year with strong stick is necessary. When the plant grows to a height of 0.75 to 1 m with single stem, the graft is likely to lodge due to wind blow and hence it has to be staked in the second year also with a strong support.

The flower panicles emerging later in the season need to be removed during the first two years of growth of the graft to boost up proper vegetative growth and thereby achieving proper height and good canopy. The plants are allowed to flower and fruit from third year onwards.

Weak and criss cross branches are removed leaving 4 to 5 strong ones. The canopy of the plant should be round parallel to the ground and vertically semicircular Jettisoning branches on one side only when noticed should be pruned for providing round and compact shape to the plant (open umbrella shape).

Studies on root distribution of a 10 year old cashew trees revealed that more than 90 per cent of the cashew roots are within 2 m radius and maximum depth upto which roots extended was 9.5 m. But more than 90 per cent of the cashew roots are found within 1m depth. The cultural operations should then be restricted to 1 m depth and 2m radius around the trunk of the tree, so that whatever nutrients applied can go to the root zone. Cashew is commonly grown on slopy land in west and east coasts. Soil erosion and leaching of plant nutrients are generally expected in such situations. To avoid soil erosion terracing and catch pit opening are essential.

Terracing and opening catch pit

In the second and third year, terrace of 1.8 m radius around the trunk of the plant is to be formed in slopy areas by cutting the soil across the slope and spreading below. A catch pit across the slope at the periphery end of terrace is to be provided for withholding water during pre-monsoon and post monsoon shower in slopy areas. A small channel connecting the catch pit-sidewise is to be provided to drain out excess water during rainy season.

Manuring

Research findings do indicate that cashew require regular fertilizer application to ensure early and higher yield in new plantation and regular high yields from mature trees. It was reported that a 30 year old cashew tree removes 2.80 kg N, 0.75 kg P_2O_5 and 0.75 kg K_2O per year.

Preliminary trials on nutrient requirements indicated that annual application of 750 g N, 150 g P_2O_5 and 150 g K_2O per tree per year is optimum dose for cashew. It was advised to apply the fertilizer in single dose in post-monsoon season when there is optimum moisture in the soil.

During the first year of planting 110 g urea and 200 g rock phosphate are to be applied. For application of fertilizers, a circular trench of 10 cm depth at a distance of 0.5m from the centre of the trunk is to be opened and the trench should be closed immediately after the application of fertilizers.

In the second year, ⅔ of recommended dose of fertilizer is applied in circular trench of 10 cm depth at a radius of 0.75 m away from the plant and covered with soil immediately.

From the third year onwards, full dose of fertilizers is applied at the radius of 1.5m away from the plant to the circular trench of 25 cm width and 15 cm depth and covered with soil.

Irrigation and drainage

Cashew being a hardy crop with extensive root system can absorb soil moisture from deeper layers and in general the crop is not irrigated. However, in initial stage cashew may require irrigation in summer especially in sandy soils. The experimental results showed that with irrigation cashew yield can be increased to 1.5 to 2 times. For a grown up tree i.e., four years onwards irrigating @ 200 litres per tree once in fifteen days from January to March is beneficial. Drip irrigation right from planting upto seven years @ 60-80 litres per tree once in four days was also found equally beneficial. Care must be taken to see that plants are irrigated only after flowering. Depending upon varietal character irrigation should be started one or two weeks after flowering. Hence, wherever irrigation facilities are available, the crop can be irrigated to get more yield and profit. Cashew cannot withstand water stagnation, flooding or impeded drainage. Adequate drainage should be provided wherever there is possibility of water stagnation.

Weeding

Weeds may compete for nutrients, moisture and also for light with cashew plants. Keeping the cashew orchards free of weeds is one of the important aspects of management. The first round of weeding may be done before heavy rains and fertilizer application (June) and the second weeding may be taken up during fertilizer application which falls normally in the month of August-September. Weeds have to be slashed or uprooted before seed setting in weeds so that multiplication of weeds is reduced considerably. In the initial two to three years of the establishment of graft in the main field, weeds are to be removed 2 m around the plant. The weeds prevailing in the remaining interspaces are to be slashed twice annually.

Mulching

Mulching the cashew plantations with organic matter prevents weed growth, reduce surface evaporation, during summer regulates the soil temperature, improves the soil fertility and also prevents soil erosion. Therefore, green matters obtained during weeding may be utilised for mulching the plantations at the base of the respective trees.

Pruning

Cashew is sun loving tropical tree and does not tolerate excess shade. Providing uniform sunlight to each and every part of the canopy therefore assumes major importance to increase the production. Though regular pruning is not advisable for cashew owing to its exuding gum resins from the cut ends, whenever the trees and branches are over crowded the excess branches may be removed for facilitating uniform and maximum interception of sunlight by the crop canopy.

ORGANIC FARMING IN CASHEW

N Yadukumar,
Rtd. Principal Scientist
ICAR-DCR Puttur

Introduction

Cashew is grown over an area of 10.07 lakh ha with a production of 7.36 lakh tons in India. The cashew is generally grown on least fertile soil. Added to this cashew is a neglected crop. Result is non-exploitation of full yield potential. Fertilizer management in cashew is very much crucial. Because, cashew being totally neglected crop does not receive manure at all. If fertilizers are applied significant increase in yield is realized there by exploiting maximum production potential of the crop. Considering average annual removal of major plant nutrients at the present level of production by six and above years old cashew trees and total productive area under cultivation in India the total nutrient removal from soil is up to the tune of 185 thousand tons of N, 40.24 thousand tons of P_2o_5 and 120 thousand tons of K_2o annually. Actual estimated addition of the nutrients through fertilizer application is meager for the reason that only 20% of the total area (1, 43,250 ha) under cultivation receives fertilizers. If we take this into account 11.17 thousand tons of N, 2.99 thousand tons of P_2o_5 and 2.7 thousand tons of K_2o are applied through fertilizers. This much quantity of fertilizers is too low compared to any other horticultural crop

Though cashew tree sheds 20-40kg leaves and apple annually 50% of this is used for composting and application to other important crops like Areca nut, coconut and rice in west coast and East coast region where cashew is generally grown in addition to the above crops. There is a local practice of collecting cashew leaf litter at the time of harvest of the crop which coincides with summer season and apply the same to cattle shed where it undergoes half decomposition due to presence of cow dung and cow urine and trampling of the biomass. Such half decomposed biomass instead of applying to cashew garden goes to other important crops like areca nut, coconut and rice. Occasionally cashew leaf litter is also collected for fuel purpose. These practices lead to general depletion of nutrients in cashew garden every year there by reduction in productivity. If the above mentioned huge quantity of biomass is properly utilized for application to cashew garden considerable quantity of nutrients can be retained for replenishment of nutrients. Appreciable quantity of nutrients present in the crop residue often not recycled in to the system in a systematic manner. The potential nutrients in recycling of biomass generated in cashew has been quantified as 33.8 kg N, 17.6 kg P_2o_5 and 20.6 kg K_2o/ha/year and considerable quantity of other essential elements including micronutrients (Anonymous, 2003). These organic forms of nutrients improve soil health through their effect on soil physico-chemical properties and microbial actions. All the same, use of chemical fertilizers is the easiest way of boosting crop yield. However, its increasing cost and removal of subsidies to the farmers and environmental problems the farmers are inclined to prefer organic manure to inorganic manures. The farmers of the developed and developing countries are beginning to realize the harmful effects caused by excessive use of chemical fertilizers and pesticides on the food crops produced. Those who are already conscious of the problem are now focusing attention on cost-effective and nature-friendly technologies, partly owing to the reason that present agriculture based on chemical fertilizers is becoming less and less competitive and partly also in response to the changing consumer preferences for farm produce free from chemical contaminants. Such farmers are evincing interest in leaning towards organic agriculture as

an alternative farming system. Though integrated nutrient management involving application of both organic and inorganic manuring is suggested to be the best, it is not catching up to the expected level. Technological interventions for organic production of cashew are discussed in this paper.

Varieties recommended for organic farming

Only mid and late season varieties are best suited for organic farming. The reason being that in early season varieties the crop flushes early and flowers early, which attract maximum infestation of tea mosquito. Because it is during this period (November-January) the climate is cool and dewfall during early morning followed by cloudy day results in maximum spoilage of the flowers due to highest infestation by the Tea mosquito Bug. Mid and late season (February-April) varieties escape this. Due to increased temperature during flowering and fruiting in mid and late varieties the tea mosquito population comes down thereby the crop damage due to TMB is minimum or nil. As such, control of TMB does not arise under such situations. However, under extreme changed weather conditions favorable to sudden out break of TMB controlling this pest even with chemical means is also difficult. Some of the most promising mid and late flowering varieties released are given below.

Mid season flowering varieties.

Bhaskara, Dhana (H1608), Dharashree, Amrutha (H1597), Priyanka (H1591) BPP-8, V-4, V-7.

Late season flowering varieties.

Ullal-1, Chinthamani-1 and Madakkatara-2

Production of vegetatively propagated cashew grafts organically.

The pot mixture used for raising seedlings meant for grafting should contain organic manure (cow dung), rock phosphate and biofertilizers. The potting mixture should have one1/3rd soil, 1/3rd cow dung and the remaining 1/3rd sand and 5 g each of Azospirillum, pseudomonas and Aspergillus biofertilizers and 5 g of rock phosphate. Bags filled with potting mixture is kept for raising seedlingsorganic

Planting pit and spacing

Planting grafts in bigger pit of size one cubic meter size after filling 2/3rd depth with topsoil, farmyard manure of 5kg/pit or 2kg poultry manure or 1 kg castor cake/pit is recommended. Planting of cashew grafts should be at 2/3rd depth and after planting it should be properly mulched. Normal soil and water conservation measures like terracing with crescent bund (Rejani and Yadukumar, 2007) should be taken within three years after planting. Spacing maintained can be 8M x 8M, 10M x 5M under normal density planting system and 5M X 5M, 6M X 4M under high density planting system.

Organically recyclable biomass waste (crop residue) available in cashew garden as potential nutrient source.

In general every year considerable quantity of leaf litter and cashew apple are available at the base of the crop if the same is not taken away from the location. The cashew leaf litter, apple waste and weed biomass collected at the base of the plant is to the tune of 40 kg/tree/year. When it is decomposed 65 % recovery can be expected. This amounts to 26 kg of biomass. This half decomposed biomass contains around 0.65 % N, 0.41 % P, 0.45 % K, 0.22 % Ca, 0.19 % Mg, and 369ppm Fe, 14.6ppm Cu, 16.5ppm Zn and 283 ppm Mn (Yadukumar and Nandan, 2005). The total macronutrients added to the soil when above biomass is incorporated will be approximately 169g N, 107g of P_2O_5 and 117g K_2O/tree. Soil mineralisation also takes place in the system thereby releasing the nutrients in available form. In addition to the utilization of native soil nutrients cashew requires additional quantities of nutrients for economical yields.

Results of the organic manuring trials

In an experiment conducted at NRCC, Puttur (2000-2003) it indicated that application of 20 kg poultry manure alone with soil conservation technique (With crescent bund) increased the yield by 80 per cent compared to control plot (Table.3). Subsequently to understand the performance of the crop for different combinations of organic and inorganic manures a trial was laid out in 2002 and continued up to 2003 on six and seven years old cashew trees (NRCC Selection 2 variety). The results indicated that application of biofertilizers-Azospirilum with the compost of organically recyclable biomass (ORB) available in cashew garden to meet 100% N requirement gave the highest yield of 1.053 t/hectare on the seventh year where as in the previous year it gave minimum yield. This indicated that in the long run this treatment is good. Next highest yield obtained from plot receiving 50-75 % N through inorganic fertilizer and remaining 25-50% N through compost of organically recyclable biomass (1.02 and 1.03t/ha, Table 4). Compost of ORB available in cashew garden was prepared by adding 20% of weight of total biomass with cow dung slurry. The compost so prepared contained 1.6% N, 0.54% P and 0.4% K and considerable amount of other of micronutrients. The procedure to convert cashew leaf litter and waste apple available in cashew garden into suitable compost material in a large scale is standardized at NRCC, Puttur

Preparation of Vermi compost

Attempt was also made to prepare Vermi-compost from the recyclable biomass available in cashew garden especially cashew leaf liter and apples. Cashew leaf litter and apples are allowed to decompose for 20 days after mixing with 15 % cow dung slurry. Then the material is fed to earthworms that were developed previously in plastic bucket by feeding cow dung material. Vermi compost chambers can be prepared as per the following details. Simple structure of chamber with 1.5 M height, 5 M long with 1.5 M width measurement is erected. At the bottom the chamber there should be a cement channel to fill water to prevent entry of ants. The chamber should be shaded during summer and protected from rain during rainy season by covering with shaded nets and silpauline sheet or any local thatching materials like coconut or areca nut leaves spread over the roof constructed specially for the purpose. For drainage of Vermi wash a hole should be provided which is connected to a tank with PVC pipes so that the Vermi wash can be utilized as liquid manure. Percent recovery of

compost will be 65%. The compost should be sprinkled with sufficient quantity of water as and when moisture level reduces below 40 %. For this, once in 4 days the water should be sprinkled so that the biomass always in wet condition. Nearly 750-Kg compost can be obtained from 1000-kg cashew recyclable biomass. The vermi compost contained 1.21 % N, 0.898 % P, 0.59 % K, 2.75 % Ca, 0.82 % mg, 29.66ppm Zn, 24.26 ppm Mn, 12.23 ppm Cu and 162ppm Fe. Population of useful bacteria, Fungi, actinomycetes, azospirillum are 39 x 10^6 , 39X10^5, 28x 10^5, and 0.52x 10^4 cfu (colony forming units) respectively (Yadukumar, 2007).

Nutrient management in organic farming

In the case of high density planting system it is proved beyond doubt that the recommended doses of nutrients are not required 6/7 years after planting since the crop canopy increases every year and covers the ground completely when the age of the crop reaches 6/7 years. It is at this stage crop does not perform in terms of yield and every year if we add lot of external nutrients as per the recommended doses the result will be unwanted increased vegetative growth and overlapping of branches causing heavy shade and consequent decreased flowering and fruiting resulting decreased yield. In high density planting system the leaf deposit/unit area is more than two times compared to normal density planting system. This huge deposit of leaf litter and apples contribute natural build up of nutrients in soil, which serves as rich source of nutrients. Every year external nutrient application has to be reduced. Studies on Nutrient management indicated that 1/3rd of recommended doses will be enough for maintaining cashew plantation when grown in high density planting system

In view of growing demand for organically grown cashew, strategies need to be developed for organic farming. Some of the commonly available organic farming manures like poultry manure, farm yard manure (FYM), vermicompost, oil cakes, coir pith-organic manures mixture hold promise in Cashew in organic farming and the same is under investigation at this National Research Center for Cashew. There is high potentiality to utilize cow dung slurry in major cattle cow dung producing states. Approximate quantities of cow dung available in different States are given in Table-5.

In addition to the above manures, poultry litter, and oil cakes are also available in huge quantities in most of the States. Green leaf is in abundance in Kerala, Coastal Karnataka and Maharashtra, where mostly cashew is grown. The green leaf can serve as good organic manure to cashew. Green manure crops like glyricidia, pongamia can be grown very well under rain fed conditions on the border or inside cashew plantations to produce green manure. Approximate nutrient contents in each kind of organic manure are given in Table-6

While considering the quantity of nutrients available in soil the approximate quantity of manure (organic manure) required meeting the recommended dose of Nitrogen of 500g/tree is presented in Table.6. The recommended dose of Nitrogen has been arrived based on the trials conducted in various Research Stations. In organic manure availability of nutrients normally stretches for longer period and in addition the loss of nutrients through leaching is minimum. Hence we need not apply the quantity of organic manure to the extent of actual nutrients requirement, which we otherwise calculate, when we require applying in the form of inorganic manure.

Due to nutrient loss through seepage, runoff and denitrification, hardly 50 per cent of nitrogen and 75 per cent of the applied K_2O will be made available to the plants if we apply

these nutrients through chemical fertilizers whereas, such nutrient loss is negligible in the case of organic manures. Detailed study on this aspect need to be taken up for suggesting options to farmers like, the exact quantity of different organic manures to be applied/tree depending upon the availability of these manures in the respective local markets.

The quantity of organic manures mentioned in Table.7 will meet the full requirement of P_2O_5 and K_2O in all cases except in the case of green manure and groundnut cake. When groundnut cake and green manures are used, bone meal and wood ash may be suggested to supplement P_2O_5 and K_2O requirements if the farmer prefers producing cashew organically, which fetches almost 30 per cent increase in price.

Green manuring

Leguminous crops such as *Peuraria javanica*, *Calapogonia muconoids* and *Centrosema pubescens* and *Glyricidia maculata* enrich the soil nutrients, add organic matter, prevent soil erosion and conserve soil moisture. The seeds of these cover crops can be sown in the beginning of rainy season with a seed rate of 12 kg/ha in the interspaces of cashew orchard. Beds of 30cm x30cm are prepared in sloppy degraded soils by loosening the soil and mixing compost or cow dung. Then the seeds are sown in the beds should be covered by a thin layer of soil. Presoaking of the seeds in water for 6 hours ensures better germination. Fencing is necessary to avoid cattle grazing. In addition to utilization of recyclable cashew biomass waste glyricidia can be grown in the inter space between two rows of cashew and yearly with three cuttings 60kg green biomass of glyricidia can be produced which can be added to base of the cashew plant (Yadukumar *et al,* 2007). In one-hectare area cashew plantation nearly 7 tonnes of dried green biomass can be produced and applied to cashew that is equal to application of nearly 186kg N, 40 kg P_20_5 and 67 kg K_20/ha/year. This will meet entire nutrient requirement of cashew and it was found that the same yield could be achieved compared to the plot receiving recommended Package of Practices.

Inter and mixed cropping

Leguminous crops like horse gram, cowpea, and other crops like groundnut; tapioca, vegetable and fodder crops etc are grown as intercrops in cashew plantations. Out of the annuals, biennials, fruit crops and tree species when grown as inter/mixed crops pine apple has been found the best intercrop in cashew garden for the first 7 years (Yadukumar$_1$, 2007). Pine apple could be grown in the interspaces of two rows of cashew. Between two rows of cashew three trenches have to be opened across the slope between them and size of trench should be 1M width 0.5M depth and any convenient length. In each trench two rows pineapple suckers should be planted at 60 cm between rows and 40 cm between two suckers within a row. In each trench for 1 M length half basket of compost should be added and mixed with soil before planting pineapple suckers. One-hectare cashew orchard can accommodate 15,000 pineapple suckers. Pineapple starts yielding from 2nd year and from 4th year it should be replanted in a new trench dug out by the side of existing trench and the same can be retained till 7th year of cashew plantation. After seven years because of heavy shade of branches of cashew over the pineapple and due to difficulty in picking raw cashew nuts fallen over pineapple plants it may not be feasible to grow this intercrop economically. Nearly 40 tons of pineapple fruits can be expected for sven years with a net return of about Rs. 2 lakhs. Expenditure would be Rs. 1 lakh and hence net profit from pineapple alone will be Rs.1 lakh in one ha of cashew garden. Apart from gaining a net profit of Rs.1lakh from

pineapple 30 % increase in cashew nut production was observed mainly due to better soil and water conservation in trenches where pine apple is planted across the slope between two rows of cashew.

Other crops like turmeric, ginger and elephant foot yams can be grown as intercrops organically for the first 5 years of cashew plantations. The profit realized from these crops may range from Rs. 20,000 to 50, 000/ha

Ample scope is there to grow vanilla and pepper as mixed crops with cashew if irrigation facility is provided. *Garcinia indica (kokum)* can be grown as mixed crop by maintaining same population as that of main crop-cashew (200 each/ha). All the above crops are grown organically as mixed crops.

Weed management

Generally weeding in cashew can be done twice a year. One weeding in the month of august during manure application and another weeding can be done just before the start of flushing and flowering (October or November). The weed biomass can be effectively recycled as that of cashew biomass waste explained earlier.

Management of Tea Mosquito Bug (TMB)

Tea mosquito bug can cause yield reduction to the tune of 30-40% by damaging tender shoots, inflorescences and nuts. Both adults and nymphs of TMB suck the sap from tender shoots, panicles and immature nuts and apples which results in formation of black lesions. These lesions on shoots and panicles coalesce causing shoot blight or blossom blight. The plants can escape TMB attack if the new flush is delayed. Planting mid season or late season flowering varieties would be the right strategy to escape TMB. Even early flowering varieties also flower 10-15 days late if the plants are grown organically compared to chemical fertilizer applied ones (Table-8). The delay in flowering naturally minimizes the incidence of tea mosquito by escaping multiplication of tea mosquito population. Clean cultivation is another method to check multiplication of TMB considerably. All weeds should be removed and heaped as mulch Encouraging multiplication of weaver ants (*Occoyphylla smargdina*) checks the TMB. The red ants also feed on the nymphs of the tea mosquito bugs. In the initial stages placing small pieces of jaggery at the cracks and crevices of the bark can attract the red ants

At National Research Centre for Cashew, plot of 2.5 hectares is maintained for the last 4 years and here though initially the Tea mosquito damage was noticed in small pockets, no economic loss of yield was observed. Studies on the effect of various organic pesticides like Pgalada, Phytozeal and phalini in late variety-NDR2-1 indicated that combination of Phytozeal and phalada resulted in maximum yield with minimum Tea Mosquito damage (Table-9). Phalada IIIc1 is a herbal based liquid insecticide certified as 100 % organic insecticide by Skal International (Certifying agency based at Netherland). The contents of this herbal preparations are combination of water and extracts of *Saptora japonica* roots (2%), *Annona reticulata* seeds (15 %), *Adathoda vasaka* (leaf-12 %)), *Sapindus trifolatus* (30 %), *Pongamia pinnata* (20 %). Phytizeal is a herbal based liquid insecticide combined with vermiwash which served as good nutrient source also. Phytozeal contained vermiwash (90 %) Plant extracts of *Lantana camera* flower (0.%), *Cynadon dactylon* grass (0.5 %),

Seaweed (5 %), *Calotropis procea* (2 %) and extracts of *Pseudomonas fluorescence* (0.1 %) and *Trichoderma viridae* (0.1 %). Phalini is diluted form of cashew nut shell oil mixed with water. In another observational trial it was found that tea moasquito damage score is more in both Bhaskara and Ullal-3 variety in conventional farming compared to organic farming (Table-10)

Management of Cashew Stem and Root Borer

Older cashew trees are more prone to infestation by CSRB. Adult female beetles lay eggs in the bark crevices of the stem (near to the collar region) or on the exposed roots. After hatching, the young grubs tunnel immediately into the bark of the trunk or root regions. Due to extensive feeding by irregular tunneling in the bark, the translocation of the nutrients is hampered leading to drying of leaves and twigs. In the infested portions the gum and frass (chewed fibres and excreta pellets) start oozing out from the tree, which is the initial symptom of pest attack. Curative measures should be taken up immediately which are given below.

The infested portion having frass below the bark on either the main stem or root portion (after suitably digging the soil to a depth of 2 ft) should be carefully chiseled to inflict minimum damage to the bark and tunnels should be tracked towards the fresher frass to locate the CSRB grubs, which should then be removed and killed. In case, white powdery fibres are seen it indicates that the grubs have entered to the heartwood for pupation. In such cases a pliable wire (for example automobile gear wire) should be inserted deep into the pupation hole and pushed in till a slushy sound is heard/milky white fluid flows out indicating damage to the grub or pupa. Later chiseled portion of the bark should be swabbed with 10 % Bordeaux paste. When a paste of cow dung and ash is applied to the injured portion of the bark it helps in curing of wounds.

Trees having more than 50 % of the bark circumferences damaged by insect or with yellowing of the canopy hardly ever recover. However, the existence of different pest stages in such trees will act as inoculums for the next season. Hence phyto-sanitation should be adopted by uprooting such trees, which are beyond recovery and disposed off immediately, along with removal of pest stages in other infested trees to prevent build up of pest inoculums. As the pest incidence occurs during the period of nut collection (Feb-May) the infested trees can be marked and curative measures must be adopted immediately, so that the grubs do not inflict more damage.

Yield

In the experiments conducted at National research Centre for cashew, Puttur on the organic farming the yield realized was to the tune of 1-1.3 tonne per hectare (Table-11 & 12) under high density planting system in the second harvest (4years old plantation).

References

Anonymous , 2003, Developing integrated production packages for enhancing productivity of cashew, 2003, NATP Final Report, NRCC, Puttur, DK, Karnataka: 55.

Yadukumar, N 2003, Organic farming practices in cashew plantations. Recent advances in organic farming technologies in plantation crops, short course:18-27, Nov 2003. edited by george V Thomas and Palanisamy, CPCRI, Kasaragod, Kerala.

Yadukumar, N. and Nandan S L. 2005. Recycling of organic waste of cashew Plantations by aerobic composting- *J. Plantation Crops.* **33**(2): 99-102

Yadukumar N, R.Rejani and S.L.Nadan. 2007. Green manuring for high density cashew orchards. Proceedings of the National seminar on Research, Development and Marketing of Cashew, 20-21st November, ICAR, Research Complex, Goa, pp: 59-61.

Rejani R and N.Yadukumar**.** 2007. Response of cashew plantations grown in slope areas of West Coast region of India for soil and water conservation measures. Proceedings of the National seminar on Research, Development and Marketing of Cashew, 20-21st November, ICAR, Research Complex, Goa, pp: 63-64.

Yadukumar N**.** 2007. Organic farming in cashew. Proceedings of the National seminar on Research, Development and Marketing of Cashew, 20-21st November, ICAR, Research Complex, Goa, pp: 36-46.

Yadukumar**. N_1.** 2007. Development of suitable cashew based cropping systems – inter and mixed cropping with cashew. Proceedings of the National seminar on Research, Development and Marketing of Cashew, 20-21st November, ICAR, Research Complex, Goa, pp: 62.

Table-1: Approximate quantity of nutrients available in soils of different zones (Nutrient kg/ha)

	N	**P_2O_5**	**K_2O**	**Nutrient status**
Coastal Karnataka	120	3 - 43	100	Low to high in N, Low to high in P_2O_5 and low in K_2o
Coastal Kerala	60 – 120	6 – 13	186– 345	Low in N, Low to medium in P_2O_5 and medium to high in K_2o
Maharashtra	156– 479	07 – 2.12	79 – 208	Low to medium in N, Low in P_2O_5 and medium to high in K_2o
Andhra Pradesh (Bapatla)	54 – 71	4 – 6	150-190	Low
Orissa	38-80	15-28	100-150	Low in N, medium to high in P_2O_5 and medium in K_2o

(Source: Collected from reports of AICRP on Cashew)

Table 2: Fertilizer nutrients recommendation in different states (g/tree/year)

States	**N**	**P_2O_5**	**K_2O**
Karnataka	500	125-250	125-250
Kerala	750	325	300
Maharashtra	500	250	250
Andhra Pradesh	500	250	250
Orissa	500	250	250

Source: Annual Report 1997-98, AICRP on Cashew/Cashew Production Technology, NRCC

Table 3: Influence of organic and inorganic manure coupled with soil and water conservation techniques on nut yield of 13 years old cashew orchard (kg/ha)

Treatments	Sub plot treatments			Mean	% of control
	1	2	3		
Individual tree base terracing with catch pit	818.5	946.7	1068.3	944.5	145.2
Individual tree base terracing with crescent bund	1051.1	1212.3	1261.7	1175.0	180.6
Staggered trenches between two rows	831.1	1128.9	1032.0	997.3	153.3
Control plot without any soil and water conservation	560.4	614.4	776.4	650.4	100
Mean	815.3	975.6	1034.6		
CD (0.05) for Soil conservation measures CD (0.05) values for manures CD (0.05) values for interaction	289.75 65.47 NS				

NB: 1=Control (No manure application), 2=Recommended doses of fertilizers (500g N 125 g P_2O_5, 125 g K_2O /tree + 10 kg poultry manure/ tree/ year), 3=20 kg poultry manure

Table 4: Effect of manurial doses on yield five and six years after planting

Treatments (g/tree/year)	Nut yield (kg/ha)		
	5YAP	6YAP	Total for 2 years
No fertilizers	228	669	877
100% N RFD	243	951	1194
Azospirillum+100% N-RCB	206	1053	1259
Azatobactor+100 % N-RCB	212	831	1043
25%N RFD+75 % N-RCB	112	942	1054
50%N RFD+50% N-RCB	300	1024	1324
75%N RFD+25% N-RCB	247	1031	1278
25%N RFD+75%N-PM	258	795	1053
50%N RFD+50%N-PM	315	718	1033
75%N RFD+25%N-PM	222	989	1211
CD for manurial doses		546	

RFD = Recommended Fertilizer Doses. RCB = Recyclable Cashew Biomass available in garden. PM=Poultry Manure. YAP=Years After Planting

Table 5: Annual out turn of wet dung from Cattle and Buffalo (in million tones) and nutrient potential of bovine excreta

States	Million tons of cow dung
Andhra Pradesh	77.389
Kerala	4.538
Maharashtra	107.986
Karnataka	54.806
Tamil Nadu	70.027

(Source: Gaur *et al, 1992.* – Organics in soil health and crop production, Edited by P .K Thampan.

Table 6: Nutrient status of organic manure (g/kg of manure)

Manure	N	P_2O_5	K_2O
Poultry manure	28.7	10.3	13.0
Farm Yard Manure (FYM)	8.0	4.1	7.4
Vermicompost	16.0	22.0	6.7
Green Manure Glyricidia	39.8	7.1	11.8
Cashew waste compost or compost of recyclable cashew biomass	10.5	5.3	4
Biogas slurry	18.0	9.2	8.0
Water Hyacinth compost	20.0	10.0	23.0
Castor cake	58.0	18.0	16.0
Groundnut cake	78.0	15.0	14.0
Pongamia cake	34.0	10.0	12.0
Neem cake	52.0	10.0	14.0

(Source: Organics in Soil Health in Crop Production 1993 by PK Thampan, Pee Kay Tree – Crop Development Foundation, Cochin)

Table 7: Quantity of organic manures required by adult cashew tree (kg/tree)

Manure	Quantity (kg/tree) required	Nutrients supplied g/tree)		
		N	P_2O_5	K_2O
Poultry manure	17.4	500	180	226
Farm Yard Manure (FYM)	62.5	500	256	462
Vermicompost	31.3	500	689	210
Green Manure i) Glyricidia	12.5	500	89	183
Biogas slurry	27.8	500	256	222
Water Hyacinth compost	25.0	500	250	575
Castor cake	8.6	500	155	138
Groundnut cake	6.4	500	96	90
Pongamia cake	14.7	500	147	191
Cashew waste compost	33.0	500	250	200
Neem cake	9.61	500	96	134

(Note: Calculated based on nutrient concentration available in each kind of manure as worked out at NRCC)

Table-8: Time of flowering in different varieties during 2007-08 (50% completion of flowering)

Varieties	Organic farming	Conventional farming
Bhaskara	Dec.2nd week	Nov.4th week
Ulal-3	Dec.2nd week	Nov.4th week
VRI-3	Nov..3rd week	Nov.1st week
Madakkathara-2	Jan.1st week	Dec. 3rd wek
K22-1	Jan. 3rd week	Jan. 1st week
NRCC Selection 2	Nov. 3rd week	Nov.1st week

Table-9: Effect of organic pesticides on the performance of four years old cashew tree (Madk-2)

Treatments	Yield (kg/tree
Phytozeal 5.0 ml/l + phalada IIIC 1.0 ml/l	**3.07**
Phytozeal 7.5 ml/l + phalada IIIC 1.5 ml/l	**3.52**
Phytozeal 10.0 ml/l + phalada IIIC 2.0 ml/l	**4.17**
Phalini (1:30) + Phytozeal 5.0 ml/l	**3.03**
Phytozeal 5.0 ml/l	**3.15**
Control	**1.81**

Table-10: Tea mosquito damage score in different farming systems.

Varieties	Organic farming	Conventional farming
Bhaskara	0.21	0.51
Ullal-3	0.30	2.10

Damage score (1-4), 1 = least damaged, 4 = severely damaged (panicle completely dried)

Table-11: Yield performance for the first four years under organic farming (Mdk2)

System of planting	3rd year	4th year
HDP with irrigation	2.9 kg/tree 1200 kg/ha	3.38 kg/tree 1352 kg/ha
HDP- without irrigation	2kg/tree. 800kg/ha	2.5kg/tree 1000 kg/ha
NDP-with Pineapple	3.2kg/tree 640kg/ha	4.7 kg/tree 940 kg/ha
HDP with turmeric	1.37-kg/tree 548-kg/ha	2.83 kg/tree 1132 kg/ha

Table-12: Variety wise performance of cashew grown organically up to second harvest (4th year)

Variety (HDP)	3rd year, Kg/ha	4th year, Kg/ha
Ullal-3	710	1208
Ullal-2	638	1064
Sel-2	546	544
Bhaskara	506	1212
VRI 3	593	1300
V4	284	1200
Dhana	206	1088
Kanaka	313	1092
Madakkathara2	256	1288
K22-1	273	1432
Priyanka	330	1244
Ullal4	250	1028

REJUVENATION OF SENILE CASHEW ORCHARDS

MG Nayak
Principal Scientist (Hort)
ICAR-Directorate of Cashew Research, Puttur
gangadhara.nayakm@icar.gov.in

Cashew (*Anacardium occidentale* L.) plants at a closer or wider spacing during later years get competition from neighbouring ones for sunlight and slowly start drying resulting into dead wood. Of late, only the top portion of the canopy remains exposed to sunlight and thus slowly trees go senile. Cashew also a fast growing woody perennial is characterized by spreading branches. Canopy of cashew tree gains irregular shape due to its irratic branching habit. Plantations having trees of irregular canopy shape and size are difficult to manage which makes plants to become poor nut yielders in the later years as the lower branches of canopy gradually die and become empty. In India majority of the older cashew plantations are of seedling origin of non-descript material and have poor genetic potentiality and also have gone senile due to poor management practices. Cashew requires more sunlight for its growth and fruiting.

In the past cashew was raised only in degraded and low fertile soils by soil conservation departments, plantation corporations, forest departments and also by famers for the purpose of soil conservation and afforestation. The non adoption of other cultural management practices too lead to poor growth and production from such plantations. Such plantations now have gone senile and there is some scope of improvement through rejuvenation provided subsequently they are managed well. If such plantations are of improved varieties having good genetic potentiality such plantations can be rejuvenated by limb pruning or if they are genetically low yielders they need to be top worked by beheading and grafting with better material for improving the yield performance.The other plantation management practices such as manuring, timely weeding and plant protection are also equally important for rejuvenation of such old plantations. Following some of the agronomic / cultural practices of plantation management can help in rejuvenating / improving the senile orchards.

Soil and water conservation measures

Most of the existing senile plantations are raised primarily to create vegetational cover as a measure of soil and water conservation by the forest departments (Orissa, Kerala and Karnataka). Such afforested areas with cashew cover should be treated as commercial plantations. But due to their existance in the unduating topography, the rain water has free run off and there by making the plantations to starve for moisture during summer season. In order to reduce subsoil moisture stress during summer, in west coast soil and water conservation measures, such as terracing the base of the plant , opening catch pits, terracing with crescent bund and opening pits in the middle of four plants across the slope or opening trenches of one metre width and half metre depth and any convenient length beteen two rows of cashew and burrying the coconut husk can be adopted to with hold water for longer period particularly during the pre and post monsoon showers. In east coast intercept bunds of 100 cm x 50cm x 30cm size are prepared in the cashew plantations. This bunding apart from breaking the velocity of runoff water it helps to impound rain water. Such impounded water in disc ploughed or raked soils, is helpful during summer months.

Application of manures and fertilizers

Poor yields obtained in majority of the existing senile cashew plantations could be partly due to non replenishment of soil nutrients and partly due to washing away of fertile top soil through flash run off. Sometimes nutrient drain takes place due to removal of leaf litter from the plot every year. In senile plantations annual availability of leaf litter itself is to the tune of 3.5 to 5 tonnes / ha (Kumar and Hegde,1999). These leaf litters are generally collected during peak summer season which coincides with picking (harvest) of fallen nuts. Generally just before picking of nuts the ground area is cleared by removing the leaf litter. The same biomass can be decomposed or burnt and the material can be used for manuring the cashew plantations which may meet almost one-third of the requirement of plant nutrients. The pit size can be 1M width, 1M length and 0.5M depth can be dug in the centre of four plants and the waste material can be decomposed *in situ*. This pit will act as catch pit for soil and water conservation.as well as compost pit. Before the onset of rainy season the leaf and apple biomass are collected and applied to this pit. With the receipt of premonsoon showers (one or more showers) nearly 20 % of the weight of biomass waste is applied with cow dung slurry and mixed thoroughly. Later the pit is covered with thin layer of soil.

The biomass in the compost pit undergoes decomposuition through out the rainy season and the compost will be ready towards the end of the season. During the rainy season 2 to 3 times turning of the biomass materials will further enhance decomposition in the pit. Generally there is a practice of appplication of fertilizers and manure at the base of the tree by opening circular trenches at 2m distance. While doing so some of the thick roots are cut in grown up plantation. Wounded roots attract cashew stem and root brer (CSRB) and there is likely hood of severe infestation later killing the trees. In such plots it is advisable to apply manure in pits dug out in the middle of four trees where thick roots are not found and in the same pits cashew biomass waste is also added which will decompose during the reainy season if we follow the above procedure of composting. The research results indicated that nearly 3.5 t/ha composts can be obtained from 5.5 t/ha cashew biomass waste available annually. This means, in terms of nutrient gain 36 kg N, 5 kg P and 16 kg K / ha in addition to considerable quantities of micronutrients and beneficial microorganisms if applied to the plantation in the form of compost (Yadukumar and Nandan,2005). This will be sufficient to meet 46 % N and 25 % of P and 13 % of K requirements annually in addition to sufficient quantities of micronutrients and beneficial microorganisms.

Consolidation of plantations by gap filling/replanting

At present all the old senile plantations have only 40-50% plant population due to the death of trees by CSRB infestation or other causes. Through gap filling with high yielding clones in these plantations can be consolidated and productivity can be increased . If the gaps are more than 50 % replanting with grafts of high yielding varieties may be taken up in phased manner , so that the level of production does not come down drastically. Such a replanting progamme is suggested in the states of Karnataka, Goa, Tamilnadu and Orissa.

Supplementary irrigaton

It is well proven that supplementary irrigation during fruiting season can enhance nut yield in cashew. But everyhwere water may not be available. and not possible to adopt on a large scale. The irrigation can be provided to the trees which are grown in homestead gardens

where the water is available. Two or three irrigations depending on the availability @100-200 litres of water per tree was found to double the yield in a 12 year old plantations (Yadukumar and Mandal, 1994).

Rejuvenation of old trees by pruning

The normal optimum spacing recommended for cashew is 8m x 8m. There is overlapping of canopy, in 8 to 10 years of age depending on the nature of variety unless the canopy is maintained by trimming and thinning. The research results have indicated that simple removal of dead wood, criss cross branches water shoots etc. allows better penetration of light and this has doubled the yield. Therefore in the old and neglected plantations this operation need to be taken up. Manipulation of canopy size and shape by means of pruning and training for its containment and for better yield performance was not felt as an necessary orchard management technique for cashew in earlier days. Plantations which have overlapping branches will lead to dead wood development and decline in yield in the later years. Such plantations can be rejuvenated through canopy redevelopment by limb pruning (Nayak et al., 2008).

The redevelopment of canopy is necessory in the older plantations, where the canopies are over crowded resulting in reduction in yield. This is possible by heading back (limb pruning) the exhausted canopy at 1.0 - 1.50 m height. Immediately after beheading the trees, the prunned wood needs to be removed from the plot so as to prevent the damage by shot hole borers. Remaining portion of the trunk and exposed part of roots is to be swabbed with 0.2 per cent chlorpyriphos at least 2-3 times after beheading till new canopy is developed. Regular checking for the damage by Cashew Stem and Root Borer (CSRB) is to be done and managed. The cut ends of the branches should be smeared with 10 per cent bordeaux paste to prevent the gummosis and entry of any pathogens. The best season for limb pruning is May-June i.e., immediately after the harvest of the annual crop.

The new flushes arise from the dormant buds on the trunk. These new sprouts form the canopy within a period of 6-7 months depending on the variety (Fig. 1 to Fig.2). Yield levels during the first season after pruning are slightly lower while the yield from second season onwards is better than the unpruned plants (Fig. 3 & 4). Yield performance of the 4 varieties during first 2 years after limb-pruning is given in Table 1. It was also observed that cashew varieties such as Ullal-1, Ullal-2, Chintamani-1, K-22-1, NDR-2-1, Kanaka, V-4 and NRCC Sel-2 responded well to limb pruning. The cashew trees after rejuvenation either by beheading or top working are more vulnerable for CSRB attack. The old cashew plantations can be only rejuvenated as explained above, provided they are managed well by taking care of individual plants to prevent damage by CSRB (*Plocaederus ferrugineus)*.

Table 1. Effect of limb pruning on yield of cashew

Treatment	**Yield (Kg/tree)**	
	1st year after pruning	**2nd year after pruning**
A: Variety		
VRI-1	1.62	3.19
Ullal-1	2.95	4.42
VTH 30/4	1.18	4.61
NRCC Sel-1	0.72	1.23

Good phytosanitation procedures are to be adopted to manage the rejuvenated plants. The newly developed canopy needs to be protected from Tea Mosquito Bug (*Helopeltis antonii)* and leaf beetles as they are also more vulnerable for the damage in the initial 5-6 months of canopy development. Care should also be taken to treat the cut wounds with 10 per cent bordeaux paste during the beginning of monsoon season to prevent from any fungal infection and gummosis. If the plants are properly protected the canopy redevelopment can help in enhancing the nut yield to the fullest potential of the plant after 2-3 years. The limb pruned trees be pruned or trimmed as and when requierd in subsequent years. It may be noted that the yield levels of limb pruned trees are much better than the freshly planted cashew grafts of comparable years due to better root system. Pruning operation should be taken up only after complete picking of nuts which coincides with temporary quiscent stage (May-June in West Coast) in cashew (Nayak, 1996, 2007).

Rejuvenation by Top Working

Rejuvenation of old and unthrifty cashew trees by topworking, by grafting with scions of better variety has been developed in early eighties at Agricultural Research Station, Ullal, under University of Agricultural Sciences, Bangalore (Rao, 1985; Guruprasad et al., 1988; Khan et al., 1988) and subsequently modified as per local requirement and popularized by National Research Centre for Cashew and several other cashew research centres in the country.

Though the topworking is a promising technology to rejuvenate the old senile plantations of seedling progeny in a short period, the technology could not be adopted on a large scale due to the problem of CSRB which damages and kills the topworked trees. The technology is being recommended only for the homestead gardens of young age which can be properly monitored and maintained.

Conditions and Points to be considered before top working:

- Age of the tree: Tree should be within 15-20 years age. As far as possible it should have smooth bark and should not have many crevices on the bark at collar region. The colour of the trunk should be brown or ash coloured and not black coloured.

- Trees should not have been damaged by cashew stem and root borer (CSRB): Either the trunk portion or exposed root portion on the ground should be free from stem borer damage. The symptoms of CSRB can be ascertained from the oozing of gum or the powdery mass (frass) fallen near the entry point of CSRB.

- Trees should be healthy enough with spreading lower branches. It should have well developed root system and should have capacity to cope up with the growth of the new canopy. It should be free from other pest and diseases.

Method of Top working

Top working involves two steps (i) beheading of the tree to be top worked and (ii) grafting with a elite material on the new flushes emerging out on the stumps of beheaded tree.

Beheading of the tree

The most suitable time for beheading of the tree is April-May i.e. immediately after the harvest of the crop in West Coast region. It also depends on the fruit bearing pattern of the tree (early, mid and late season) in different varieties. After selecting the tree for beheading, cut the limbs and reduce the weight of the crown and finally retain the stumps of plants at 1 – 1.5 M height (Fig.1). While pruning the limbs, care should be taken so that the bark should not have split or damaged on the retained stump. Immediately after the beheading of the tree treat the cut wounds with 10 per cent Bordeaux paste so that there should not be any gummosis and fungal infection in the wound. After beheading tree the cut plant material should be cleared from the site immediately to prevent the harbouring of pathogens and insect pests.

Grafting

Grafting of new flushes emerging from the trunk of the cut tree can be taken up after 45 to 60 days onwards (Fig.5). About 200-300 shoots emerge from the trunk below the cut end depending on the size of the remaining trunk. On a cut tree about 15-20 shoots of different branches in different directions may be selected and grafting by softwood grafting technique may be taken with the scion material of required or elite varieties (Fig. 6). The period between June to August is most suitable for top working under west coast region. After successful grafting of the shoots remaining ungrafted shoots need to be gradually removed in a phased manner. After about 4-5 months of grafting only about 10-12 successful grafts in different branches in different directions may be retained and rest may be removed. The new flushes emerging from the trunk subsequently also be frequently removed (Fig.7). Initially grafts or shoots may be protected from damage by wind and animal by providing staking and support with sticks. From second year of grafting, the plant will grow into a tree and give flowers and fruits like a normal tree (Fig.8).

In one of the experiments conducted at NRCC on top working, very good success was recorded. In a plantations of young trees of 8 years age of variety Vengurla-2 when top worked with the scion of Vengurla-4 to replace the variety in scion bank, 88 trees out of 94 top worked trees could be successfully saved and managed.

The expenditure involved and the yield performance for initial two years is furnished in Table 2. Studies on large plot trials of topworking conducted both at NRCC and Karnataka Cashew Development Corporations, revealed that utmost care is required to protect the topworked trees from the cashew stem and root borer.

Table 2. Performance of 94* top worked trees; expenditure involved in top working and maintenance.

Year	Expenditure involved in top working and maintenance (Rs)	Nut yield per plot (kg)	Income per plot (Rs)
1996-97	3098	-	-
1997-98	2688	37.8	1512
1998-99	2756	184.2	8389
Total	8542	222.0	9801

* Out of 94 trees top worked 88 trees survived
Yield and income are from plot of 88 survived trees

Pest management in the rejuvenated trees

The trees which have been top worked need to be checked for any symptoms of CSRB pest incidence right from the first week after top working at 15 days intervals. Normally the fork regions and the cut ends (if uncovered) will have the pest entry and exudation of the fine frass material in small quantity. These spots of the bark should be chiseled cautiously so as not to make more damage onto the bark of the top worked trees and the tunnel made by the grubs, which bore into the bark, can be traced out by the freshness of frass. The young grubs remaining inside need to be removed out and killed. In case the frass comes out from the root zone then the soil at that spot need to be dug out and the infested root needs to be checked for the grubs which are normally found in the underside (ventral) portion of the roots.

The direction in which the grub has moved in both the stem and root can be made out by the freshness of frass wherein the older frass is dark brown and the fresh frass will have reddish colour. In case the grubs are not removed when they are young they damage the bark severely and later enter into the heartwood during which time the frass comprises of whitish fibrous powder. The grubs have to be killed under these situations using a pliable wire or gear wire as the tunnels will be zigzag in nature. A slushy sound is heard as soon as the grubs get poked with the wire and the body fluid oozes out of the tunnel.

The chiseled surface needs to be treated using either carbaryl suspension (1.0%) or chlorpyriphos solution (0.2%). Repeated infestation of treated top worked trees is not uncommon. Hence constant vigil of these trees and those immediately next to it is of utmost importance during the months of Jul. to Nov. when the symptoms of infestation like frass and yellowing of the shoots is noticed. In certain cases where water logging occurs at the collar region the bark starts rotting at the collar region and the tree likely be attacked severely by the shot hole borers. In such cases, there is an immediate need for treating such trees by swabbing and drenching with monocrotophos (0.2%) (approx. 2-4 lts per tree)as such trees will lead to spread of infestation to the neighbouring trees in a short time.

References:

Guruprasad, T.R., Khan, M.M., Ahamed, L., Hanumanthappa, H. 1988. Success of cashew top working technology at farmer's doors. The Cashew. 2(1):10-11.

Khan, M.M., Hiremath, L.G., Kumar, D.P. 1988. Top working in cashew – A rapid method of producing scion material. Cashew Bull. 25(9):11-13.

Kumar D P and Hegde M, 1999. Recycling of plant nutrients through cashew leaf litter. *The cashew*. 13 (2): 2-8

Nayak, M.G. 1996. Training and pruning practices for cashew. The Cashew. X (2): 5-10.

Nayak M.G., 2007. Effect of pruning on cashew. In: National Seminar on Research, Development and Marketing of Cashew, ICAR Research Complex for Goa, during 20-21 November 2007.

Nayak M.G., Swamy KRM, Yadukumar N and Raviprasad T.N. 2008. Effect of limb pruning on growth and yield of cashew (Anacardium occidentale L) varieties. J. Plantation Crops. 36 (3) : 300 – 303.

Rao, V.N.M. 1985. Top working in cashew – commercial feasibility. Cashew Causserie. 7(4):5-6.

Yadukumar, N and Mandal, R.C.1994. Effect of supplemementary irrigation on cashew nut yield, In: Water management for plantation crops, problems and prospects. Centre for Water Resources, Development and Management, Kozhicode PP. 79-81.

Yadukumar N and Nandan S L. 2004. Recycling of organic wastes of cashew plantations by aerobic composting. Journal of Plantation Crops, 2005, 33(2) : 99-102.

REJUVENATION OF SENILE ORCHARDS BY LIMB PRUNING

Fig.1. Limb pruned tree of exhausted canopy

Fig.2. View of limb pruned trees after three months

Fig.3. Flowering in limb pruned tree

Fig.4. Fruiting in second year in limb pruned tree

REJUVENATION BY TOP WORKING

Fig.5. Flushing in beheaded tree for top working

Fig.6. Initial stage of top grafting

Fig.7. Successfully top worked tree

Fig.8. Two year old top worked plant

CASHEW BASED CROPPING SYSTEMS

Prof. P.L. Saroj, ARS
Director
ICAR-Directorate of Cashew Research, Puttur
pl.saroj@icar.gov.in

Introduction

Cashew takes 8 to 10 years for the canopy to cover the entire area under normal spacing and there is good scope in providing high returns to farmers by adopting intercropping. In hilly regions there is a possibility of soil erosion, nutrient losses and weed growth during initial years of planting. Intercropping is the best option to minimize erosion, nutrient losses and conserve soil and moisture and to realize higher returns from unit area during the early stages of cashew plantation. Pineapple can be grown as a suitable intercrop between two rows of cashew for the first seven years. The spacing to be maintained for cashew is 8m x 8m (156 trees/ha) or 7.5 m x 7.5 m (175 trees/ha) or 10 m x 5 m (200 trees/ha). Growing pineapple in trenches across the slope between two rows of cashew helped to conserves the soil moisture, which in turn increased the yield of cashew (main crop) by 1.5 times compared to cashew alone. Pineapple can be grown as a profitable intercrop under irrigated as well as rainfed conditions in west coast region (Yadukumar *et al.,* 2003). Maize and groundnut can be grown successfully as intercrops in newly planted and two years old cashew orchards (Abeysinghe *et al.,* 2003). Other crops such as Tapioca, Turmeric, Ginger, Cucurbits, Colocasia and Elephant Foot Yam have been found to be suitable intercrops in West Coast region while Colocasia, Brinjal, Groundnut, Blackgram were found to be good intercrops in East Coast region. Weed suppression was best in plots carrying cashew / cassava and cashew / plantation / cassava mixtures with a 50-60% reduction in the frequency of weeding per annum (Adeyemi, 1998).

The term *cropping system* refers to the crops and crop sequences and the management techniques used on a particular field over a period of years. This term is not a new one, but it has been used more often in recent years in discussions about sustainability of our agricultural production systems. You can choose from many different types of crops, and you can plant them in different combinations.

Allelopathy is the release of a chemical substance by one plant species that inhibits the growth of another species.

Double-cropping (also known as sequential cropping) is the practice of planting a second crop immediately following the harvest of a first crop, thus harvesting two crops from the same field in one year.

Intercropping is the presence of two or more crops in the same field at the same time arrangement that results in the crops competing with one and another.

Monocropping, or **monoculture,** refers to the presence of a single crop in a field. This term is often used to refer to growing the same crop year after year in the same field; this practice is better described as *continuous cropping*, or monocropping.

Relay intercropping is a technique in which different crops are planted at different times in the same field, and both (or all) crops spend at least part of their season growing together in the field. An example would be dropping cover-crop seed into a soybean crop before it is mature.

Strip cropping is the presence of two or more crops in the same field, planted in strips such that most plant competition is within each crop rather than between crops.

Advantage of Intercropping

- Intercropping gives additional yield income/unit area than sole cropping.
- It acts as an insurance against failure of crops in abnormal year.
- Inter-crops maintain the soil fertility as the nutrient uptake is made from both layers of soil.
- Reduction in soil runoff and controls weeds.
- Intercrops provide shade and support to the other crop.
- Inter cropping system utilizes resources efficiently and their productivity is increased
- Intercropping with cash crops is higher profitable.
- It helps to avoid inter-crop competition and thus a higher number of crop plants are grown per unit area.

Disadvantages of intercropping

- Yield decreases as the crops differ in their competitive abilities.
- Management of different cultural practices seems to be difficult task.
- Improved implements cannot be used efficiently
- Higher amount of fertilizer or irrigation water cannot be utilized properly as the component crops vary in their response of these resources.
- Harvesting is difficult.

Challenges in cropping systems

Pests and diseases*:* Certain insect pests and diseases may spread easily from one crop to the next through the crop residues. Avoid crop combinations where this is a problem.

Markets

Markets do not always exist for new crops you may want to plant as part of your rotation. It may be hard to find seed, you can't find anyone to buy the yield, or prices are too low to make it worthwhile growing the crop.

Knowledge, skills and labour

Managing rotations properly requires more skills than a single crop. It also needs work at different times of year. People may be reluctant to try out new crops because they are not used to growing or eating them.

West Coast

Pineapple as intercrop

Pineapple can be grown as an intercrop in cashew garden profitably for the first 7 years. Both main and intercrop can be planted simultaneously. Normally pineapple can be grown in the inter spaces available between two rows of cashew plants planted at 8m x 8m (156 trees/ha) or 7.5 m x 7.5 m (175 trees/ha) or 10 m x 5 m (200 trees/ha). Pineapple is planted with the onset of pre-monsoon showers in three trenches dug out at 90 cm distance across the slope between two rows of cashew. In leveled land straight trenches can be opened between two rows of cashew. Each trench is of 1 m width, 0.5 m depth and convenient length. Pineapple suckers with 8-15 leaves are planted in each trench in two rows at 60 cm apart. The distance between two plants within a row is 40 cm. Before planting pineapple suckers the trench should be half filled with mixture of top soil, farm yard manure and rock phosphate. Nearly 2.5 kg of farm yard manure and 160 g of rock phosphate/metre length of trench should be added and thoroughly mixed. Fertilizers should be applied annually in two split doses (May-June and September-October). Fertilizers are applied at the rate of 25 g N, 7 g P_2O_5 and 25 g K_2O/pineapple sucker/year. Each time whenever fertilizers are applied in September-October period, earthing up of soil at the base of suckers in each row is done after weeding. This operation is most important for pineapple for better anchorage in addition to better rooting. Nearly 35% of the plant population yields in the second year itself. Remaining 65% yield can be realized during the subsequent years. In the fourth year replanting of pineapple should be done in the freshly opened trenches at the adjacent areas between the two existing trenches.

Pepper as inter / mixed crop

Trailing pepper on the stem and branches of grown up cashew trees (more than 6 years) is also adopted. Separate application of manure is necessary for pepper vine. With the onset of monsoon, pit size of 45 cm x 45 cm x 45 cm should be opened about 45 cm away from the cashew tree at the base and pits should be filled with top soil, 200 g rock phosphate, 200 g lime and 0.5 kg neem cake. Rooted pepper cuttings should be planted during June with the onset of monsoon (South-West Monsoon season). Once the vine establishes and starts growing, the vine should be tied to the stem of the tree at the base with jute thread. This practice should continue till vines grow to almost 1.5 m height all around the stem surface of the cashew tree. Cashew stem girth will be around 30 cm when it is 6 years old and because of the rough stem surface of the cashew tree, pepper vine easily clings to the plant and spreads to all the remaining thick branches. This actually when exposed to filtered sunlight through cashew canopy, it flowers profusely during rainy season. From second year onwards regular application of recommended doses of fertilizers in split doses to pepper (100 g N, 40 g P_2O_5 and 140 g K_2O g/tree/year) at 45 to 60 cm away from the base results in better growth and yield.

Ginger as intercrop

Ginger can be grown as an intercrop in the initial 3 to 4 years of cashew plantation. Particularly this is more suitable in the interior areas of west coast on hillocks with forest surroundings. Whenever forest surroundings are noticed growing ginger in the initial years before taking up regular plantation is a common practice in west coast region. With the onset

of pre-monsoon season (April-May) raised beds of 2.5 m length, 1.5 m width and 0.25 m height should be prepared across the slope between two rows of cashew. With this operation all the jungle growth including small bushes will be removed and soil is loosened. Loose and made up soil present in the raised bed, acts as good soil and moisture conservation structure which also facilitates better penetration of cashew roots. Even the weeds will be controlled while preparing beds for ginger. Approximately 10 quintal disease free ginger rhizomes are required as seed material for planting one ha. Rhizomes of ginger should be planted in raised bed at 10 cm distance from one planting spot to another spot.

Farm yard manure or compost at the rate of 15 t/ha has to be applied initially to the bed after planting ginger rhizomes. Soon after planting; thick mulch has to be applied at the rate of 10 t/ha. Application of heavy mulch is necessary to conserve moisture during pre-monsoon and later to avoid soil erosion during rainy season. Heavy mulch also is necessary to conserve moisture soon after the cessation of rain so that this will continue for another 3 months without necessitating irrigation. Ginger crop is of 7 to 8 month duration and harvesting can be done in the month of January. Total cost of cultivation includes items like clearing of jungle, raised seed beds, cost of ginger seed rhizomes, application of FYM and weeding and mulching. One can expect a yield of around 60 quintals ginger per hectare. In the subsequent 2 to 3 years, part of rhizomes removed from the previous crop can be utilized as seed material each year and to that extent the cost of cultivation is reduced. Ginger is prone for deadly disease Rhizome rot, which needs proper care.

Fodder and legume forages

Experiments conducted at Agricultural Research Station, Ullal revealed that among the fodder crops as intercrops, NB-21 grass gave the highest green fodder yield (41.9 t/ha) over Guinea grass (27.6 t/ha) and para grass (18.0 t/ha). Among legume fodders, *Sonthus hamata* ranked first in green fodder yield (12.55 t/ha) followed by *Mimosa invisa* (10.25 t/ha) and *Lupinus* spp. (7.28 t/ha). The unutilized interspace of cashew in coastal Karnataka was successfully exploited for 1st three years of plantations by growing fodder and grasses like NB-21, Guinea grass and para grass with NB-21 yielding highest green fodder of 21 t per ha (Chalapathi, 1989).

Andhra Pradesh

At Bapatla, groundnut, green gram and black gram can be grown as inter crops in rabi season. Groundnut recorded a maximum yield of 1400 kg/ha and had higher cost benefit ratio (1:1.96). Horsegram as an intercrop resulted in net profit of Rs.19900/- with a cost benefit ratio of 1:1.80 (Table 7). Whereas, inter cropping with flower crop like marigold with cashew recorded the highest net profit of Rs.65, 967/- per hectare (Table 8). During the year 2011-12, cluster bean, marigold, amaranthus and mesta were grown as intercrops. Cluster bean recorded maximum yield of 9097 kg/ha and gave higher cost benefit ratio 3.7 and led to maximum net returns of Rs. 94,002/-. In the West Godavari district, cashew is grown in combination with *Casuarina* and coconut.

Tamil Nadu

Among field crops, pulses and oil seeds were attempted as intercrops for cashew. Groundnut performed better as an intercrop in cashew in terms of total returns (Rs. 16,188/- per hectare) whereas, the highest cost benefit ratio for black gram (1:2.1) revealed black gram as a suitable intercrop for cashew (Table 9). Black gram led to the highest C: B ratio of 1:2.1 followed by groundnut (1:1.19). However, groundnut resulted in maximum net profit of Rs.16, 187/ha (Table 10). Further, medicinal plants are also found to be suitable intercrops for cashew. Intercropping of *Aloe vera* with cashew recorded higher BCR value of 4.1. *Ocimum sanctum* intercropped in cashew showed sustained performance for four years and *Aloe vera* + cashew for three consecutive years. Hence, *Ocimum* and *Aloe vera* could be promoted as profitable intercrops in cashew.

Orissa

Vegetable crops such as brinjal, cowpea, chilli, bhindi, pumpkin, colocasia were evaluated for their economic suitability as intercrops with different doses of fertilizer. The yield and total net returns per hectare from inter-crops as well as main crop after 4 years revealed that maximum return was received from colocasia (Rs 66,216/-) followed by bhindi (Rs. 58,155/-), brinjal (Rs. 58,035/-), cowpea (Rs 57,635/-), chilli (Rs. 56,815/-), pumpkin (Rs 52,493/-) and control (Rs 40,075/-) (Table 12).

West Bengal

In the eastern humid region, intercrops such as bottle gourd, *Amaranthus*, pumpkin, cucumber and bitter gourd were evaluated at Jhargram. Maximum yield was obtained in cucumber (10.607 Q/ha) followed by bottle gourd (9.615 Q/ha) and amaranths (5.160 Q/ha). The yield of cashew was only 6.00 Q/ha without an intercrop while it was 9.87Q/ha with amaranthus. . The benefit cost ratio (2.44) confirmed that cashew + bottle gourd was the most profitable practice followed by cashew + amaranths (benefit cost ratio of 1: 1.93) and cashew + cucumber (benefit cost ratio of 1: 1.81). Intercrops such as coriander, dill and fenugreek were grown in open canopy area under 5m x 4m spacing. Maximum yield was obtained from fenugreek (14.77 q/ha) followed by coriander (6.74 q/ha). Significant difference was noticed in the yield of cashew between cashew grown alone and cashew grown with intercrops. The yield of cashew was 1.28 q/ha without an intercrop, while it was more than 2 q/ha with intercrops. The cost benefit ratio (0.41) confirmed that cashew + fenugreek was the most profitable practice followed by cashew + dill (benefit Cost ratio: 1: 0.14). When eucalyptus (*E. teretecornia*) was grown as intercrop in cashew, cashew yield was reduced from 200 g per tree for cashew grown alone to 50 g per tree for cashew grown with eucalyptus. The percentage of TMB infestation on cashew was greater (78.8 per cent) when *Eucalyptus* was intercropped with cashew than sole crop of cashew (20 per cent) (Ghose, 1993).

Madhya Pradesh

Under Bastar plateau zone of Madhya Pradesh, intercrops like cowpeas, bush type French bean, cluster beans, ricebeans, urd beans, moong beans, soya beans and ground nuts grown in 3 year old cashew orchard, recorded higher net returns than sole crop of cashew (Gupta, 1999).

References

Abdul Salam, M. (1999). Cashew and pepper live in harmony. *The Cashew*. 13(3):54-55.

Abdul Salam, M. (2001). Cashew and pineapple live in harmony. *The Cashew*. 15(4):12-13.

Abeysinghe, D.C. 2009. Effect of intercropping of young cashew (*Anacardium occidentale* L.) on land productivity. In: *Recent Developments in Cashew Research.* Attanayaka, D.P.S.T.G., and Jayasekera, S.J.B.A. (eds). Proceedings of the Cashew Research Workshop held on 20 November 2009 at the Faculty of Agriculture and Plantation Management of the Wayamba University of Sri Lanka, 23p.

Adeyemi A.A. 1986. Cashew/arable crops intercropping experiment. CRIN Annual Report. p. 60.

Aliyu OM Hammed LA. 2008. Nigerian cashew economy: A review of nut production sector. Paper presented at the International Academy of African Buisiness and Development (IAABD) Conference. University of Florida, Gainesville, USA. May 20–24, 2008.

Anonymous, 2006, Intercropping in Cashew. Annual Report 2004-05. All India Coordinated Research Project on Cashew. Directorate of Cashew Research, Puttur. Pp: 66-69.

Anonymous, 2007, Intercropping in Cashew. Annual Report 2005-06. All India Coordinated Research Project on Cashew. Directorate of Cashew Research, Puttur. Pp: 65-68.

Anonymous, 2008, Intercropping in Cashew. Annual Report 2006-07. All India Coordinated Research Project on Cashew. Directorate of Cashew Research, Puttur. Pp: 66-70.

Anonymous, 2009, Intercropping in Cashew. Annual Report 2007-08. All India Coordinated Research Project on Cashew. Directorate of Cashew Research, Puttur. Pp: 59-62.

Anonymous, 2010, Intercropping in Cashew. Annual Report 2009-10. All India Coordinated Research Project on Cashew. Directorate of Cashew Research, Puttur. Pp: 61-63.

Anonymous, 2011, Intercropping in Cashew. Annual Report 2010-11. All India Coordinated Research Project on Cashew. Directorate of Cashew Research, Puttur. Pp: 72-74.

Anonymous, 2012, Intercropping in Cashew. Annual Report 2011-12. All India Coordinated Research Project on Cashew. Directorate of Cashew Research, Puttur. Pp: 73-77.

Chalapathi, K. (1989). Eucalyptus of fodder grasses as intercrop in cashew in Dakshina Kannada. *The Cashew*. 3(4):17-18.

Ghose, S.N. (1993). Effect of eucalyptus plants as intercrop in the cashew plantation – A case study in West Bengal. *The Cashew*. 7(2):17-19.

Gupta, C.R. (1999). Intercropping in cashew orchard under rainfed condition – a model for Bastar Plateau zone of Madhya Pradesh. *The Cashew*. 13(2):18-22.

Kumar, D.P., Khan, M.M. and Hiremath, I.G. (1986). Black pepper as mixed crop in cashew. *Cashew Causerie*. 8(4):17.

Liu Kangde, Liang Shibang and Deng Suisheng. (1998). Integrated Production Practices of Cashew in China. *Integrated Production Practices of Cashes in Asia* (edited by Minas K. papademetriou and Edward M. Herath). Food and Agriculture Organization of The United Nations, Regional Office for Asia and Pacific, Bangkok, Thailand.

Mandal, R.C. (1992). *Cashew Production and Processing technology*. p.195. Agro Botanical Publishers (India), Bikaner.

Maung Maung Lay. (1998). Integrated Production Practices of Cashew in Myanmar. *Integrated Production Practices of Cashew in Asia* (edited by Minas K. papademetriou and Edward M. Herath). Food and Agriculture Organization of the United Nationss, Regional Office for Asia and Pacific, Bangkok, Thailand.

Ohler, J.G. 1979. *Cashew*. Koninklijk Instituut voor de Tropen, Amsterdam, 260p.

Opoku-Ameyaw K. Oppong F K. Amoah F M. Osei-Akoto S and Swatson E. 2011. Growth and early yield of cashew intercropped with food crops in northern Ghana. *Journal of Tropical Agriculture* 49 (1-2): 53-57, 2011.

Opoku-Ameyaw, K. and Appiah, M.R. 2000. Improving the growth of cashew (*Anacardium occidentale*) seedlings inter planted into mature sheanut stands in northern Ghana. *Ghana J. Agric. Sci.,* 33: 159–164.

Opoku-Ameyaw, K., Oppong, F.K., Ofori-Frimpong, K., Amoah, F.M., and Osei-Bonsu, K. 2003. Intercropping robusta coffee with some edible crops in Ghana: agronomic performance and economic returns. *Ghana J. Agric. Sci.,* 36: 13–21.

Raj Ganguly 2011. Analysis of pro-poor agriculture value chains in Maharashtra: preliminary findings. In: Proceedin*gs of workshop on policy options and investment priorities for accelerating agricultural productivity and development in India*, November 10-11, 2011, India international centre, New Delhi.

Rodrigo, V.H.L., Stirling, C.M., Teklehaimanot, Z., and Nugawela, A. 2001. Intercropping with banana to improve fractional interception and radiation use efficiency of immature rubber plantation*s. Field Crops Research,* 69 (3): 237–249.

Saroj, P.L. and Arora, Y.K. (1994). Horticulture based agroforestry systems of Doon Valley. *Indian Journal of Soil Conservation*. 3:60-65.

Surendra G.B.B. 1998. Integrated Production Practices of Cashew in Myanmar, In: Integrated Production Practices of Cashew in Asia (edited by Minas K. Papademetriou and Edward M. Herath), Food and Agriculture Organization of The United Nations, Regional Office for Asia and the Pacific, Bangkok, Thailand.

Swaminatha, C. (1999). Early growth performance of mango and cashew coplanted with four nitrogen fixers in a tropical alfisol. *Journal of Sustainable Forestry*. 8(2):15-26.

Warui, C.M. 1985. Development in cashew cultivation and research in Kenya. *Acta Hortticultuurae.* 108:233–237 Available at http://www.actahort.org/books/108

NUTRIENT MANAGEMENT IN CASHEW

T.R. Rupa
Principal Scientist (Soil Science)
ICAR-Directorate of Cashew Research, Puttur
rupa.tr@icar.gov.in

Cashew is grown on a wide range of soils, from the sandy seacoast to laterite hill slopes, pure sandy soils to sandy loam, laterite soil, deep loam and red latosols, but several of these soils have low effective cation exchange capacities and low exchangeable base status. It is also grown on black soils in Tamil Nadu and Andhra Pradesh to a limited extent. Majority of the cashew growing soils in India are lateritic, red and coastal sands which are acidic in nature and poor in soil fertility. Limited or no use of fertilizers and organic manures leading to multiple nutrient deficiencies is one of the major causes of low productivity of cashew in India. The deficiencies of nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), zinc (Zn), boron (B) and molybdenum (Mo) are on the rise in cashew growing soils. It has been estimated that for every one kg of cashewnut produced the plant depletes the soil by 64.1 g N, 2.05 g P, 24.7 g K, 4.19 g calcium (Ca), 1.57 g sulphur (S), 525.7 mg iron (Fe), 63.6 mg manganese (Mn), 87.8 mg Zn and 26.5 mg copper (Cu) nutrients (Beena *et al.,* 1995). Cashew requires regular fertiliser application to ensure early and high yields in new / young plantations, and regular high yields from mature plantations.

Manures and fertilizers are the important inputs which account for 20-30 per cent of the total cost of production, moreover, the fertilizer utilization efficiency is low due to various losses and soil fixation. The availability of soil nutrients to cashew plants depends on several factors. Low levels of available nutrients in the soil may be due to low amounts in the parent material from which the soil is derived, fixation and immobilisation of nutrients, or leaching losses of nutrients under high rainfall conditions. Nutrient imbalances in the soil may also cause limited availability of nutrients. Low nutrient levels may also result from continuous cultivation because of removal of nutrients by cashew plants without subsequent replenishment, leading to nutrient mining in the soil. Due to its extensive root system, cashew can draw its nutrients from large volumes of soil, and as a result it can perform reasonably well on poor soils where other crops fail to do so.

Nutrient dose and response

The major nutrient requirement of cashew plant demands more liberal application of N followed by K, while P is needed in comparatively lesser quantity. Nitrogen has more influence on tree growth, production and quality of cashew than any other nutrient. Nitrogen and P were most important nutrients during the pre-bearing stage, but at the bearing stage, K together with N is also important. The response of cashew to applied N is tremendous and the same is observed universally. Increase in cashew yield due to N application was reported by several workers. Urea is the most commonly used nitrogenous fertilizer in India. However, in Nigeria urea and sulphate of ammonia are generally used. Falade (1984) reported that sulphate of ammonia was superior to urea particularly when medium or high doses of N were applied to cashew.

Phosphorus is the second most limiting nutrient after N in the nutrition of cashew. Phosphorus plays an indispensable role as a universal fuel for all biochemical work in living

cell and in particular root development. Phosphorus deficiency is common in cashew growing acid soils in which the mineral fraction is dominated by kaolinite and sesquioxides. Conflicting reports are observed regarding the response of cashew to P fertiliser. Phosphate fixation of water soluble P is greater in cashew growing acidic soils dominated by kaolinitic type of clay mineral but allows the use of rock phosphate as a good source of P to cashew crop. Of phosphatic fertilizers for use on acid soils in India, the slow-release and more efficient ground Mussoorie (rock) phosphate is popular.

Potassium is the second largest nutrient next to N required by cashew. Potassium is necessary for several basic physiological functions like the formation of sugars and starch, synthesis of proteins, normal cell division and growth, and neutralization of organic acids. It helps reduce the influence of adverse weather conditions like drought, cold, and flooding. Significant positive effects of K on growth, nut weight and yield of cashew were reported by several researchers. Of different sources of K fertilizers, Muriate of potash (potassium chloride) is most commonly used fertilizer in cashew. The recommended dose of K varies from 125 to 750 g/tree/annum as basal depends upon the nature of soil, spacing and age of the cashew plant.

The recommended dose of fertilizers for cashew for major producing states is given in Table 1. Based on the initial fertility status of soil, nutrient dose may vary from location to location. About 10 to 15 kg farmyard manure (FYM)/plant/year is recommended in addition to primary nutrients (N, P and K). The recommended dose of fertilizers varies with the age of plants, plant density and fertility of the soil. Studies conducted at ICAR-Directorate of Cashew Research (DCR), Puttur indicated that application of 500 g N and 125 g each of P and K and 10 kg poultry manure per tree per year under normal density planting system (10 m x 5 m; 200 plants/ha) and 250 g N and 50 g each of P and K and 10 kg poultry manure per tree per year under high density planting system (4 m x 4 m; 625 plants/ha) is found superior in terms of higher nut yield for rainfed cashew in Karnataka. In high density planting system of cashew, the fertilizer recommended is reasonable up to 80-100 per cent canopy coverage which is normally achieved during the initial 6-8 years after planting. After certain stage of the crop, reduction in recommended doses of fertilizers per plant may be necessary due to the nutrient build up in soil due to the deposit of cashew biomass fall out. It has been estimated that by systematically recycling all the waste biomass produced by cashew, it is possible to get back 20.7 kg N, 10.5 kg P_2O_5 and 30.8 kg K_2O /ha/year (Yadukumar *et al.,* 2003).

Table 1. Recommended dose of Fertilizers to Cashew

State	Nutrient dose for mature cashew plantations (from 5th year onwards) (g/tree/year)		
	N	P_2O_5	K_2O
Kerala	500 750	125 325	125 750
Karnataka	500 500	250 125	250 125
Tamil Nadu	500	200	300
Andhra Pradesh	500 1000	125 125	125 125
Maharashtra	1000	250	250
Odisha	500	250	250
West Bengal	1000	250	250

Source: Compiled from ICAR-DCR, Puttur and AICRP-Cashew Centres

Integrated nutrient management practices involving chemical fertilizers, organic manures / green manuring and biofertilizers which constitute an efficient nutrient management strategy in cashew are essential to maintain / enhance the soil quality and for sustainable production. Green leaf manuring with *glyricidia* and sesbania in cashew resulted in higher nut yield and improvement in soil nutrient content. The *glyricidia* contributed 186 kg N, 23.6 kg P_2O_5 and 126.2 kg K_2O/ha and sesbania contributed 141 kg N, 17.9 kg P_2O_5 and 162.3 kg K_2O/ha (Yadukumar *et al.,* 2008). The use of biofertilizers is of relatively recent origin. Application of *Azospirillum*, *Azotobacter* and Vesicular Arbuscular Mycorrhizae increased the germination percentage of nuts and plant growth, and reduced the incidence of fungal diseases in the nursery (Kumar *et al.* 1998).

The amounts of nutrient elements recycled in canopy fallout may partially meet the nutrient requirements of cashew. About 15.5–37.7% of tree total requirements of macronutrients are recycled from canopy biomass fallout of leaves, cashew apples and flowers from six year old cashew trees in Australia (Richards, 1993). Studies conducted at ICAR-DCR, Puttur on nutrient budgeting and nutrient balance in a six year old cashew plantation of 'Bhaskara' variety under high density planting system (625 trees/ha) showed a negative N, P and K balance of 113, 38 and 92 kg/ha in control plot where no fertilizer was applied. A strong positive N, P and K balance ranged from 128 to 253, 18 to 54 and 34 to 128 kg/ha were recorded in plots with 2/3rd and full dose of recommended fertilizers (750 g N and 150 g each of P_2O_5 and K_2O per tree/year).

Organic production of cashew offers immense potential. Cashew plantations have vast potential of organic biomass available for recycling. The availability of cashew leaf litter from different age group plantations (10 to 40 years) ranged from 1.38 to 5.20 t/ha. Vermicomposting of cashew leaf litter and apple by using local earthworm *Eudrilus spp.* has been standardized at ICAR-DCR, Puttur. About 5.5 tonnes of available cashew biomass waste per ha can be converted into 3.5 tonnes of compost or vermicompost and helps in meeting nutrient requirement to cashew by 50 per cent.

The application of fertilizers through the irrigation water (fertigation) has the advantages of increasing the efficiency of the fertilizers and reducing the costs of labour and machinery for its application. Fertigation allows the application of nutrients with greater frequency, without increasing the cost of the application, minimizing losses by volatilization and leaching and optimizing nutrient absorption by the roots. The nutrients most frequently applied in fertigation are those with greater mobility in the soil. Water soluble fertilizers like urea, diammonium phosphate and muriate of potash are used for fertigation through drip lines from December to March and application of 2 kg castor cake to soil during August. Fertigation is done once in a week from December to March. With fertigation quantity of nutrients (through fertilizers and organic manures) to be applied can be reduced to half of the quantity of recommended nutrients. An increase of 100 per cent and 226 per cent in yield was observed in the treatment received half of recommended dose of NPK in inorganic form (Recommended dose: 500 g N, 125 g each of P_2O_5 and K_2O/tree/year) of nutrients through fertigation and balance half applied in organic form through castor cake as compared to the above dose through soil and separately irrigated and absolute control (without manure and irrigation) respectively indicating better nutrient use efficiency.

Time and method of fertilizer application

The key to enhance fertilizer use efficiency is to synchronize the time of fertilizer application with the growth need of the crop and period of high root activity. Highest root activity and peak absorption of N, P and K occurred during the flushing and early flowering phase (September to December) and suggested that the onset of this phase is the most appropriate time for fertilizer application in a cashew orchard. The annual dose of fertilizers to cashew are to be applied in two split doses, the first split dose at the onset of the monsoon period and the second split dose during the post-monsoon period when the soil moisture condition is at its optimum; if only one application is given, it should be in the post-monsoon period when enough moisture is available.

Cashew trees are surface feeders with about 50 per cent of the root activity being confined to the top 15 cm of the soil and about 72 per cent of root activity was found within a 2 m radius from the tree trunk (Wahid *et al.* 1993). This suggested that application of fertilizers within a radius of 2 m from the main stem results in efficient utilization of the applied nutrients. During the 1^{st}, 2^{nd}, 3^{rd}, 4^{th} and 5^{th} year of planting $1/5^{th}$, $2/5^{th}$, $3/5^{th}$, $4/5^{th}$ and 5^{th} year onwards full quantity is to be applied. George *et al.* (1984) standardized the methods of fertilizer application to cashew and reported that application of N, P and K fertilizers in two circular trenches (1.5 and 3.0 m from the trunk) for sandy soils, a single trench method (25 cm wide and 15 cm deep circular trench at 3 m from the trunk) for sloping ground, and the band method (in a circular band 1.5-3.0 m from the trunk + soil incorporation) for flat ground are best suited. The root activity of cashew in relation to phenological phases studied by Beena *et al.* (1995) employing ^{32}P soil injection technique reported that 'flushing and early flowering phase (September to December)' is the most appropriate time for fertilizer application in cashew orchard. The annual dose of fertilizers to cashew are to be applied in two split doses, the first split dose at the onset of the pre-monsoon period and the second split dose during the post-monsoon period when the soil moisture condition is at its optimum; if only one application is given, it should be in the post-monsoon period when enough moisture is available.

Foliar feeding

The essential micronutrients *viz.,* Fe, Mn, Zn, Cu, B, Mo, chlorine (Cl) and nickel (Ni) are needed by plants in very small quantities and mainly function as components of a series of enzymes. Deficiency or toxicity of these elements in soil adversely affects the growth and development of cashew plants. Among micronutrients, deficiencies of Zn, B and Mo are more common in cashew growing acid soils. Iron and Al toxicity is a distinct problem. Micronutrient deficiencies in soil not only limit the cashew production but it also has negative effects on human health. Foliar feeding is often the most effective and economical way to correct micronutrient deficiencies in horticultural crops. Foliar application of nutrients normally reduces the loss through adsorption, leaching and other processes associated with soil application. Deficiencies of micronutrients can be corrected by foliar sprays of ferrous sulphate (0.5-1%), manganese sulphate (0.5-1%), zinc sulphate (0.5%), copper sulphate (0.1%), solubor (0.1%) and Mo (0.1%) salts to cashew at the emergence of the flush, panicle initiation and fruit set stages.

It is crucial that level of micronutrients in soil and plant should be optimum for growth and development since the micronutrients' need is site specific. The deficiency and toxicity limits of micronutrients in plant are rather narrow. This calls for location specific management of

micronutrients in cashew so that these do not become toxic to plant. To minimize wide spread deficiency of micronutrients, it would be the best option to incorporate them into macronutrient fertilizer sources like urea, diammonium phosphate / rock phosphate, muriate of potash etc. which facilitates to apply small quantity of micronutrient fertilizers over a large field area in a uniform manner.

References

Beena, B., Abdul Salam, M., and Wahid, P.A. 1995. Root activity of cashew (*Anacardium occidentale* L.) varieties in relation to phonological phases. *J. Plantation Crops*, 23(1): 35-39.

Falade, J.A. 1984b. Effect of lime on the efficiency of two nitrogen fertyilizers applied to cashew in acid sandy soil. *J. Plantation Crops,* 12(2): 140.

George,T.E., Veeraraghavan, P.G. and Rao, D.S. 1984. Studies on the leaf nutrient content of cashew (*Anacardium occidentale* L.) in relation to methods of fertilizer application. *Indian Cashew J.,* 16(2): 11-13.

Kumar, D.P., Hegde, M. and Guruprasad,T.R. 1998. Fertigation for higher nut production in cashew (*Anacardium occidentale* L.). *Cashew Bulletin*, 35(4): 2-4.

Richards, N.K. 1993. Cashew response to water and nutrients in a sandy red earth soil of the Northern Territory. Technical Bulletin Northern Territory, Department of Primary Industry and Fisheries. 202: 17-38.

Wahid, P.A., Kader, K.V.A. and Salam, M.A. 1993. Rooting pattern of cashew. Rooting pattern of tropical crops (Eds. Abdul Salam, M.A. and Wahid, P.A.), Tata Mc Graw Hill Publishing Co. Ltd. Pp. 223-234.

Yadukumar, N., Raviprasad, T.N., Nagaraja, K.V., Haldankar, P.M., Godase, S.K., Susanamma, K., Gajendran, G., Mahalingam, T., Lenka, P.C., Mohapatra, R.N. and Bandyopadhyay, B. 2003. National Agricultural Technology Project. Final Report on developing integrated production packages for enhancing productivity of cashew. National Research Centre for Cashew, Puttur, D.K., Karnataka. 95 p.

Yadukumar, N., Rejani, R. and Nandan, S. L., 2008. Studies on green manuring in high density cashew orchards. *J. Plantation Crops,* 36: 265-269.

IRRIGATION AND FERTIGATION IN CASHEW

N Yadukumar and T.R. Rupa
Retd. Principal Scientist (Agronomy) ICAR-DCR, Puttur and
Principal Scientist (Soil Science)
ICAR-Directorate of Cashew Research, Puttur
rupa.tr@icar.gov.in

Although the cashew may grow and produce in regions with mean annual rainfall distribution ranged from low rainfall (300-600 mm in Gujarat) to high rainfall (2700 to 3000 mm in West coast and NEH region) with a drought of 4 to 5 months, irrigation allows maximum productivity. In cashew flushing, flowering and fruit development stages are critical phases that decide the nut yield. Any form of stress, (biotic or abiotic) during these phases can decrease the yield substantially. Due to the non-uniform distribution of rainfall, cashew experiences severe moisture stress from December to May, which adversely affects its flowering and fruit set causing flower drying and immature nut drop. Water availability strongly influences flowering and fruit set and can affect fruit drop, fruit size, yield, nut quality characteristics and canopy development. Studies in India have shown that nut yield can be enhanced by providing protective irrigation with 200 L of water per tree once in 15 days from January to March during the summer season. Research results in Brazil and other countries have shown that irrigation could increase productivity by up to 300 per cent depending on the region. Drip irrigation is the most efficient irrigation system with savings of between 40 and 60 per cent over other irrigation systems. In drip irrigation only a portion of the soil area around each plant is irrigated. Water movement into and through the soil from point source such as drip irrigation increases the capacity of soil water movement phenomenon affecting the dimension of wetted volume, movement of fertilizer in the soil solution / irrigation water.

Water requirement, time and method of irrigation

Cashew tree is considered drought resistant to some extent and is generally grown as an unirrigated crop, but the yield can be doubled, if irrigated. Low productivity is the main concern in cashew cultivation in India. Of several factors associated for such low yields, the low moisture availability during the fruiting season which normally coincides with the onset of dry season in the cashew growing areas is one of the factors. Field experiments conducted at ICAR-DCR on fertigation in cashew indicated that under normal density planting system (7 m x 7 m), the effective canopy coverage per tree is 12.56 m^2. The quantity of irrigation water calculated based on the effective canopy area was 12.56 L/tree/day from December to January (Daily open pan water evaporation is 5 mm) and 20 L/tree/day from February to March (Daily open pan water evaporation is 6.5 mm) to meet 20% of the cumulative pan evaporation (CPE). Similarly, for 40% CPE and 60% CPE, the irrigation rate was 24 L/tree/day and 38 L/tree/day from December to January and 36 L/tree/day and 58 L/tree/day from February to March, respectively. In order to meet 20% CPE, four drippers of 2 L/h discharge rate can be fitted at two equidistant points 1 m away from the base of the tree. Similarly, to meet 40% and 60 % CPE, four drippers and six drippers of 4 L/h discharge rate can be fixed. Drip irrigation can be given for 1 h 30 min during December and January and 2 h in February and March.

Case study for estimating water requirement of cashew tree to meet 20% CPE

Age of the tree : 5 years
Canopy spread : 4 m, Canopy spread = canopy diameter = mean of EW and NS length
Canopy area = πr^2 where r = radius of the canopy.

If the radius is 2 m, the total area covered by individual tree canopy is 3.14(π) x 2^2 = 12.56 m^2 (Ground coverage by canopy)

Daily CPE = 5 mm, 20% of CPE = 1 mm, Therefore, quantity of water to be given to meet 1 mm of water in 12.56 m^2 area = 12.56 x 1/1000=0.01256 cubic M, 1cubic M =1000 L. Therefore, 0.01256 cubic M =12.56 L/tree/day. Like this quantity of water required to be given is calculated depending upon canopy coverage and daily water evaporation.

Supplementary irrigation with limited source of water (protective irrigation)

- Protective irrigation during peak summer season reduces fruit drop and thereby increase in nut yield.
- Black polyethylene mulch with irrigation at a rate of 60 L/tree once in fortnight resulted in maximum fruit retention of 66.15 per cent which was significantly superior to other treatments such as irrigation alone, polyethylene mulch alone and without any irrigation. Irrigating @ 200 L/tree once in 15 days starting from November to March resulted in two fold increase in yield over control (No irrigation). In cases of limited availability of water, irrigation is to be given from January to March (5 irrigations) once in 15 days @ 200 L/tree to obtain 50 to 100 per cent higher yield.
- In West coast, the rainy season extends upto November and December (North East monsoon) resulting soil moisture content going up to 10 to 15 per cent by weight. During January to March, the soil moisture is as low as 8.82 to 9.30 per cent.
- The field capacity and permanent wilting point in this region for sandy loam type of soil is usually 20 and 7 per cent respectively.
- Soil moisture depletes after August. On the other hand, atmosphere and soil temperature increases gradually. These triggers flowering in cashew in December in case of early varieties and January and February in case of mid and late season varieties.
- Soon after the flowering, at the time of nut set and nut development in January to March the crop undergoes moisture stress.
- It is during this period the crop requires protective irrigation for doubling the yield.
- Drip irrigation system in cashew orchards where water source is available is also recommended.

Drip Irrigation

- If good water source is available and drip irrigation facilities are provided, irrigating 80 L/tree once in four days or irrigating daily at a rate of 20 L/tree through drippers placed at four points at equidistance 1m away from the base of the plant can be followed.
- Irrigation to be started from second fortnight of December to end of March (30 irrigations, 2400 L/tree/year).
- In four to eight years after planting, the increase in cumulative yield due to irrigation is 165 per cent of that of control plot receiving no irrigation.
- Irrigation at 20 L water/day from December to March has wetted 7.75% of the given ground area and 56% of the effective root zone.
- Irrigation increased the yield through increased tree canopy area, flowering laterals/tree, bisexual flower production, nut retention, number of nuts produced per tree and weight of nuts.

Fertigation for efficient water and nutrient management

(a) Normal density planting system (200 trees/ha)

- Fertilizer mixture used for application of 50 per cent recommended doses of fertilizers (500 g N and 125 g each of P_2O_5 and K_2O per tree/year).
- The fertilizers like Urea, DAP and MOP (20 kg Urea, 6 kg DAP and 4 kg MOP) are dissolved in water by continuous stirring and applied to 200 plants (1 ha) through drip irrigation system per month through venturi. Like this 5 applications are given for one season.
- Each split dose is given once in each month starting from October to December and from January onwards the monthly-allotted dosage is further split into four doses and given once in a week up to February through drip irrigation system.
- Highest profit of about Rs. 27,300/- per ha (with a B:C Ratio of 3.71) can be achieved in plot receiving half of recommended dose of nutrients through fertigation and balance half applied in the form of castor cake to soil, while the profit is about Rs. 9000/- when the NPK dose was given to soil.

(b) High density planting system (625 trees/ha)

- Fertilizer mixture used for application of 50 per cent of lower dose of fertilizers i.e. 250 g N and 62.5g each of P_2O_5 and K_2O /tree/year.
- The fertilizers like Urea, DAP and MOP (31.25 kg Urea, 9.375 kg DAP and 6.25 kg MOP) are dissolved in water by continuous stirring and applied to 625 plants accommodated in an area of 1 ha through drip irrigation system per month. Like this 5 doses will be given for one season.

- Each split dose is given once in each month starting from October to December and from January onwards the monthly-allotted dosage is further split into four doses and given once in a week up to February through drip irrigation system.

- The Organic manure-castor cake at the rate of 2 kg/tree is to be applied in August when sufficient moisture is available in pits dug out in dripping point located at 1 m distance from base of the tree. The rate of drip irrigation is to be given to meet 20% of evaporative demand. This is equal to 7 L for 1 hour 45 minutes/day from December to January and 9L for 2 hours 15 minutes /day from February to March. Totally two drippers of 2 L/hr capacity should be installed at the base of the tree located at 1 m equidistance from base of the tree.

- Highest profit of about Rs. 48,400/ha with B: C ratio of 3.39 can be achieved in plot receiving half of lower dose of nutrients through fertigation and balance half applied in the form of castor cake. While profit of Rs. 40,000 can be achieved when same dose of NPK is applied to soil.

HIGH DENSITY PLANTING AND CANOPY MANAGEMENT IN CASHEW

MG Nayak
Principal Scientist (Hort)
ICAR-Directorate of Cashew Research, Puttur
gangadhara.nayakm@icar.gov.in

High density planting of late became a very popular technology in most of the crops to harness the initial benefits of closer planting in the orchards. In tree crops when go for wider spaced planting lot of space will get wasted, at least for a initial few years. Many occasions, the mixed or inter cropping in the vacant spaces with annual crops species is suggested to cover such spaces and exploit maximum out of the given piece of land. But in crops like cashew as the production is as such very low and requires to meet the demand in short span of time, high density is proved to be an successful venture in the initial few years to achieve higher productivity.

Requirements of high density

For a successful high density orchard an early bearing precocious variety is most essential requirement. The precocious variety's will help to take early benefits of closer spacing. Secondly, the plant should be slow growing, so as to avoid pruning and throwing away the vegetative growth. It was suggested in other crops either (i) a variety should be dwarf and compact, (ii) should be grafted on a dwarfing root stocks, (iii) go for use of growth reducing chemicals or growth retardants or (iv) adopt regular pruning of unwanted growth in order to control the size of the plant within the allotted spaces. As in cashew dwarf types or dwarfing root stocks are yet to be identified or exploited and Paclobutrazol an growth retardant becomes a cost lier affair and also not recommended for want of information on several issues the only option remains is pruning and canopy management.

Studies were conducted on high density planting of cashew at Directorate of Cashew Research, Puttur, Shantigodu since 1996 onward and in coordinating centres in different cashew growing States. The results are quite encouraging. It has been proved that cashew yield can be increased to 4 folds up to 6 years and 2.5 folds up to 12 years if high density planting system of 625 trees/ha.is maintained. The above result was compared with normal density of 156 trees/ha. Details are as follows:

System of planting	Spacing (M)	Density No./ha	4th to 12th year Cum.yield Kg/ha
Normal density	8 x 8	156	2275
High density	4 x 4 upto 11 years and 8 x 5.6 x 5.6 after that	625 upto 11 years and 312 after that	3944

High density planting of cashew is more suitable in less fertile area. Because in area where soil fertility is low growth of the plant is very much slow resulting less ground coverage in the initial years. In such locations if normal density planting with 8m x 8m spacing (156 trees/ha) is done the yield is very low in the initial stages of plant growth.

Economics

It was worked out that the net profit/ha was Rs.77054 in high density planting plot for the first 12 years. Where as in normal density plot (156 trees/plot) the profit was only Rs.26201/ha.

Package for establishing high density cashew orchards

Pits of 100cm x 100cm x 100cm (Lbd) should be opened at 4M distance between two rows as well as in each row between two pits. In slopy area pits should be opened all along the contour line at 4m distance from one row to another row as well as from one pit to another pit within the row. The pits are normally opened with the onset of monsoon so that soil is soft during this period for easier work. The pits should be kept open for a week or so for exposure to sun light to ward off termites, ants and other insects. The pits are then filled with a mixture of top fertile soil, with 8-10 kg organic manure and 200g rock posphate. Cashew grafts of high yielding varieties should be planted in the pits after scooping out 1 spade full of soil in the top centre of the pit. After planting grafts proper staking should be done to avoid breakage in the graft joint due to wind blow. Mulching with dried leaves or green leaves should be done to prevent soil erosion particularly in slopy area during rainy season and also to conserve moisture in summer months. Care must be taken to see that all side shoots coming out below and above graft joint is removed frequently up to 0.45 M from ground level. This is necessary for providing proper shape to the plant with solitary strong stem and for the convenience of cultural operations like weeding, fertlizer and organic manure application, plant protection works and for picking nuts. This also avoids stem borer infection to some extent.

The recommended manurial schedules are as follows. The fertilizers and organic manures in the first year are applied within 50cm radius from the stem of plant @366g urea, 67g muriate of potash and 200g rock phosphate/tree/year. Out of this dose 200g rock phosphate is given at the time of planting graft as explained earlier. The organic manures should also be applied at the time of planting .In the second year fertilizer and organic manure should be applied at 75 cm radius away from the stem of the plant in circular trench dug out (25cm width 15cm depth). The poultry manure @ 2kg/plant should also be applied in the trench and covered with soil. Mulching should be done immediately after the application of manures. Third year onwards full dose of fertilizers and 5kg of poultry manure/ plant should be applied in circular trench dug out 1.5m away from stem of the tree(1100g urea 625g rock phosphate and 200g muriate of potash/plant/year). Manures should be applied soon after cessation of heavy showers (August).

Deblossoming should be done for the first one years to encourage development of proper canopy in case of growth of the plant is not up to satisfaction. Regular shape pruning should be done to achieve umbrella shape canopy with uniform spread .During the first 6 years the crop canopy covers almost 100% of the given ground area. Beyond 6 years because of over lapping of branches thick shade is formed which in turn reduces yield. It is at this stage branches towards the periphery end is cut back by 0.5m radius around to allow 80% of light interception by the crop canopy and remaining 20% to the ground penetrating through gaps in the canopy. Normally pruning is done during August. Soon after this 10% bordeaux paste is applied to the cut ends of the thicker branches. Detopping at 3m height from 5th year onwards is necessary. By 11th year it is necessary to thin out tree population to 50% by removing every alternate tree in each row. Once the canopy has developed pruning of leader shoots (Last years growth) should be done at least once in two years regularly. At

least 60% of the canopy spread should be used for pruning. Length of leader shoot to be pruned should not be less than 8cm and more than 12cm. This will further increase yield by giving out more number of productive lateral shoots which flower in the same year.

Advantages of high density planting is that the weed growth is minimum due to early ground coverage by the crop canopy causing heavy shade over the ground space. This restricts weed growth. Under normal density planting system the trees are at wider spacing leading to maximum exposure of ground area to sun light causing maximum growth of weeds that directly compete with cashew for nutrient and moisture. In high density planting system because of less exposure of ground to sun light the soil temperature during peak summer season is reduced there by reducing soil moisture loss through evaporation. The evaporation from ground surface is also reduced considerably due to heavy deposit of cashew leaves under high density planting system. These leaves when incorporated in soil will be a good source of Nutrients for better plant growth and yield.

Ultra high density planting

Going for much closer spacing with precocious pruning responsive cashew varieties was tried and the results were encouraging. A close spacing of 2.5 M x 2.5 M or 3 M x 3 M which can accommodate 1600 plants or 1111 plants/ha yielded better results and recommendation of this is awaited.

Canopy Management

Cashew like any other wild tree grow very fast with its spreading branches erratically if they are not managed properly. As cashew is highly sun loving plant it requires lot of pruning and thinning of branches to maintain the shape of canopy. If proper pruning and training is done from the beginning the subsequent removal of heavy vegetative growth can be avoided.

Training

Training is a method to direct the plant growth to a desired form. Some of the parts of a plant are pruned with a view to giving the plant a frame work. Support may also be provided. Detopping etc. may also be done. Training is combined with pruning.

- Training is judicious removal of any plant part to give proper shape/to provide a good frame work for the future.
- Training is done in the initial years of planting.
- A strong central stem is allowed to grow.
- Branches are spaced properly.
- The trees are skirted (trunk is kept clean) upto a height of 60-75cm to keep the lower branches off the ground. This should be done every year upto 4-5 years by removing the lower branches.

- The trees are also pruned or detopped to a workable height (5-6m from ground) after 4-5 years of planting.
- During 1st and 2nd year of planting, the flower panicles are also removed to encourage vegetative growth.
- Around the trunk soil mounds may be provided to strengthen the tree's anchorage against cyclonic winds/heavy winds.
- The plants should be provided with staking support during 1st, 2nd and 3rd year of planting.
- Training facilitates easy cultural operations, nut collection, monitoring of CSRB etc.

Pruning

Pruning is judicious removal of unwanted plant parts. When annual growth of a plant are specifically removed, the operation is called pruning. In pruning the form of the tree is not at all affected, but its cropping is highly influenced.

The trees are pruned annually in two ways:

- Thinning - A few shoots or branches that are considered undersirable, are removed entirely without leaving any stub.
- Heading back - Removing the terminal portions of all branches leaving their basal portions intact.

Pruning is done to divert a part of the plant energy from one part to another. When a branch is headed back, the buds below the cut sprout and develop into new shoots. Pruning of any kind, according to its severity, changes the nutritive conditions within the tree and consequently limits or encourages fruit bud formation.

- Heading back may be a good practice for plants in which fruit bearing shoots are produced laterally from basal portions of the previous year's growth.
- Heading back may be disastrous for plants that produce fruit bearing shoots from the terminal portions of the shoots.
- The minimum amount of pruning which is common to all, is the removal of broken or diseased branches, dead wood, dried twigs / branches, criss-cross branches, water shoots / sprouts, crown suckers etc.
- Annual pruning may be very light in the beginning and it may be heavy after some years. Otherwise, the trees may lack vegetative vigour and make very little growth.
- Heavy pruning may extend the juvenility of plants.

a) Water shoots/water sprouts

They are Extraordinarily vigorous vegetative shoots which grow from high points on the main branches in an upright direction at the expense of the parent branches from which they arise. They consume lot of food material. They are much thicker than the normal shoots. They bear much larger and coarser leaves. They grow in such rapidity in one season that they out grow and impoverish the rest of the neighbouring drooping branches of the tree. They are unproductive. If water shoots are not properly removed, they soon close the centre of the tree and obstruct light. They should be removed as soon as they appear.

b) Making pruning cuts

- While removing an entire branch (thinning) the cut should be made close to and even with the outline of the mother limb. No stub portion of the branch should be left on the limb. A clean wound heals smoother and more rapidly.

- While heading back a shoot, the pruning cuts are made between nodes. This results in continued branching and shoot growth. Branches with a diameter of 2cm or less could easily be removed with a secateur, without splitting the shoot/tearing away the bark. Thicker branches can be removed with a garden saw / sickle.

c) Treating of cut wounds

- To avoid fungal infection, to prevent drying of the tissues, and to promote healing of wound (to facilitate the development of callus tissue), the cut surfaces should be treated with Bordeaux paste (10%).

- The wounds under 2.0-2.5cm in diameter need not be treated. The smaller wounds on the tree top may be sprayed with Bordeaux mixture (1%). The wounds greater than 5cm in diameter should be treated with Bordeaux paste (10%).

Training and Pruning in Cashew

Pruning as an horticultural practice was not being followed in tropical evergreen fruit crops for the improvement of yield as the need for such improvement was not felt. Of late, pruning is gaining importance in fruit trees, such as mango, guava, fig. etc. as an orchard management technique to improve the sanitation, easy cultural operations and yield.

In cashew the need for pruning as an orchard management practice is imperative since the nut yield in the existing orchards is very low and demand on the other hand is increasing many folds. The studies conducted at ARS, Ullal, have indicated that removal of dead wood and criss-cross branches from old and unthrifty trees markedly increased the yield. Average yield increased from 1.44 kg/tree before pruning to 2.36, 4.39, 5.53 and 6.08 kg/tree during the first, second, third and the fourth years of pruning respectively. Therefore, there is a need for pruning cashew trees once in 2-3 years.

Studies conducted at NRCC Shanthigodu on the effect of time and severity of pruning in cashew trees of 12-13 years old indicated that the leader shoot pruning done in July and August will help in doubling the nut yield. This has resulted in the production of higher number of lateral shoots and higher number of bisexual flowers per panicle.

a) Training of young cashew plants

Training in cashew should be limited to the removal of criss-cross branches, branches with narrow crotches to facilitate proper light penetration and development of strong scaffold branches to give the young tree a uniform crown around the stem. The lower branches on the main stem are to be gradually removed in the first 2-4 years to a height of 60-75 cm from the ground level.

b) Pruning of old cashew trees

As the age of the tree advances the productivity goes down due to the fall in the vigour of the plant. At that stage severe pruning helps in the production of more vegetative growth which results in higher yields.

Leader shoot pruning

In a large tree about 60 per cent of the leader shoots are to be pruned in May-June by heading back to 2/3rd of the length. Along with this the water sprouts, criss-cross branches, dead and dried shoots are to be pruned by thinning. Pruning of leader shoots should not be carried out every year as this may lead to over exhaustion of the tree which is already weak. Hence, pruning may be taken up once in 3 years.

References

Balasimha, D. and Yadukumar, N. 1993. Effect of plant density on photosynthesis in cashew. Indian J. Plant Physiology. 36(1):5-7.

Nayak, M.G. 2011. Pruning and Canopy Architecturing in Cashew. NRCC Tech. Bull. No. 13. 19pp. National Research Centre for Cashew.

Yadukumar, N., Bhaskara Rao, E.V.V. and Nayak, M.G. 2002. High Density Planting in Cashew. NRCC Tech. Bull. No. 8. 23 pp. National Research Centre for Cashew..

MANAGEMENT OF TEA MOSQUITO BUG IN CASHEW

PS Bhat
Principal Scientist (Entomology)
ICAR-Directorate of Cashew Research, Puttur
shivarama.bhatp@icar.gov.in

Preamble

Tea Mosquito Bug (TMB) is one of the major pests of cashew. Three species of TMB, *viz., Helopeltis antonii* Signoret, *Helopeltis bradyi* Waterhouse and *Helopeltis theivora* Waterhouse are found in India. Among them, *H. antonii* is the dominant species. TMB belong to family: miridae, sub family: bryocorinae and tribe: monaloniini. The genus *Helopeltis* was upgraded mainly to differentiate it from the closely resembling genus *Pachypeltis.* The early records these pests especially in tea commonly called as 'tea bug' and 'tea mosquito' and the damage was reported as 'tea blight', 'mosquito blight' and 'spot blight'. The same common terminologies are in usage even now. Both nymphs and adults feed by sucking the plant parts, injecting poly-phenoloxydase(toxins) from their salivary glands. Typical feeding damage by *Helopeltis* spp. Appears as a discoloured necrotic area or a lesion around the point of entry of the mouth parts inside the plant tissue. The infestation of inflorescence results in "blossom blight". Each insect can damage 3-4 shoots or panicles leading to heavy loss in yield. Under outbreak situations, a damage of 25-30 per cent may be expected.

Biology

The adult bugs are slender; elongate, 6 to 8 mm long, reddish brown in colour with a black head, red thorax and black and white abdomen. Colour variation among the adults has been reported. A pin like, knobbed scutellar process occurs dorsally in both the nymphs and adults except in the first instar nymphs. The pre-oviposition and oviposition periods ranged from 3 to 5 days and 5 to 10 days, respectively. More than 75 per cent of the eggs are deposited during the first half of oviposition period. The presence of sex pheromone in females of TMB has been demonstrated. The eggs are inserted into tender shoots, stalk of inflorescence and on the leaf midrib and petioles, either singly or in groups of 2 to 6. The presence of a pair of minute silvery hair like unequal chorionic processes indicates the presence of an egg. The five nymphal instars are completed in 8 to 13 days. Adults live for about 5 to 18 days and the total life cycle is 20 days. A mass culture technique for TMB has been amari nizin using cashew shoot as a host material.

Alternate hosts

The nymphs and adults of TMB feed on a wide variety of plants such as eucalyptus, mahogany, neem, cocoa, cinchona, guava, drumstick, black pepper, Singapore cherry, cotton, mehendi and allspice. During off season, the activity is mainly confined to these hosts and the pest migrates to cashew during flushing, flowering and fruiting period of cashew. Cashew is the most preferred host for TMB during the cropping season.

Distribution

The pest is distributed in most of the cashew growing regions of Kerala, Karnataka, Goa, Maharashtra, Tamil Nadu, Andhra Pradesh, Gujarat, Chhattisgarh and Orissa. Neem is the primary host of *H.antonii* especially in Tamil Nadu and southern parts of Karnataka and Andhra Pradesh. The pest spreads to cashew from neem in these areas, whereas in Maharashtra, Gujarat and Chhattisgarh it is confined mainly to cashew. Apart from *H.antonii H. theivora*, *H.bradyi* and *Pachypeltis mesarum* Kirkaldy are also causing similar damage to cashew in certain areas.

Nature of damage

Typical feeding damage by *Helopelti*s spp. Appears as a discoloured necrotic lesion around the point of entry of the labial stylets into the plant tissue. The lesion can be elongate or spherical, and becomes darker with age as the tissue around the stylet puncture dies, in response to the enzymatic action of the insects' salivary secretions. Nymphs and adults of *H. antonii* initially tap the plant surface with labial tip followed by immediate insertion of stylet intracellularly with a minimum depth of 0.3mm. Water soaked lesion appeared within a minute after insertion of stylet indicating rapid diffusion of salivary secretion. Feeding on a single site lasted with a maximum of 17 min and evacuated the contents of plant cells leaving initially the cell walls intact and uncollapsed. Subsequently, the melanization and necrosis of feeding lesions appear. In the salivary gland of *H. antonii*, hydrolytic enzymes (protease and lipase), oxido-reductase enzymes (catechol oxidase, catalase and peroxidase) and free amino acids were detected. The salivary enzymes caused phyto-toxaemia on various host plants as well as detoxification of defensive chemicals especially in the neem. The role of free amino acids existing in salivary secretion was to protect the salivary enzymes from denaturing by defensive chemicals of host plants.

Both nymphs and adults suck the sap from tender leaves, shoots, panicles and immature nuts and apples. The injury due to insertion of stylets by the insect induces exudation of resinous gummy substance. TMB also releases certain toxic secretion into cashew. All these activities of the insect lead to the typical formation of necrotic lesion symptoms around the point of stylet insertion by the bug. The lesions on shoots coalesce and ultimately result in drying of shoots/ shoot blight.

The infestation of inflorescence or panicles results in blossom blight. In certain endemic areas, most of the flushes dry up and the tree presents a scorched appearance. The immature nuts infested by TMB shrivel and dry up, while older nuts and apples develop a scabby appearance. Each insect can damage 3-4 shoots or panicles during its life cycle thereby, leading to heavy loss in nut yield.

Seasonal abundance

Helopeltis spp. Exhibit a continuous cycle of generations throughout the year likeother Tropical mirids. On cashew, the build up of the *H. antonii* commences during October/November amari nizing with the emergence of new flushes, after the cessation of the monsoon. The population reaches a peak during January, when the trees are in full bloom. The pest in n the field till May and is absent during the monsoon (June-September) especially in older plantations. However, the population

exists in a negligible number during monsoon period. But in young plantations, the pest is noticed continuously with a higher intensity during February and March. Negative relationship between rainfall and incidence of *H. antonii* is reported , whereas, in guava no such relationship was observed between incidence of *H. antonii* and weather factors . However, in Tamil Nadu, the outbreak of *H. antonii* depends on its severity on neem. Once, severe outbreak occurs on neem, the population rapidly spreads to cashew, guava, drumstick and ber, wherein damage on cashew will be severe on panicles and tender apple and nuts. Similar situation also prevails in west coast condition in a different form. The population build up is regular in young plantations in which all the plants will have infestation. Subsequently, it will be patchy as the age of plantation progress and in the plantations of the age group of 10 years and above, low level of population prevails. But, whenever, old plantations are situated near to young plantations, under severe outbreak condition, the population from young plantation rapidly spreads to older plantations, resulting in severe outbreak. The life table studies carried out with *H. antonii* on cashew, neem and guava revealed that rapid build up of population is more likely on neem and cashew than on guava. The demographic studies of *H. antonii* on cocoa, neem and henna suggested that the pest can multiply more rapidly on cocoa and neem than on henna and also sustained under unfavourable conditions on both the host plants.

Fluctuations in the weather parameters were found to influence the build up of tea mosquito bug under field conditions. Minimum temperature and sunshine hours were highly correlated with increased *H. antonii* populations. The maximum temperature and afternoon humidity also had significant effect on *H. antonii* population. The largest populations were observed in December and January. The *H. bradyi* population showed significant correlation ($p < 0.01$) with minimum temperature. The observations of minimum temperature and sunshine hours can be an indicative to predict the behavior of the field trend of *Helopeltis* spp. Populations and planning control measures.

Incidence of disease

The fungal pathogens, *viz*., *Gloeosporium mangiferae* and *Phomopsis anacardii* have been reported to cause blossom blight in association with TMB. The feeding injury by the bug is one of pre-disposing factors for the infection and expression of die-back disease caused by *Colletotrichum gloeosporoides* and *Botryodiplodia theobromae*. When the dried shoot is split open, discolouration may be seen in softwood region indicating the manifestation of the fungal disease. A loss of 25 to 50 per cent nut in nut in yield has been reported from Karnataka, Maharashtra, Goa, Kerala and West Bengal due to combined effect of TMB and disease incidence.

Natural enemies

A total of four endo- parasitoids have been recorded parasitizing eggs of TMB in west coast regions of the country. They are *Erythmelus helopeltidis* Gahan. (Mymaridae) *Telenomus* sp. (Laricis group) (Scelionidae) and *Chaetostricha* sp. (Trichogrammatidae) and *Gonatocerus* sp. Nr. *Bialbifuniculatus* Subba Rao. In the east coast , *Ufens* sp. Is the only egg endo- parasitoid observed on TMB. However, the attempts to multiply these endo-

parasitoids under laboratory conditions was not successful, as these require live TMB eggs for the development.

Several species of spiders, *Hyllus* sp., *Oxyopes sehireta*, *Phidippus patch* and *Matidia* sp. Have been observed predating on TMB . Several species of reduviid bugs (*Sycanus collaris* (Fab), *Sphedanolestes signatus* Dist. And *Endochus inornatus* Stal., *Irantha armipes* Stal. And *Occamus typicus* Dist. Have also been recorded as predators. Ants of the species *Crematogaster wroughtonii* Forel (Formicidae) and *Oecophylla smaragadina* Fabricius predate on nymphs of the pest. *Aspergillus flavus* and *A.tamarii* are reported as entomopathogens on TMB.

Varietal resistance

Though all the germplasm accessions and varieties are potentially susceptible to this pest, “Bhaskara”, a variety developed at ICAR-Directorate of Cashew Research, Puttur escapes TMB damage due to non-overlapping of the cropping period with that of peak pest population. This variety was developed from a tree of seedling origin identified during 1982 from severely of TMB infested location, situated at Forest Department Cashew Plantation, Gaodengrem, Canacona Taluk, South Goa. This variety has mid-season flowering habit which aids in escaping from the attack of TMB under low to moderate outbreak situation. In the case of pest damage on first batch of panicles, the trees flower again enhancing the possibility good yield during the same season. In the varieties like Ullal-1 and Madakkathara-2 major flowering /fruiting is delayed *i.e.*, in the month of February onwards. As these months are not favourable for the multiplication and establishment of TMB, these varieties suffer less due TMB.

Chemical control

Proper surveillance for pest damage symptoms during flushing, flowering and fruiting period is essential for the management of this pest. Whenever the incidence of pest is noticed on 5-10 per cent of the flushes, the first round of pesticidal spray should be given. The second round of spray should be invariably completed within 3-4 weeks time if the TMB population still persists. If panicle damage is severe (beyond 50%) because of delayed insecticidal application, further sprays will not result in improved yields. Hence, it is absolutely necessary to keep a constant vigil on the build up of the pest especially during first month of flushing and to initiate timely insecticidal control. However, a two spray schedule(need based) is being presently recommended instead of routine/earlier recommended three spray schedule. The third spray needs to be taken up only based on necessity i.e., in case pest population persists even after the second spray.

The present recommendation for chemical management of tea mosquito bug is as follows:

First spray	:	Monocrotophos(0.05%) or Profenophos (0.005%) - at flushing stage
Second spray	:	λ-cyhalothrin (0.003%) or triozophos (0.05%) – at flowering stage.
Third spray(if pest persists)	:	λ-cyhalothrin (0.003%) – at fruit set stage

Though cashew is an insect pollinated crop, use of λ-cyhalothrin (0.003%) during the flowering stage did not affect the fruit set. Among the different insecticides, λ-cyhalothrin (0.003%) has higher benefit cost ratio (4.5).

Whenever die- back disease is noticed, the affected shoots and branches below the site of infection should be pruned and destroyed. The cut surface should be protected with Bordeaux paste (10%). Spraying the canopy with Bordeaux mixture (1%) may be followed after this process.

General precautions for insecticidal application:

- Chemical should be mixed properly and filtered before filling the sprayer.
- Spraying should be done in the early hours of the day (7-11 AM) or in the evening (3-6 PM).
- Spraying should be taken up immediately when initial symptoms of TMB damage are noticed first.
- If it rains immediately after spraying, the spraying has to be repeated.
- Entire canopy area should be sprayed with chemical. Approximately, 6-8 litres of solution is required for a tree of 15 -20 years depending upon the canopy.
- Same insecticide should not be used repeatedly. It is better to alternate equally effective insecticide for each spray.
- Empty chemical container should be destroyed by puncturing / cutting into pieces and buried into the soil.
- Drinking water source should not be contaminated while spraying.
- Cloth mask covering nose and mouth should be invariably used by the person who attends to spraying.

Conclusion

Among the three species of species of *Helopeltis viz., H. antonii*, *H. theivora* and *H. bradyi*; *H. antonii* is the endemic species able to inflict severe damage on cashew. The presence of protease enzyme activity in the salivary secretions of *H. antonii* gives an indication that if the gene for protease inhibitors is incorporated in these host plants through DNA recombinant technology, it may increase biochemical basis of resistance and thereby natural control of *Helopeltis* spp. Can also be improved. Similarly, for biological control with host specific egg parasitoids of *Helopeltis* spp. Have shown some potential in reducing the host population especially in cashew. Since, these parasitoids are specialist parasitoids and not amenable for mass culture, there is a limited scope for augmentation. However, their activities can be increased by evolving proper conservation and enhancement techniques for specialist parasitoids. The vast fauna of spiders and reduviids in cashew suggest the future trust in management of this pest. Since, the presence of sex pheromone communication was well demonstrated in all species of *Helopeltis*, further investigations have to be intensified to identify the bioactive components of sex pheromone and for further synthesis. The synthetic sex pheromone can very well be used as a lure and kill method and as a monitoring tool to undertake insecticidal control in a judicious way especially on cashew and tea. Thereby, indiscriminate insecticidal spray can be avoided on cashew and also the potential risk of pesticidal residues in cashew kernels can be reduced. The non-insecticidal methods like use of synthetic sex pheromone (as lure and kill method) and biological control will have better scope to reduce the dependency on insecticidal control.

MANAGEMENT OF CASHEW STEM AND ROOT BORER

TN Raviprasad
Principal Scientist (Entomology)
ICAR-Directorate of Cashew Research, Puttur
tnr.prasad@icar.gov.in

Cashew farmers experience several hardships in cashew cultivation due to variation in climate, rainfall and also due to severe insect pest incidence which finally leads to significant loss in nut yield. In cashew, several insect pests attack during various stages of the crop and result in moderate to heavy loss of the crop yield depending on level of insect pest population. Out of these pests, two are major insect pests cause considerable yield loss in most of the cashew growing regions of our country. These are a) Tea Mosquito Bug (TMB) scientifically known as *Helopeltis antonii* and b) Cashew Stem and Root Borers (CSRB) scientifically known as *Plocaederus ferrugineus* and *Plocaederus obseus*.

The adults and nymphs of TMB suck plant sap and lead to drying up of shoots and flower panicles, leading to considerable loss during that cropping season. However, incidence or absence of the pest varies over the years. The other pest, cashew stem and root borers infest the vital bark portion of yielding cashew trees and lead to gradual death of such infested cashew trees. The pest population of CSRB increases over the years resulting in constant loss of tree population. Thus, productivity in a given location gets reduced over the years. In this brochure, the symptoms of infestation and various approaches to be adopted for managing this pest is mentioned for the benefit of the cashew farmers of the country.

What is cashew stem and root borer?

The insect is normally noticed by cashew farmers at larval stage which feeds on the bark portions of the stem and roots, by making irregular tunnels which enlarge as the larva grows in size. The farmers can notice larvae, pupae and unemerged immature adults in the damaged portions of infested trees. The adult insects belong to the “beetle” group of insects which have hard and stout body and are strong fliers. The adult beetles of this group have long antennae and are active during the night. Hence, these adult beetles are normally not noticed in the cashew plantations during day time.

What are the symptoms of pest damage?

At the base of the CSRB infested tree, gum and fibrous material are exuded in small quantities in the initial stage of attack. During later stages of attack, the infested tree canopies show a sickly appearance and the green leaves turn yellowish and start dropping prematurely. In the severe stages of attack, the twigs dry off and the bark on the trunk starts splitting. At this stage, large quantity of chewed fibers and gum (commonly known as frass) are seen as big lumps at the base of the CSRB infested tree.

When does the pest incidence occur?

Normally the pest incidence is noticed during the months of Dec. to May in different cashew growing tracts of the country. Different stages of infestation are generally seen all round the year. However, certain stages of the pest are noticed in certain months only. During the onset of rainy season the healthy trees turn dark green, whereas, the infested trees remain yellowish, which is a sure indicator of the pest attack in those trees. During the nut collection period, close observation of the tree bases reveals the initial infestation symptoms which can be treated suitably prior to onset of monsoon.

How does the pest damage the cashew trees?

The adult female beetles lay eggs (which resemble rice grains) inside the crevices of the bark of stem or exposed roots. Young grubs hatch from these eggs in 5 – 7 days and immediately start boring into the bark. The grubs feed voraciously for a period of 6 to 8 months and grow rapidly in size and fill the tunnels with chewed fibre and excreta. Their zigzag feeding interferes with movement of water and nutrients in the tree trunk and root zone leading to premature leaf fall, drying of branches and gradual death of the tree. Full grown larvae make tunnels in the heart wood and form a hard cocoon made of calcium secretions. The pupae stay inside these cocoons for 60 – 90 days and adult beetles emerge from such cocoons and continue the life cycle.

What are the insecticides which can manage the pest?

Several insecticides have been evaluated at various research centers, for over a decade. Some of the insecticides have been recently banned / being withdrawn and hence, alternate effective insecticides were evaluated later on. It is to be noted that any insecticidal treatment without removing the pest stages will not be effective.

The pest stages of CSRB in the infested cashew trees (both in the stem region and in the root zone also) have to be carefully removed by skillful chiseling of the tunnels in the infested portion and destroyed. The larvae will be present on the fresh fiber portion of the tunnels both in the stem and in the roots. The fresh fiber in the tunnels can be traced by their light color while, older fibers will be darker. In case the larvae have entered into the heartwood for pupation, they can be killed by inserting a gear wire / any other bending metal wire and poking into the tunnel till a slushy sound is heard or white fluid flows out. After removing or destroying the larvae and other pest stages, the chiseled portion should be swabbed thoroughly with chlorpyriphos (0.2%) solution and the same needs to be drenched onto the soil near the root zone. This has been proven to minimize the re-infestation by the pest.

Repetition of the treatment should be done, if fresh pest infestation symptoms occur after 30-45 days. Another point to be borne in mind is not to damage more than 50 per cent of the bark circumference, as this will lead to girdling and death of the treated tree. In case, more than 50 per cent of the bark circumference has been damaged or the leaf canopy has yellowed, such trees should not be treated, as they do not recover. These trees need to be uprooted and pest stages in those trees should be destroyed. The timber of such uprooted trees should be shifted out of the plantation and can be used as firewood.

How do we prevent the spread of pest infestation?

Two aspects are to be borne in mind to prevent spread of pest infestation;

i) reduction of pest population in a given location and
ii) rescuing the trees in initial stages of infestation.

To achieve these aspects, the CSRB infested trees should be identified in the initial stages of infestation during the nut collection period and marked suitably. Treatment of all such initially infested trees should be done AT A TIME and if possible on a community basis following the method mentioned above. Also, the trees which have yellowing of the canopy and / or have more than 50 per cent of the bark circumference damaged should be uprooted and pest stages in the root zone should be destroyed. This approach is called "PHYTOSANITATION" which helps to reduce the pest population in a given location and leads to lesser fresh incidence of the pest in the subsequent years. Extensive field trials have shown that on adopting this phytosanitary measure, a reduction in the number of freshly infested trees and also a significant reduction in the number of larvae occurring per infested tree could be achieved.

For more details, please contact :

The Director, ICAR-Directorate of Cashew Research, Puttur - 574202,
Dakshina Kannada Dist., KARNATAKA (Phone 08251 -230902, 236490
FAX : 08251-234350)

OR

Principal Scientist (Agricultural Entomology)ICAR-Directorate of Cashew Research,
Puttur - 574202, Dakshina Kannada Dist., KARNATAKA
(Phone 08251-230902, 236490 FAX: 08251-234350 Mob: 09448409930)

TRANSFER AND IMPACT OF CASHEW PRODUCTION TECHNOLOGIES

Sajeev M.V.
Scientist [Agricultural Extension]
ICAR-Directorate of Cashew Research, Puttur
sajeev.mv@icar.gov.in

Introduction

Agricultural extension in India is largely deployed by government, implemented mainly through government institutions and to some extent through non-government agencies. In India, the extension efforts, particularly transfer of technology efforts, have largely been taken up by the state departments of agriculture and other disciplines as a state subject. The Indian Council of Agricultural Research (ICAR) as the apex body to provide new technologies in agriculture and allied aspects has its own transfer of technology activities. The extension efforts of ICAR, particularly through its institutes are largely of frontline extension programmes. Transfer of technology efforts in cashew by ICAR are also mostly frontline in nature while large scale field level extension work being taken up by line departments of various states. This chapter looks at the various approaches, models and methods used in transfer of technology by DCR, Puttur and summarises impact of recommended cashew production technologies.

Transfer of technology methods adopted by DCR, Puttur

The extension efforts of ICAR, particularly through its institutes are largely of frontline extension programmes. DCR Puttur, over its past 25 years of existence has also made such efforts which are mostly frontline in nature. This article takes a look at the technology backstopping efforts made by the institute since its existence.

Participatory Technology Demonstration Plots

To provide technology backstopping to farmers on frontline cashew production technologies developed by Directorate of Cashew Research and other cashew research stations, cashew demonstration plots based on Farmer Participatory Technology Development (PTD) model were laid out at selected farmers' plots. These PTD cashew gardens serve as demonstration plots to prove the effectiveness of the recommended cashew cultivation practices to farmers while for scientists, these demonstration plots are the tools for assessment and refinement of the recommended practices based on the performance of technologies at micro location level. Laying out of farmer participatory demonstration plots started from the year 1988 as part of the research project; "Transfer of Technology Programmes in Cashew" with the following objectives:

i) To provide technology backstopping on frontline cashew production technologies.
ii) To assess, refine and demonstrate the frontline cashew production technologies.

This research project is externally funded by Directorate of Cashew nut and Cocoa Development, Cochin. Under this programme, every year interested farmers are being

selected for demonstrating the frontline cashew production technologies. Interested farmers are requested to apply for the demonstration plots. The application should be addressed to 'The Director, Directorate of Cashew Research', Puttur. In their application, the farmers should mention the root map to their plots. The farmers should have at least two acres of land for demonstration. The plot should be located by the road side, so that the performance of the crop can be observed by the fellow cashew farmers. A team of scientists from DCR assess the plots for their suitability as demonstration plots, after checking the application. Based on report of the team, demonstration farmers will be selected for the particular year. The newly selected demonstration farmers are provided with subsidy and are being trained every year at DCR, Puttur on Cashew Production Technology.

The farmer participatory technology demonstration gardens are regularly visited by the project team and other scientists. The conditions of these plots are assessed based on the criteria viz., removal of forest trees, gap filling, initial training, pruning, soil and water conservation practices, application of manures and fertilizers and plant protection measures. Technical advice is being given to the demonstration farmers based on conditions of the plots.
So far in Dakshina Kannada district a total of 162 model cashew demonstration gardens were laid out. Among the five taluks of the districts, in Puttur taluk more number of plots were laid out and 78 plots were under normal density system whereas remaining 84 plots were under high density planting system. The varieties/types which were distributed as planting material are Bhaskara, VRI-1, VRI-2; Ullal-1, Ullal-3; H-3-13; VTH 174; BLA 139-1; H-3-17; BPP-3; VTH 59/2; VTH 30/4; T.No.40; Selection-1, 2; Goa 11/6; H 32/4; V-4; NDR-2-1 and Ullal-4. PRESENTLY 26 new FLD plots are taken up in tribal farmer plots under Tribal Sub Plan scheme. The technologies demonstrated include recommended varieties and planting densities.

Thematic campaigns

In order to provide intensive training to the cashew demonstration farmers and cashew growers on important aspects of cashew cultivation viz., soil and water conservation measures (terracing and opening of catchpits), plant protection measures (control of TMB and CSRB) and initial training and pruning, thematic campaigns are being organized. These thematic campaigns were organized in collaboration with NGOs like SKDRDP, Dharmasthala; KJP Research Foundation; Sri Durga Charitable Society and Development Departments.

Prior to the campaign wide publicity was given to attract large number of cashew growers. During campaign, the cashew growers were being exposed technologies through different extension methods viz., exhibition, specially prepared literature; lecture-cum-discussion by experts and field demonstration. Mostly these campaigns were organized at the cashew demonstration plots.

All together, 19 campaigns on SWC measures, 17 campaigns on plant protection measures and 4 campaigns on initial training and pruning were organized and the impact of these campaigns were very high.

Attempts were also made by the Directorate to assess the effectiveness of the campaigns by assessing the knowledge level of the participants on SWC and PP measures before and

after the training. It was found that the campaigns were effective in imparting knowledge to the respondents on SWC/PP measures were the number of respondents having higher level of knowledge was more after the training compared to before the training.

Lessons Learnt

- Collaboration with NGO's and village institutions like schools and panchayats encourages participation of the farmers.
- Intensive training using various modes of training increases effectiveness of the programmes.
- These types of programmes serve as a platform in which problems about utilization of cashew and other plantation crops can be discussed and solutions be suggested.

Cashew Field Days / Cashew Days

In order to inform the cashew growers about the latest research developments in cashew and to get the feedback from the farmers about the usefulness of the cashew production technologies disseminated, Cashew Field Days / Cashew Days are being organized either at DCR, Puttur or at the Cashew demonstration plots of progressive cashew growers.
The farmers / cashew growers on the programme day are explained about the research results at respective plots during the field visit. An exhibition depicting the latest developments in cashew research and useful information about cashew also will be arranged using photos, panels, charts, specimens etc for the benefit of the farmers.

After the field visit and exhibition, seminar-cum-discussion are arranged during which experts in cashew research development and progressive cashew growers share their experience with the other farmers. At the end, question answer session is arranged to clarify the doubts of the farmers on various aspects of cashew cultivation and to express their feedback about the usefulness of the technologies. DCR, Puttur has so far organized 20 such programmes for the benefit of cashew growers, of which a total of 3000 farmers were benefited.

Efforts in Capacity Building

1. Training on "Cashew Production Technology"

In order to educate the extension personnel who are working in development departments in cashew growing states training programmes on "Cashew Production Technology" is being organized regularly. This programme is of two types viz., Refresher course and Special course. Refresher course is being organized for three days whereas special courses are being organized for five days. These programmes are open to extension personnel from all cashew growing states.

During the training, the participants will be trained on the various aspects of cashew cultivation through lecture-cum-discussion mode, visit to various experimental plots, visit to farmers' participatory demonstration plots, visit to private cashew nursery and processing industry. So far 50 such training programmes were conducted at this centre, out of which 1300 participants from all over the cashew growing states participated and benefited.

2. Training on "Vegetative Propagation of Cashew"

To meet out the demand for quality cashew planting material (softwood grafts), which is increasing in all cashew growing states, training programme on vegetative propagation of cashew is being organized regularly. During these training programmes theory and practical sessions on softwood grafting technique and nursery management are being imparted to the participants through intensive training for two days. Participants (nursery assistants / supervisors) from development departments and government owned plantations are regularly being deputed for this programme. So far at DCR, Puttur, 51 such training programmes were organized out of which around 650 participants were trained.

3. Training farm women on cashew apple utilization

Cashew apples are rich in Vitamin C and minerals and have many advantageous effects on human beings. Interestingly, only 10-15 percent of the cashew fruits are utilized by processing, that too to produce country made liquor called 'Fenny' only in Goa. The fruit is wasted mainly due to its disliking qualities such as astringency and arid principles since the fruits are rich in tannin which causes throat and tongue irritation after eating. But the fruits can be made suitable for consumption by removing the undesirable tannin and preparing value added products such as clarified juice, syrup, squash, canned fruits, pickles, jam, jelly and chutney. With this aim DCR, Puttur initiated training programmes on 'Cashew apple utilization' with farm women as the target audience.

During the training the trainees will be imparted training through participatory learning (ie) 'learning by doing'. In addition to this literature on cashew apple utilization will be provided to the trainees. The method demonstrations so far organized were on cashew apple preparation viz., juice/squash, jam and chutney. So far four such programmes were organized out of which a total of 293 farm/rural women were trained.

When the impact of these programmes were assessed by using post-exposure questionnaire (31 respondents) and through mailed questionnaire (20 respondents) it was found that the home level adoption of the demonstrated products was at a average of 50.00% whereas the large scale adoption was poor. The reasons quoted by the respondents for non adoption of the products at a large scale were no awareness about the information on establishment of small scale units, no adequate facilities, non availability of adequate quantity of cashew apples, no adequate time, poor economical background and marketing problems.

4. Other training programmes

Apart from these, training on IPM in Cashew, pruning in cashew and composting of biomass, cashew apple utilization, soil and water conservation in cashew and high density planting and pruning in cashew are also provided. So far, eleven such trainings were conducted covering more than 400 farmers and officials. The Directorate also conducts training programmes on request, apart from the trainings provided under the routine schedule.

Production and supply of planting material

In order to produce and supply quality planting material for cashew (grafts) to the farmers and development departments, two revolving fund schemes were started at Directorate of Cashew Research, Puttur. These are ICAR Revolving Fund Scheme (at Kemminje campus) and DCCD Regional Nursery scheme (at Shantigodu campus). The ICAR revolving fund scheme is functioning from 1990-91 onwards whereas DCCD revolving fund scheme is in place from 1996-97. So far around 17,00,000 grafts were produced and distributed to farmers and development departments from the two revolving fund schemes.

Other extension efforts

Apart from the above routine approaches DCR also participates in exhibitions/expos at important venues across the country by putting up exhibition stall with posters / charts / live specimens depicting the news, information, technologies developed / available on cashew in the country thus aiding in technology dissemination to visiting farmers and other stakeholders. Scientists and technical staff of this Directorate also participated in the exhibitions for explaining technical information to the visitors.

Field visits / Consultancy / Evaluation programmes were also done by the scientists on request. Team of scientists has visited the cashew plots of farmers in all cashew growing states of India upon request. Scientists also participated in various workshops and seminars on cashew organized at various parts of India and presented paper and delivered lectures on various aspects of cashew cultivation. Periodically team of scientists from the directorate participated in the phone-in programme of Doordarshan (Kannada) on Plant Protection and other aspects of cashew. Various Radio talks were delivered on cashew varieties and other cultivation practices and production technologies. Scientists of Directorate delivered talk on various aspects of cashew cultivation and processing aspects. Television interviews are also given on cashew varieties in other states which were telecast in Hindi also by D.D. News. The Scientists also participated in various State Level Workshops cum Seminars on Cashew and delivered talk on topics like cashew production technology, plant protection and training and pruning in cashew. DCR Scientists also visit the Frontline demonstration plots set up under NHM in other districts and states of the country for evaluation on the same.

Future thrust for transfer of technology

DCR focuses on frontline extension of cashew production technologies in line with the mandate of ICAR. Presently, Transfer of Technology efforts by DCR utilises traditional methods which have only moderate reach. The limited staff available for extension and the approach of frontline transfer of technology will further make it difficult in reaching the cashew production technologies to wider audience. The future thrust is on:

- Utilising advances in knowledge management using ICTs towards better technology realization and transfer of technology. Platforms like mobile telephony are to be utilised by implementing mobile advisory services to cashew farmers.

- Retaining interest of new generation cashew farmers and attracting more of them towards cashew farming is a big challenge. Utilising social media marketing by reaching

them through innovative social media platforms like Facebook and Twitter is to be explored in this regard. Transfer of technology efforts of DCR has to be made available on social media platforms for increased reach and effective transfer of technology.

- Better utilization of advances in social capital research has to be made towards social mobilization for formation of cashew farmer groups aiding in participatory transfer of latest cashew production technologies.
- Identification of sustainable cashew based farming systems through extension research will prove to be beneficial towards planning meaningful outreach activities for overall improvement of cashew farmer livelihoods.
- Knowledge about technology fatigue existing in the Cashew sector is presently not much available. More emphasis has to be given for extension research and the knowledge about technology fatigue has to be made available in the coming years. This, along with advances in participatory research has to be used towards successful technology backstopping in the future.

Impact of recommended cashew production technologies.

The cashew cultivation in India mainly confines to the states of Kerala, Karnataka, Maharashtra and Goa along the West Coast and Tamil Nadu, Andhra Pradesh, Orissa and West Bengal along the East Coast region. It is also grown in plains like Chhattisgarh, Gujarat, Bihar and Northeast Hill Regions like Meghalaya, Manipur and Tripura and also in Andaman and Nicobar Islands. In India, it is cultivated in an area of 9.82 lakh ha with a production of 7.28 lakh tonnes and productivity of 772 kg/ha. India has the maximum area (21.6%) under cashew nut and is the third largest producer (17.3%) of raw nuts in the world. After Vietnam, the country is the second largest exporter, accounting for 34 percent of the world's export of cashew kernels. As far as Karnataka State is concerned, Dakshina Kannada District is the major cashew producing region. Increasing production in this district will contribute largely for the Karnataka state's production. Cashew cultivation receives dwindling importance in Dakshina Kannada District in relation to the prices of other crops like arecanut, cocoa, rubber and coconut.

To improve the cashew cultivation scenario of major cashew-growing regions, assessment of the impact of recommended cashew production technologies are very important. Hence, to explore the applicability of technology impact premise in the context of Cashew cultivation, the present study was undertaken at DCR with the objective to measure the impact of different varieties on area, production and productivity of cashew and to measure the impact of recommended production technologies on cashew production and productivity in Dakshina Kannada district of Karnataka. Purposive sampling technique was used to select Dakshina Kannada district since it is a major cashew producing area of Karnataka with presence of two research stations besides other development departments working on cashew and hence having better chances of technology utilization at farm level. Farmers from all the five taluks of the district namely Mangalore, Buntwal, Puttur, Belthangady and Sullia represented the sample.

An 'ex-post-facto cause to effect' design was applied. Detailed questionnaire measuring the adoption status of the farmers, along with their profiles, was developed, pre-tested and utilized for the study. The questionnaire contained 123 questions and took about 45 minutes to elicit information from one household. The data were collected during the 2012-13 through questionnaire and personal interviews. Appropriate statistical measures such as Phi,

Spearman's rank correlation and regression analysis were employed to arrive at conclusions. Data was analyzed using Microsoft Excel 2007 and IBM SPSS Statistics Ver. 20.

Adoption and Impact of different varieties on cashew area

Results of the study on impact of recommended varieties on total cashew area showed that highest area under cashew is covered by the variety Ullal-3 (41%) followed by variety Bhaskara (26.62%). It may also be noted that adoption pattern also shows similar trend with variety Ullal-3 adopted by 59 per cent of farmers followed by variety Bhaskara (55%). Most farmers have adopted a minimum of two cashew varieties in their field and 'Ullal-3 + Bhaskara' combination emerges to be the most popular one in the study area. Varieties Ullal-1 and Vengurla-4 (V-4) were found to cover around 8 percent each of rest of the area. But, these varieties are not popular among farmers with only 13 and 4 percent farmers respectively adopting the said varieties in the district.

Table 1: Variety wise adoption and impact on cashew area

Variety	Adopted by (% farmers) *	Rank	Area covered (%)	Rank
Bhaskara	55	2	26.62	2
NRCC Seln-2	19	3	5.21	5
Madakkathara-2	4	8	4.62	6
Ullal-3	59	1	41.00	1
Ullal-1	13	4	7.66	4
Ullal-4	11	5	2.93	7
VRI-3	7	6	2.66	8
V-4	5	7	8.43	3
V-7	4	8	0.75	9
Other varieties	3	-	0.09	-
Total	92**	-	99.96	-
Seedling origin	8	-	0.04	-
** the percentages won't add upto 100 due to adoption of multiple varieties by single farmer* *** represents total percentage of farmers who have adopted released varieties*				

Other varieties like NRCC Selection-2 (5%), Madakkathara-2 (4%), Vridhachalam-3 (VRI-3) (3%), Ullal-4 (3%) and Vengurla-7 (V-7) (1%), have low impact on total cashew area. In total, improved varieties were found to be adopted by 92 percent of the farmers while 8 percent were still continuing with seedling origin plantations. However seedling origin plantations have only negligible coverage in farmer fields (0.04%). Variety wise adoption and impact on area is given in figure 1.

Impact of cashew varieties on production and productivity

Analysis of variety wise impact on cashew production showed that farmers realized highest yield from variety Bhaskara (4.73 kg/tree) followed by Madakkathara-2 (4.45 kg/tree). This was followed by Ullal-1 (3.90 kg/tree) and Ullal-3 (3.87 kg/tree). Ullal-4, another

recommended variety was at fifth position with a yield of 3.67 kg/tree while NRCC selection-2 fared low at sixth place with 3.47 kg/tree. Productivity under normal density (8x8m) as well as high density (5x5m) planting was highest for Bhaskara (737.88 & 1882.54 kg/ha) and Madakkathara-2 (694.20 & 1771.10 kg/ha). This was followed by Ullal-1 (608.40 kg/ha), Ullal-3 (603.72 kg/ha) and Ullal-4 (572.52kg/ha) under normal density. Under high density planting system, Ullal-1 (1556.10 kg/ha), Ullal-3 (1540.26 kg/ha) and NRCC Selection-2 (1374.12kg/ha) stood respectively at third, fourth and fifth positions. High density plantations of Ullal-4, VRI-3, V-4, V-7 and other varieties were not observed during data collection for this study. Variety wise impact on production and productivity is presented in table: 2.

Table 2: Varietal impact on production and productivity of cashew

Sl. No	Variety	Production (kg/tree)**	Rank	Productivity (kg/ha) under normal (8x8m) density	Rank	Productivity (kg/ha) under high (5x5m) density	Rank
1.	Bhaskara	4.73	1	737.88	1	1882.54	1
2.	NRCC Seln-2	3.47	6	541.32	6	1374.12	5
3.	Madakkathara-2	4.45	2	694.20	2	1771.10	2
4.	Ullal-3	3.87	4	603.72	4	1540.26	4
5.	Ullal-1	3.90	3	608.40	3	1556.10	3
6.	Ullal-4	3.67	5	572.52	5	-	-
7.	VRI-3	3.06	7	477.36	7	-	-
8.	V-4	1.51	9	235.56	9	-	-
9.	V-7	3.00	8	468.00	8	-	-
10.	Other varieties	2.23	-	347.88	-	-	-
11.	Seedling origin	1.23	-	147.60	-	-	
** *In trees above 5 years of age*							

Bhaskara variety was released during March 2006 for coastal region of Karnataka. This variety is having midseason flowering habit (Dec-Mar) with a flowering duration of 60 days and has potential to escape from the attack of the tea mosquito bug (TMB) under low to moderate outbreak situation. The average yield was reported to be 10.7 kg/tree at DCR. The nut and kernel weight are 7.4 g and 2.2 g respectively. The shelling percentage is 30.6 and kernel grade conforms to export grade W240. The potential to escape from the attack of the tea mosquito bug (TMB) along with very good yield potential have definitely favoured this variety in its high adoption among farmers of Dakshina Kannada district. Madakkathara-2 (NDR 2-1) is a selection released in 1987. The mean yield reported from research station is 17 kg/tree. The nuts are bold (7.3 g nut weight) with shelling percentage of 26.2. Kernel weight is 2g having a count of W 240 export grade. However, this highly yielding variety was found to be adopted by only 4 percent of the farmers mainly due to low awareness in this district.

Ullal-3 is a selection released in 1993 from ARS, Ullal. It is early in flowering (November - January) and fruiting period is very short (50-60 days). The fruiting is from January to March

and sometimes starts from last week of December. It is a high yielding variety with average yield of 14.7 kg/tree. The nut size is medium with nut weight of 7g. The shelling percentage is 30 and the kernel grade conforming to W 210 grade. Its mid season nature coupled with higher yields seems to have made it a favourite among farmers. Ullal-1 is a selection released by ARS, Ullal in 1984. The average yield is 16 kg/tree. The duration of harvest is long (about 110 days). The nut weight is 6.7g with shelling percentage of 30.7. Even though the variety recorded slightly higher yields (3.90 kg/tree) in field compared to Ullal-3 (3.87 kg/tree), the adoption by farmers (13%) was found to be far below than its counterpart Ullal-3 (59%) which tops in adoption among farmers in all varieties.

Production and productivity profile of cashew farmers

The production and productivity profile of cashew farmers showed that farmers achieved a mean production of 425 kg and productivity of 2.92 kg/tree. In case of production, majority fell in to medium (40%) and low (43%) producer categories while they were almost equally divided into high (33%), medium (36%) and low (31%) categories with respect to productivity achieved.

Table 3: Classification of farmers based on production and productivity of cashew

Categories	Production			Productivity		
	f	%	Range	f	%	Range
High	13	17	>674	25	33	>3.96
Medium	30	40	674-177	27	36	3.96-1.87
Low	32	43	<177	23	31	<1.87
Mean	425			2.92		
SD	497			2.09		

Technology impact on production and productivity of cashew

The recommended cashew production technologies starting with recommended varieties were categorized to eight groups such as Varieties, Planting and initial care, Soil and water conservation, Manures and fertilizers, Pruning and training, Plant protection, Intercropping and Harvesting and post harvest technologies. Their impact on production and productivity were studied separately and are presented here.

Adoption and relationship of cashew production technologies towards cashew production and productivity

The overall adoption of cashew production technologies had received an index score of 44. Majority (51%) of the farmers belonged to medium adopter category while rest was almost equally divided between high (25%) and low (24%) categories (Table 4). Most cashew production technologies scored moderate to poor adoption index with exception of recommended varieties (72) and planting and initial care technology (73). Soil and water conservation technology (48) and pruning and training (43) showed medium adoption index while manures and fertilizers (30), plant protection (20), intercropping (22) and harvesting and post harvest technologies (43) scored low adoption index. Correlation analysis showed

that four technologies; soil and water conservation, pruning and training, plant protection and harvesting and post harvest technologies had highly significant relation with the cashew production achieved by farmers (table 5) while pruning and training had a significant relation with the productivity of cashew.

Table 4: Adoption index of farmers for cashew production technologies

Sl. No	Category	Range	Respondents	
			f	%
1	Low (<Mean-1/2S.D)	<36.27	18	24
2	Medium (Mean(+/-)1/2S.D)	36.27-51.39	36	51
3	High (>Mean+1/2S.D)	>51.39	19	25
Mean= 43.83, S.D=15.12				

Cashew farmers were found to adopt maximum practices under planting and initial care (Rank 1) followed by recommended varieties. Also, these practices were easy to adopt and initial interest plays a major role in the high adoption rate of this technology. Soil and water conservation techniques were also moderately followed by most of the farmers (Rank 3). The increased availability of heavy machineries at affordable per hour rates for land leveling, pit digging, terrace making etc. is a major reason behind this. Also, the practices under this technology are mostly adopted along with or in continuance with planting and after care thereby increasing its chance of adoption due to initial interest. Accordingly, the technology also showed a positive significant relationship (r=0.344**) with cashew production achieved by farmers. Adoption of pruning and training along with harvesting and post harvest technologies stood together at fourth place with adoption index of 43. Pruning and training was also found to have significant relationship with production (r=0.338**) as well as productivity (r=0.271*) of cashew. Harvesting and post harvest technologies was also found to have highly significant relationship with production (r=0.321**). Adoption of manures and fertilizers was found to be poor among farmers with adoption index of 30. Intercropping was another technology which was poorly adopted (Rank 6). Low to medium adoption with respect to most cashew production technologies could be attributed to the fact that farmers are yet to realize the importance of recommended technologies on the yield and potential economic benefits that accrues from their adoption.

Table 5: Relationship of cashew production technologies towards cashew production and productivity

Technology	Adoption Index	Production	Productivity
		'r' value	'r' value
Varieties	72	0.174 NS	0.020 NS
Planting and Initial Care	73	0.201 NS	-0.011 NS
Soil and Water Conservation	48	0.344**	0.165 NS
Manures and Fertilizers	30	0.094 NS	-0.042 NS
Pruning and Training	43	0.338**	0.271*
Plant Protection	20	0.345**	0.146 NS
Intercropping	22	0.062 NS	0.014 NS
Harvesting and Post Harvest	43	0.321**	0.123 NS
Overall adoption	44	-	-
NS – Non-Significant, ** - Significant at 1 % level, * - Significant at 5 % level			

Plant protection, which is one of the most important components affecting production, scored the lowest adoption index (20) among cashew farmers in the present study. Non-adoption was particularly high for plant protection technologies against Cashew Stem and Root Borer

(CSRB) due to the complexity of the technology while majority had adopted measures against Tea Mosquito Bug (TMB) due to less complexity, higher trialability and observability of results in comparison to measures recommended against CSRB. The technology showed highly significant positive relation (r=0.345**) with cashew production. It is obvious from these findings that there is tremendous scope in the region for increasing adoption of recommended cashew production technologies.

Contribution of cashew production technologies towards variability in cashew production and productivity

Regression analysis revealed the extent of contribution of each production technology towards variability found in levels of cashew production and productivity in the district (Table 6). Plant protection component which scored the lowest adoption index and also showed highly significant relation (r=0.345**) with cashew production achieved by farmers emerged as the most significant contributor towards cashew production (b=0.339**) in the district. This clearly indicates that adoption of plant protection techniques cannot be ignored at any cost if cashew production in the district has to be improved. The findings also calls for development of plant protection measures which are user friendly (less complex), having relative advantage over existing technology and also compatible with farmer situations. Soil and water conservation technology which showed a significant relationship (r=0.344**) with cashew production, is also found to have a significant contribution towards explaining the variability in cashew production (b=0.326*). Interestingly, intercropping; another poorly adopted technology was also found to have a significant contribution towards explaining the variability in cashew production (b=0.243*). Recommended varieties, manures and fertilizers and harvesting and post harvest technologies were found to have a non-significant but negative contribution towards cashew production. This is explained by the fact that in case of recommended varieties, even though the study found that highest production was given by Bhaskara, Madakkathara – 2, Ullal - 1 and Ullal - 3 varieties, the same varieties covered only 26.62, 5.21, 7.66 and 41.00 percent respectively of total area under cashew cultivation. Thus, the findings make it clear that by increasing the adoption and area coverage of above varieties we can bring a quantum increase in cashew production in the district.

Table 6: Contribution of cashew production technologies towards variability in cashew production and productivity

Technology	Production	Productivity
	'b' value	'b' value
Varieties	-0.131 NS	-0.077 NS
Planting and Initial Care	0.037 NS	-0.159 NS
Soil and Water Conservation	0.326*	0.208 NS
Manures and Fertilizers	-0.195 NS	-0.184 NS
Pruning and Training	0.178 NS	0.313*
Plant Protection	0.339**	0.139 NS
Intercropping	0.243*	-0.097 NS
Harvesting and Post Harvest	-0.012 NS	0.024 NS
	R^2 = 0.406	R^2 = 0.149
NS – Non-Significant, ** - Significant at 1 % level, * - Significant at 5 % level		

Farmers in the study area were found to have poor adoption in case of manures and fertilizers for cashew. The study also found that harvesting cashew from the trees itself is a common practice to avoid theft and this coupled with improper drying practices including less

number of drying days has contributed more volume to the cashew production. If proper harvesting and drying practices are followed it will decrease the total volume of cashew thus explaining the negative relation. Similarly by increasing the adoption levels of manures and fertilizers in cashew and by adopting proper harvesting and post harvest drying techniques the cashew production can be further improved. All the recommended production technologies together could explain only up to 40 percent of variability in cashew production (R^2 = 0.406). Adoption of pruning and training in cashew orchards was found to have a significant contribution towards increasing the per unit productivity of cashew orchards. However the adoption level of this technology is very low at present. The study reveals that increasing adoption of soil and water conservation techniques and development and popularization of user friendly plant protection measures can contribute largely to increased cashew production while increasing adoption of pruning and training in cashew orchards can significantly increase the per unit productivity of cashew orchards. The results clearly indicate that socio-economic and bio-physical factors along with policy environment have a larger contribution in explaining cashew production and productivity and technology component alone cannot be expected to bring a positive impact. Understanding the above dynamics in technology impact can help researchers and extension agencies working in cashew sector to design better innovations and effective outreach strategies.

Socio-economic impact of cashew cultivation

Ten major social and economic impact indicators were studied to arrive at the socio-economic impact of cashew farming among the respondents. Study on impact on cropping pattern didn't record much of change with only 17 percent of farmers increasing area under cashew over the years (1.5 acres) while only negligible percent (3%) of them purchased new lands (2 acres) for cashew cultivation. Impact on labour engagement was also low with only 20 percent farmers hiring labour for cashew and only one tenth of them opting for increased family labour engagement (11%). The hiring of labour was noticed particularly for plant protection and harvesting operations with farmers mostly engaging one to two labourers during this period. While a large majority (85%) reported no change in farm expenditure due to cashew cultivation, 43 percent of farmers reported an increase in farm income due to cashew cultivation. Farmers reported an average increase of Rs. 2272/year in farm expenditure and Rs. 4188/year in farm income due to cashew cultivation. Resultant increase in family incomes was also reported by 36 percent of the farmers to the average of Rs. 4259/year followed by an average increase of Rs. 2666/year in their family expenditure. The above indicators were measured as average for preceding 10 years of cashew cultivation.

Analysis of social impact presented a better picture in comparison to economic impact with majority (61%) of the farmers reporting increased social participation while nearly two-third (67%) majority could increase their contacts with extension agencies and research institutes due to cashew cultivation. Majority (56%) reported increase in their mass media exposure while a large majority (63%) reported an increase in their opinion leadership status due to cashew cultivation. It can clearly be seen that the social benefits of cashew cultivation are far more than the economic benefits.

Classification of cashew farmers based on the social and economic benefits accrued shows that nearly half of the cashew farmers (47%) belong to high social impact category while in case of economic impact large majority (80%) belonged to low benefits category. Overall, nearly half of the cashew farmers (47%) recorded medium levels of socio-economic impact

(Table 16). It may be noted that the low level of economic impacts are compensated to a large extent by the high social impact due to cashew cultivation.

Constraints faced by farmers in cashew cultivation

The socio-economic impact of cashew cultivation is largely influenced by the constraints faced by farmers. Studies conducted by DCR revealed 12 constraints as reported by farmers and are classified under technical, management, economic/marketing and processing constraints. Majority (83 %) reported poor price and the high price fluctuations in market for raw cashew nut as the major constraint (Rank 1). Lack of cashew farmer associations/groups and availability of cashew nuts from African nations allow cashew nut processors to manipulate the raw cashew nut prices. Low availability of hired labour was the second biggest constraint reported (71%). Migration of workforce to urban areas, easy job availability through MNREGA scheme and respectable job avenues in many private firms for women have acted as reasons for low availability of workforce in villages. Attack of tea mosquito bug and resultant crop loss (41%) and death of yielding trees due to cashew stem and root borer attack (35%) were also major technical constraints (Rank 3 & 4). This is a matter of concern since cashew yields are largely influenced by the attack of Tea Mosquito Bug (TMB) while attack of Cashew Stem and Root Borer (CSRB) eliminates the crop itself.

Flower drying (Rank 5) and poor yield in some varieties (Rank 6) like NRCC selection-2 (flower drying), VRI-3, V-4 and V-7 (poor yield) were also major constraints. Problems in collection of nuts from large plantations and the resultant theft due to delay or inaccessibility was another constraint reported by farmers. Price control and manipulation by cashew processors were also identified as a constraint by certain section of farmers. Cultivation of cashew in poor soils and wastage of cashew apple due to lack of processing avenues were the other constraints cited by farmers.

PROCESSING AND PRODUCT DIVERSIFICATION IN CASHEW APPLE

P. B. Pushpalatha[1], A Sobhana and C. Mini
[1] Professor and Head,
AICRP-Cashew Centre, CRS, Madakkathara

The cashew apple, formed by the swollen pedicel is an important produce of cashew tree. Yield of cashew apple in six to eight times that of the cashew nut. The production of cashew apple in India is estimated as 0.6 to 0.7 millon tons per annum (Sobhana and pushpalatha, 2014). This natural resource is totally wasted in the country, expect in Goa where it is commercially exploited for production of feni.

Strengthening processing and value addition of cashew apple is the only alternative to control the waste of this nutritionally rich natural resource. Ripe cashew apple is soft, fibrous and has a characteristic ehavi. It is a rich source of Vitamin C, often several times more than citrus fruits (Ohler, 1979). 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. Cashew apple contains 12.3 per cent carbohydrates, 0.2 per cent proteins, 0.9 per cent fibre and 0.2 per cent minerals (CSIR, 1985). The ascorbic acid content ranges from 170-350 mg per 100 g of apple (Champakam,1983). Cashew apple juice contains 10.7 per cent sugars and has an acidity of 0.3 per cent. Glucose and fructose are the major components of sugar (Rao, 1984). Cashew apple is comparable with several other fruits in content of most of the nutrient but superior in Vitamin C and riboflavin.

The astringent principles present in cashew apple gives an unpleasant biting taste when used in the raw form and limits the use of cashew apple as a table fruit. Apart from the presence of astringent principles which limits its use in the raw form as well as processed product, cashew apple as a commodity has other limitations as well. 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. Fragmented and scattered nature of cashew plantations also creates problem in collection and utilization of cashew apple (Balasubramaniam, 1977; Nanjundaswamy *et al*., 1984). The system of collection of cashew nuts from fallen fruits after considerable delay also limits the availability of quality cashew apple for processing purposes.

The apple show great is variability with respect to size, colour, TSS, ascorbic acid, proteins, tannins, specific gravity, juice recovery *etc* (Chandran and Dhamodharan, 1985 , Ghosh and Kuadu, 1989, and Kutty M.C, 2000). Hence varieties suitable for different products are to be identified and used for getting quality. Kumar and Aravindakshan (1985) listed K-27-1, Anakkayam-1, Madakkathara-1 and Sawantwadi as the varieties suitable for processing. According to Kutty (2000), varieties H-1593, H-1600, V-4, K-19-1, Madakkathara-2, Dhana, Kanaka and M 26/2 have desirable attributes with reference to quality parameters. Amrutha, Anakkayam-1, Dharasree and V5 are identified as suitable varieties for preparation of candy and tutty frutty (Suman 2005).

To overcome the availability of cashew apple as raw material for processing, technology for long term storage of cashew apple and its primary processed forms has been standardized at Cashew Research Station, Madakkathara under Kerala Agricultural University. Technologies has also been developed for commercial production of different cashew apple products. The technologies are yet to become popular, for which technology dissemination programmes are to be taken up. It is a proven fact that self help groups of women can successfully run the cashew apple processing units. Eventhough major quantity of production of cashew apples are wasted, a limited quantity is used for direct consumption and product development.

Post harvest problems.

Fruits have special significance to human health as protective food due to their vitamin and mineral contents. They are highly perishable and begin to deteriorate immediately after harvest mainly because of their high moisture content. The post harvest spoilage of fruits is attributed to the continuing physiological activities like respiration and transpiration which result in the degradation of stored energy and loss of moisture. Shriveling, wilting, spoilage by micro organisms, loss of texture, etc are the symptoms of deterioration and perishability. Cashew apple is a non climacteric fruit and is usually collected after falling on the ground along with the nut. This increases the chances of bruising and further damage by micro organisms leading to fermentation and deterioration. Since many of the fruits are seasonal, long term storage techniques are needed for the availability of raw material and product preparation throughout the year. Cashew apple is such a fruit and is available mainly during December – May. All these are to be looked in to during the post harvest handling and preservation of cashew apple.

Cashew farmers miss the opportunity for enhanced income generation since they sell raw nuts to traders and completely wasting the nutritious cashew apple. The seasonal production of cashew apple is one of the greatest handicaps for the processing industry, along with its unpleasant biting sensation when used in raw form and limits the use of cashew apple as a commercial table fruit. KAU has standardized the value addition technologies in cashew apple for the first time in India and rather value addition in the commonly wasted pseudo-fruit of Kerala. The seasonal production, one of the limitations in cashew apple processing, is overcome through long term storage techniques developed by Kerala Agricultural University. Technologies are also standardized for the removal of the unpleasant biting sensation of raw cashew apple before processing, which limits its use as table fruit. Though various techniques are available to process the fruit into various products, they are yet to become popular among the common man. By effective utilization of cashew apple on a commercial scale, the farmers can be assured of increased income, in addition to the income from nut, which definitely will encourage them to take up cashew cultivation with profound interest. Large number of technologies has been developed by various research stations in India, more specifically Cashew Research Station, Madakkathara, for the economic utilization of cashew apple by processing it into various value added products.

Uses of cashew apple

i) Direct Consumption

Cashew apple, because of its attractive shape and colour tempt every body to consume it. However several reasons limits its direct consumption. The astringency due to tannin content is one of the reason which produce an irritation in the mouth while consumption. The addition of salt, chilli powder, spice powder etc help to increase the taste level of raw apple. Minimally processed cashew apple can catch a niche market, provided suitable technology for short term storage is developed.

ii) Primary processing and preservation

Primary processing is adopted for immediate preservation of produce for future use when they are available in large quantity. Cashew apple being seasonal and highly perishable primary processing is inevitable.

Generally ripe cashew apples are primarily processed into juice and pulp while green apples are preserved in salt.

Ripe cashew apples

i) Juice

Extraction and preservation: The ripe apples are washed well preferably in 3% salt solution. Juice is extracted with the help of hydraulic press and filtered. De-tanning is to be done to remove the astringent principles from the juice. An efficient method of de-tanning and clarification (Mini and Mathew, 2008) of cashew apple juice for beverage preparation involves addition of 5g powdered sago (as paste) per litre of the juice and keeping for 12 hours. The upper layer of the clear juice is decanted carefully without mixing with sediments. This juice is preserved by addition of 2.5g Potasium meta Bisulphite (KMS) and citric acid per litre of juice.

ii) Pulp

Pulp is prepared from ripe cashew apples. The cleaned apples are dipped in 5% salt solution for three days for de-tanning by changing water every day. Fourth day, the fruit are taken out washed thoroughly and stored in KMS 1% salt solution. The apples are taken out from KMS solution, washed well in water, pressure cooked and pulped with the help of pulper. It is better to store the apples as such and prepare pulp as when required.

Green cashew apples

Green cashew apples are de-tanned in the same way using 8% salt solution. They are taken out, made into pieces and preserved in salt.

The primary processed products are used for product development.

3. Product development

i) Juice based products

The products based on juice, that possess commercial value are syrup, RTS and carbonated drink. They possess nutritious and refreshing properties. Syrup contain 276 mg Vitamin C and drink contain 140 mg vitc/100 g

Syrup is prepared by adding 65 % sugar while RTS and carbonated drink contain 12% sugar. Carbonated drink is prepared by adding chilled carbonated water at 100psi to the required quantity of syrup.

As the sugar content in syrup is high, it will act as a preservative. The KMS and citric acid in the juice will also provide preservation quality.

Pasteurization is to be given for RTS for getting a shelf life of 3 months. The CO_2 in the carbonated drink itself is a preservative.

ii) Pulp based products

Cashew apple jam

Blending is another technique used in food processing to increase the acceptability of products. The jam prepared with cashew apple pulp blended with 50% mango pulp was more acceptable than that prepared with cashew apple alone.

Cashew apple halwa and candy

Halwa and candy are semi moisturized products, prepared using the technology of dehydration. Halwa is made by mixing coconut milk, sugar and ghee with pulp and concentrating to the desired consistency by heating. Nowadays the technology of vacuum concentration is gaining momentum as the sensory and nutritional quality of the product will be well preserved.

Candy is prepared by progressively increasing the sugar content de-tanned cashew apple by dipping in sugar solutions of brix from 30 to 70^0. One kilogram of cashew apple on processing will give 745g of candy

iii) Green cashew apple product

Cashew apple pickle

Cashew apple pickle is a product which gained high marketability. It is prepared and preserved using salt, oil and vinegar. Green cashew apples are pickled like any other pickle adopting lactic acid fermentation. Primary processing of cashew apple is very important for pickle making.

iv) Products adopting fermentation technology

Cashew apple can be utilized for the manufacture of the fermented products like wine, vinegar, liquor and alcohol. Cashew apple vinegar can be prepared by alcoholic and subsequent acetic fermentation of juice. Cashew liquor is made by distillation of the pure juice of cashew apple without addition of any extraneous matter. 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.

Cashew apple wine can be mixed with fresh juices of orange, pineapple, tomato, grape and cashew apples as well as tender coconut 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.

Cashew apple powder

The technology for production of cashew apple juice powder has not been standardized. However osmotically dehydrated cashew apples can be powdered to obtain cashew apple powder. 1kg of good quality fresh cashew apple on processing can yield about 200 g of osmotically dehydrated cashew apples. Ready to serve beverage mix, fruit- milk/milk shakes, ice creams, ice candy mix, etc. can be prepared from clarified juice by homogenization, spray drying and mixing with fruit/milk powder as required.

Different confectionery products and culinary products can be prepared using cashew apple. Cashew apple is also reported to have medicinal properties neutraceutical application and agricultural uses.

Cashew apple waste utilization

Cashew apple is used for preparation of ehavi compost animal feed and pest management. A valuable by- product that can be obtained from cashew apple waste is pectin. Pectin is used in manufacturing jams, jellies, marmalades, preserves etc. the yield of pectin from cashew apple varies from 1.60 to 2.03%. the cashew apple pomace of the fruit waste has been identified as ideal medium for pectinase enzyme (Venkatesh, 2003).

Primary requirements to start cashew apple processing unit

A building with adequate area according to turnover envisaged and having electricity and water connection are mandatory for starting a commercial production unit. Apart from

utensils gas connection etc minimum equipments and machineries are required to facilitate primary processing, storage, processing and value addition of cashew apple as given below.

The infrastructure facilities developed for processing of cashew apple can be used for processing of other fruits. . This will help maximum utilization of infrastructure facility developed. Cashew being seasonal in nature, the availability of raw material round the year will be a problem and processing of other fruit based products can be thought off. Also the products including that of cashew apple can be produced and marketed according to market demand. Hence the basic knowledge on processing and value addition of fruits in general is required to run the unit profitability.

Apart from these common value added products, there are certain novel dehydrated products, prepared from cashew apple and may reduce the problems faced by traditional products

Osmo-dehydration

Cashew apple could be dehydrated and stored under ambient condition for a period of six months without affecting the quality by adopting the technique of osmotic dehydration. Compared to the previous processing techniques, this dehydration technique can be considered as a useful technique for the production of safe, stable, nutritious, tasty, economical and concentrated foods, which contain no sugar and can be ehavior on under Intermediate Moisture Food.

Osmotic dehydration is a useful technique for the concentration of fruit and vegetables, realized by placing the solid food, whole or in pieces, in sugars or salts aqueous solutions of high osmotic pressure. It gives rise to at least two major simultaneous counter-current flows: a significant water flow out of the food into the solution and a transfer of solute from the solution into the food. Dept of processing Technology, College of Agriculture, Vellayani has standardized osmotic dehydration technique for cashew apple.

Osmo-dehydration of cashew apple involves three phases.

Phase I- Good quality fruits are made into 10 mm slices, subjected to blanching and osmotically dehydrated by dipping them in aqueous honey solution of 60^0 brix at 50^0 C for 24hour, so that about 50% water from the fruits migrates to honey syrup.

Phase II- Vacuum or air drying – Fruits are drained and dehydrated to 15-20% moisture by vacuum or air drying depending on the cost considerations.

Phase III- Packaging- The dehydrated fruits are packed under modified atmospheric condition with nitrogen in flexible laminated pouches.

1. Spray drying

All types of cashew apple beverages from Kerala Agricultural University are produced by addition of varying concentration of sugars to clarified cashew apple juice. High concentration of sugar and problems in transportation and storage are the main drawbacks of this traditional system of beverage production. Spray drying is one of the best answers to these problems, where the juice is directly converted into solid or semi-solid particles using the machine, spray drier. This novel dehydration method has better control of the process and it increases the product quality. Among the drying techniques, spray drying is used in a wide range of products in food industries to produce dry powders and microcapsules.

Dehydrated cashew apple powder can be prepared with and without cashew apple juice. The cleaned fruits are soaked in 2% salt solution for tannin removal, taken out and rinsed in water. After surface drying, the fruits are sliced, steam blanched and treated with sulphur dioxide. Then juice is extracted, clarified, spray dried and packed as cashew apple powder with juice. The pulp or the residue of apple, obtained after juice extraction, can be dried, powdered, sieved and packed as cashew apple powder without juice.

2. Products from dehydrated cashew apple powder

Frozen desserts and dairy confectionery prepared by optimization of juice concentration and spray drying open an excellent avenue for cashew apple ehavior on. The only constraint here is the large capital investment required for spray drier equipment. Technical expertise and multiple use of the machines for a variety of agro- based products are a must for the year round profit from such enterprise.

Conclusion

The research efforts bestowed for utilization of cashew apple have resulted remarkable achievements especially the work done at Cashew Research Station, Madakkathara (KAU). The research and technology dissemination in this area is to be strengthened to increase cashew apple utilization and prevent the loss of their natural resource.

While analyzing the situation of value addition of fruit crops, it is understood that emphasis has been given in the past only to major fruit crops in the country and the wealth of indigenous fruits has not been brought to the forefront. But in the present scenario of changing food habits, job profile and health awareness, new and improved processed products are in demand world over. To satisfy this demand, there is a constant search for and an effort to develop products from hitherto little sources. In this regard, Kerala offers exciting possibilities of adding new dimensions to the processing industry. Consumers have become increasingly conscious on the health and nutritious aspects of their food and tendency is to avoid synthetic foods and choose nutrition through natural resources. Indigenous fruits such as cashew apple, which are at present underutilized, have an important role to play in satisfying the demand for nutritious, delicately flavoured and attractive natural foods of high therapeutic value.

References

Balasubramaniam, 1977. Crisis in cashew industry- causes and some possible solutions. Cashew Bull.3: 8-16

Champakam,1983. Distribution of ascorbic acid and ascorbic acid oxidase activity in the developing cashew apple (Anacardium accidentale L.). J. Hort. Sci.58 (3): 447-448

Chandran and Dhamodharan, 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

Ghosh and Kuadu, 1989. Studies on physio-chemical characteristics of cashew apple of different types at CRS Jhagram. Cashew Bull. 26 (1) : 13-18

Kumar and Aravindakshan 1985. Studies on somequalitative aspects of cashew apple. Indian Cashew J. 17 (5) : 19-21

Kutty., M.C (2000), Development pattern, storage ehavior and variability in processing characters of cashew apple. Ph.D thesis. Kerala Agricultural University, Thrissur

Mini and Mathew, 2008 Recipes for cashew apple products. Kerala Agricultural University p.15

Nanjundaswamy *et al*., 1984. Utilisation of cashew apples for the development of processed products. Proceedings of First International Symposium on cashew Research Development, March, 12-15, 1979. Pp. 151-159

Ohler, 1979 Cashew Communication 71. Department of Agricultural Research. Kaninklijk Insituut voor de Tropen. Amsterdam. Pp.63-75

Rao, 1984. Scope for development of alcoholic beverage from cashew apple. Proceedings of First International Symposium on Cashew Research and Development, 12-15 March, 1979 pp 161-164

Sobhana A and Pushpalatha P.B 2014. Cashew apple- an Unexploited fruit for processing In: Cashew handbook 2014; pp.119-124

Suman 2005. Physico chemical and nutritional attributes of cashew apple and its products. Ph.D thesis. Kerala Agricultural University, Thrissur

CASHEW NUT PROCESSING

D Balasubramanian
ICAR-Directorate of Cashew Research, Puttur
balasubramanian.d@icar.gov.in

The economic interest has made many countries of the world to encourage the cultivation of cashew and it is fast becoming an export produce in many developing countries. Among horticultural crops, cashew has been known to provide very high economic returns. The raw cashew are either exported or processed prior to export. The cashew kernel is the main product which has aroused economic interest in the wide spread cultivation of cashew. The kernel is widely consumed as snacks and used as a basic ingredient for confectionaries in most countries of the world because of its good nutritive value. Primarily raw nuts, cashew kernels and cashew nut shell liquid (CNSL) are the three main cashew products which are traded in the international market. The importance of cashew (*Anacardium occidentale* L.) for the Indian economy has been due to its role as an earner of foreign exchange and also to its employment generating capacity in the processing sector. Cashew processing in India started as a small cottage industry and has developed into a highly organized labour intensive industry and gradually progressing towards mechanization. Since the world demand for cashew kernels has been rising steadily for several years in the past conferring significant price increase, the processing of cashew remains still a highly profitable industry.

Cashewnut processing industries:

India is the largest producer, processor and exporter of cashew in the world. There are about 3750 cashew processing factories employing more than 10 lakh personnel with an estimated processing capacity of 20 lakh TPA. Export of cashew kernel in the year 2012-13 was around 1.01 lakh MT valued Rs 5063 Crores. Cashew industries have a simple organizational structure and mostly under private management i.e. proprietorship (63%) or partnership (19%). Since it requires large amount of capital investment and working capital, most of the industries depends on commercial banks and state financial agencies. About 62% of the industries are categorized under "Manufacturer exporter". This is primarily due to encouraging export policy and higher exchange value for USD. Tiny processing units i.e. up to 100 TPA and medium capacity processing industries i.e. 100-500 TPA accounts for 39% and 42% respectively, due to raw nut shortage and financial constraints. In order to run the factory through out the year, 50% of the factories import raw nut during off-season from African countries. About 8.21 lakh MT raw nuts were imported during 2012-13. Most of the industries utilized capacity is below 50%. About 90-95% of women force is employed in these industries at different stages of operation. Total employees strength varied between 50 and 400. Men labourers are involved in drying, stacking, roasting, kernel drying and packing. The State Government fixes labour wages and it differs from state to state.

Raw cashew nut:

Raw cashew nut is kidney shaped one with approximately 3.5mm thick leathery outer skin (Epicarp) and thin hard inner skin (Endocarp). Between these two walls of the shell is a honeycomb structure, which contains the phenolic material, commercially, known as cashew nut shell liquid (CNSL). The kernel is inside the shell wrapped in a thin brown skin known as testa.

Raw nut procurement:

Cashew nut is a seasonal crop, harvesting of nuts in India starts from March to June. It has been found that the processors obtain raw material in four ways. I) Directly from producers; ii) Direct purchase from local market; iii) Through commission agents and iv) Through imports. While procuring the nuts, normally 3 tests are conducted.

Visual test:

Size and colour of the nuts to check the maturity.

Floating test:
About 1 kg of sample is transferred to a vessel containing water. After continuous stirring floaters are collected and counted. Mostly immature nuts, due to its lower density than water, improperly filled nuts and deteriorated nuts floats. Based on the percentage of floaters the raw nut quality is assessed.

Cutting test:

Raw cashew nut sample of 1 kg is collected from different bags and mixed together. 1 kg raw nut is taken from diagonal samples and cut open using hand cutting tool. Based on the kernel appearance i.e. white, shriveled, black spotted or rejects, the percentage of good kernel is calculated. This is considered for valuating price of fixing the price.

Cashew nut processing:

It can be defined as the recovery of edible kernel from raw nut by manual or mechanical means. In India, the processing is mostly manual and it consists of moisture conditioning, roasting, shelling, kernel drying, peeling, grading and packing. Cashew shell is pliable and unsuitable for any type of manual or mechanical opening in its natural state. Conditioning or roasting, however, will harden and make cashewnuts brittle, susceptible for cracking or

splitting. Various conditioning methods followed India are: (i) Open pan roasting; (ii) Drum roasting; (iii) Oil bath roasting and (iv) Steam boiling.

- **Drum roasting:**
  In this process the nuts are fed into an inclined rotating drum which is heated initially to such an extent that the exuding oil ignites and burns, thus charring the shell. The drum maintains its temperature because of the burning cashewnut shell liquid (CNSL) oozing out of the nuts. Roasting generally takes about 3-5 minutes and the drum is rotated by hand during this period. The roasted nuts, which are still burning, are covered with ash to absorb the oil on the surface. The shell becomes brittle and rate of shelling and the outturn of whole kernels reported to be highest among the three methods of roasting.

- **Oil bath roasting:**
  Though it is an outdated method in India, majority of Brazil and African countries still follows this system. The roasting equipment consists of a rectangular vessel, 2-3 feet wide and 3 feet deep, with a flat bottom. The whole assembly is embedded in brickwork furnace which uses spent cashew shell as fuel. In this method, raw nuts are passed through a bath of heated CNSL maintained at a temperature of approximately 190-200°C by means of screw or belt conveyor for 1-3 minutes.

- **Steam boiling:** This method is adopted in the factories where hand and leg operated shelling machines are used. The nuts after conditioning are given a mild roasting in an equipment for 20-25 minutes at 5.6-7.0 kg cm^{-2} . This process helps to loosen the kernel and make its removal easy.

Shelling:

- **Manual:**
  Nuts after roasting are shelled (decortication) manually in most of the units in Kerala and Tamil Nadu. Manual shelling is an operation requiring some amount of dexterity. Nuts are knocked 2-3 times on each of the long edge of a wooden mallet or light hammers taking care to see that the whole kernels are released without damage or breakage as far as possible. The outturn will be 90 % of whole kernels. Individual workers' output is about 15-20 kg per 8 h of working day. Workers smear ash or clay on their hands to avoid contact of corrosive shell oil with the skin.

- **Mechanical:**
  The mechanical shelling gadget consists of two blades, between which the raw nut is inserted. The gap is adjustable and therefore it will be advantageous if the raw nuts are pre-graded on the basis of size. By means of lever operated by leg, the blades are brought together which will cut the shell without damaging the kernel inside. The nut is cut to the depth of the shell and a hand lever is pressed to open the shell into

two parts. The pressure exerted by the foot and hands should be so regulated as to cut only the shell and not the kernel. The kernel is then scooped out by means of sharp needle. The output per worker per 8 hours shift in this method is estimated to be 14-22 kg of kernel. The main disadvantage of this method is while handling the mild roasted kernels the CNSL oil may contaminate it, and varying size of the nuts requires careful manipulation during cutting to avoid injury to the hands.

Kernel Drying:

The kernels after separation from the shells are dried to reduce the moisture and loosen the adhering testa. The most commonly used drier is 'Borma dryer'. Kernels are placed in trays with wire mesh bottom and loaded into metal chambers. Indirect hot air from furnace and blower assembly helps to dry out the kernel moisture. Spent shells from the decortication process are burnt as a source of heat and air temperature ranging from 70-100°C will be prevailing inside the whole chamber. In order to get uniform drying, the position of trays is changed at intervals of 30 min. The normal duration of heating is 8-10 h. The moisture content of the dried samples will be in the range of 2-4 per cent (db).

Peeling:

Peeling is the operation of removal of the testa from the kernels. As the kernels are quite brittle after removal from the dryer they have to be cooled for 24-48 h for moisture absorption. A slight pressure applied through the fingers separates the testa. Sharp bamboo sticks or SS blades are also used to remove the adhering testa. The average peeling capacity is 7-10 kg/head /day.

Grading and conditioning:

Kernels are graded on the basis of specification prescribed by Govt. of India under the export (quality control and inspection) Act 1963, which recognizes 23 different export grades of kernels. The kernels are conditioned before packing in sealed tins. If the kernels are too dried at the time of packing, they are liable to breakage during transport by land and sea. If the moisture exceeds limit of 5 per cent kernels become susceptible to microbial and oxidative spoilage.

Packaging of kernels:

Cashewnuts are subjected to rancidity and very quickly go stale. Therefore packing should have low permeability of oxygen and moisture. Method of packing should involve either vacuum or inert gas inside the packing. At present the bulk of cashewnuts is packed in tin containers weighing 25 lbs. Tins kept on vibrating platforms are filled with kernels through a chute. After filling and weighing the tins are evacuated filled with CO_2 with the help of "VITAPACK" machine and sealed. Introduction of alternative method of flexible packaging (Mould Vacuum Packaging) with nitrogen as inert gas is gradually gaining importance. After securing ISO 9000 and introducing HACCP (Hazard analysis and critical control points), importing countries are following stringent quality standards for cashew kernels and the present system of tin packaging is bulky and difficult to dispose off these tin containers.

हर कदम, हर डगर
किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद

Agrisearch with a human touch