e-TRAINING MANUAL

on

Cashew Production and Post-Harvest Technologies

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FOREWORD

Cashew is an important foreign exchange earning plantation crop of India. India is the first country to exploit the commercial value of this crop. ICAR-Directorate of Cashew Research (DCR) is the nodal agency for cashew research in the country. The research on cashew was initiated in the early 1950s. Then All India Coordinated Spices and Cashew Improvement Project (AICS & CIP) was started at CPCRI, Kasaragod. Later in 1986 National Research Centre for Cashew (NRCC) was established at Puttur, D.K., Karnataka to take forward the research programmes on cashew and in 2009, NRCC was upgraded as Directorate of Cashew Research (DCR).

The demand for cashew is increasing at both global and national levels. However, the cashew yield levels in India have been low, mainly due to insect pest attacks and lack of proper management of cashew orchards. Thus, it has become imperative to transfer the scientific cashew production technologies to the cashew growers to enhance the cashew productivity and production in the country. Besides, development of value added products of cashew kernel and apples is needed for improving the income of the cashew growers. Towards achieving this, DCR is continuously striving by improving the cashew production and processing through research and extension activities.

I am pleased that ICAR-Directorate of Cashew Research, Puttur in collaboration with Meghalaya Basin Management Agency (MBMA), Govt. of Meghalaya is organizing a National Level Training Programme on “Cashew production and postharvest technologies” during 10-14 February 2020 for the farmers and officials. The training emphasizes on the latest concepts and practices in the field of cashew production and processing for the benefit of stakeholders.

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

11/2/2020.

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Citation:

Eradasappa, E., Mog, B., Savadi, S. and Mangalassery, S. 2020. Training manual on Cashew Production and Post Harvest Technologies. ICAR-Directorate of Cashew Research, Puttur, Karnataka, India. 143p.

Published by:

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India
February, 2020

Training Sponsored by

Meghalaya Basin Management Agency (MBMA)
Govt. of Meghalaya

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DCR at a glance

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ICAR- Directorate of Cashew Research, Darbe (P.O), Puttur, Dakshina Kannada, Karnataka, India

History

Cashew (*Anacardium occidentale* L.) is a tree native of Eastern Brazil, which was introduced into India by the Portuguese in the 16th Century. Over the years, cashew became a crop with high economic value and is earning considerable foreign exchange for the country. Research on cashew in India was first initiated in the early 1950s. The Indian Council of Agricultural Research (ICAR), sanctioned ad-hoc schemes for Research Centres located at Kottarakkara (Kerala), Ullal (Karnataka), Bapatla (Andhra Pradesh), Daregaon (Assam) and Vengurla (Maharashtra). In 1971, ICAR also sanctioned an All India Coordinated Spices and Cashew Improvement Project (AICS & CIP) with its headquarters located at ICAR-Central Plantation Crops Research Institute (CPCRI), Kasaragod. The CPCRI Regional Station, Vittal (Karnataka) was given the mandate to carry out research work on cashew while four Centres under Universities (viz. Bapatla, Vridhachalam, Anakkayam and Vengurla) were assigned the research component on cashew under AICS & CIP. During the V and VI plan periods, three more Centres (viz. Bhubaneswar, Jhargram and Chintamani) came under the fold of AICS & CIP and with shifting of work of Anakkayam Centre to Madakkathara. The recommendations made by the Quinquennial Review Team (QRT) constituted by ICAR in 1982, working group on Agricultural Research and Education constituted by the Planning Commission for VII Plan Proposals and the Task Force on Horticulture constituted by ICAR resulted in the establishment of National Research Centre for Cashew (NRCC) at Puttur on 18 June 1986. During the VII Plan, AICS & CIP was bifurcated in to two separate project, one on cashew and another on spices. The headquarters of independent AICRP on Cashew was shifted to the newly established NRCC, Puttur in 1986. NRCC was upgraded and renamed as **Directorate of Cashew Research (DCR)** by ICAR on 23 March 2009 under XI Plan. At present, this AICRP on Cashew is operating at 14 Centres distributed in major cashew growing regions of the country. The prefix “ICAR” is added before the Institute name since 2014 as per the ICAR, New Delhi order.

Location

The main campus of ICAR-DCR is situated 5 km away from Puttur town at Mottethadka village of Kemminje (12.45°N latitude, 75.15°E longitude and 90 m above MSL). The main campus has an area of 68 ha having an Institute building with Research Laboratories and an Administrative Block and Field experiment plots. Besides, the Directorate has an Experimental Station at Shantigodu, located 13 km away from the main campus which has an area of 80 ha. The institute is conducting and coordinating research on different aspects of cashew such as germplasm collection and conservation, crop improvement, crop production, crop protection, post harvest technology and transfer of technology.

Vision, Mission and Mandates

Vision

- Accomplishing self- sufficiency in raw cashewnut production and maintaining premier position as the largest producer, processor and exporter at the global level.

Mission

- To promote overall growth through the enhancement of production and productivity in cashew.

Mandates

- To undertake strategic, basic and applied research for enhancing productivity, quality, processing efficiency and value addition of cashew.
- To serve as a national repository of genetic resources and scientific information on cashew.
- To coordinate All India Coordinated Research Project on Cashew for addressing location and region-specific problems.
- To promote capacity building through the transfer of technology and consultancy services to stakeholders.

Organogram

The Director is the administrative head of this Directorate. The Institute Management Committee (IMC), Research Advisory Committee (RAC) and Institute Research Committee (IRC) assist the Director in the matters relating to the management and research activities of the directorate, respectively. The research and extension on various aspects of cashew are conducted in five divisions viz. Crop improvement, Crop management, Crop protection, Postharvest technology and Transfer of technology. The institute also has different

laboratories for sections of Horticulture, Soil Science, Plant Breeding, Plant Physiology, Biotechnology, Plant Protection and Postharvest Technology. The other facilities available at the directorate include Audio Visual Laboratory, Prioritization, Monitoring and Evaluation Cell (PME), Institute Technology Management Unit (ITMU), Agricultural Knowledge Management Unit (AKMU), Vigilance Cell, Women cell, Library and Museum. The Directorate also functions as headquarter for the All India Coordinated Research Project on Cashew.

Library, AKMU, ITMU

The Directorate has got a well-established library in the field of cashew research. The library is serving as an Information Centre on all aspects of cashew research and development in the country. The CD database viz. CABHORT, CABPEST, AGRICOLA and AGRIS, SOIL CD, CROP CD, PLANTGENE CD and TROPAG CD and online CAB database are also available. The library is equipped with automation software and barcoding facility. The library has 1938 books and 2030 back volumes of various journals. The library subscribes 35 national and 2 international journals. The library is a member of Consortium of Electronic Resources on Agriculture (CeRA), New Delhi. Tech-Focuz digital library software is also available for CD Database search. The AKMU has been providing internet facilities and wi-fi connectivity andAudiovisual laboratory facilities to the staff and trainees. The Institute Technology Management Unit (ITMU) shoulders the responsibility of commercialization of technologies developed by the Directorate

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Spectrum of variability in Cashew: conservation and utilization

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Introduction

Cashew (*Anacardium occidentale* L.) belongs to the family *Anacardiaceae* and is a native of Brazil. It was introduced to India by Portuguese during 16th century. Presently, the cashew plants in wild state as well as in well managed orchards are seen in Maharashtra, Goa, Karnataka and Kerala along the west coast, Tamil Nadu, Andhra Pradesh, Orissa and West Bengal on the east coast. To a limited extent, the crop is also seen growing in Chattisgarh, Gujarat, Assam, Arunachal Pradesh, Meghalaya, Tripura, Manipur, Nagaland and Andaman and Nicobar Islands (Singh 1998). After the establishment of National Research Centre for Cashew (NRCC) at Puttur, Karnataka in 1986 (Now the Directorate of Cashew Research-DCR), the germplasm collection through vegetatively propagated material started and a coordinated approach was brought in the cashew gemplasm collection by organizing joint survey teams consisting of scientists of DCR and the centres of All India Coordinated Research Project on Cashew (AICRP on Cashew) of the respective cashew growing states (Bhaskara Rao and Swamy, 2000).

The germplasm survey and collection were carried out in cashew growing states namely Karnataka, Kerala, Maharashtra, Goa, Tamil Nadu, Andhra Pradesh, Orissa and West Bengal. The non-traditional areas such as Garo Hills (Meghalaya), Bastar (Chhattisgarh), Gujarat, Dadra & Nagar Haveli and Andaman & Nicobar Islands were also surveyed for germplasm collection. So far, 542 accessions have been collected and conserved in the National Cashew Field Gene Bank (NCFGB) at the Directorate. Similarly, Regional Cashew Gene Banks (RCGBs) have also been established at AICRP Centres which are maintaining a total of 1557 accessions (Table 1).

Evaluation and characterization of cashew germplasm

For systematic characterisation of cashew germplasm, the collected scion material of the accession is grafted onto a suitable root stock and each grafted accession is then grown in the field gene bank with 6 grafts/accession and spacing of 6m x 6m at the Directorate.

Recommended agronomic practices are adopted and observations are recorded on 3 selected plants in each accession after 10th year of planting and after obtaining 6 annual harvests for 68 descriptors following "Cashew Descriptors" (IBPGR 1986). So far 478 clonal accessions out of 539 accessions have been evaluated and 444 are conserved in a conservation block by planting 4 plants per accession at a closer spacing of 4 m x 4m.

The information on first set of 56 accessions planted in 1986 was published in the Catalogue of Minimum Descriptors of Cashew Germplasm Accessions-I during 1997. The second set of 97 accessions planted in 1987 and 1988 was documented in the Catalogue of Minimum Descriptors of Cashew Germplasm Accessions-II during 1998. The third set of 102 accessions planted in 1989 and 1990 has been included in the Catalogue of Minimum Descriptors of Cashew Germplasm Accessions-III during 2000. These are the first efforts made in characterisation of clonal accessions of cashew in the world and so far, 255 accessions have been characterised and catalogued (Swamy et. al 1997, 1999 and 2000). Recently, fourth catalogue containing information on 108 accessions planted during 1991-97 and fifth catalogue containing information on 115 accessions planted during 1998-2003 have been prepared and are in process of publication. An attempt has been made to develop a core collection of cashew germplasm accessions (49) from 478 accessions of cashew following advanced maximization strategy with heuristic approach and they were established in the field.

The germplasm accessions which are unique and have potential (verified / verifiable) attributes of scientific/commercial value are registered in NBPGR, New Delhi (Table 2)

Unique types in germplasm accessions

The germplasm accessions conserved in the NCFGB at DCR, Puttur include the diverse types such as high yield, bold nut, semi-tall, compact, Cashew Nut Shell Liquid (CNSL) free, purple pigmented, high shelling percentage, cluster bearing, big apple and early maturity types. The range and mean of characters for some quantitative characters is given in the Table 3. Three wild species namely, *Anacardium pumilum, A. othonianum* and *A. microcarpum* are also conserved. The collection also has seedling accessions of 23 exotic collections of which nine were collected from Brazil, Nairobi, Mtwara, Lindi, Nacala, Mozambique, Ex Tanganyka, Singapore and Australia and 14 from Republic of Panama.

Utilisation of germplasm

Of the 29 cashew varieties and 13 hybrids released in the country, the varieties are *per se* selections made from the germplasm material. These 29 varieties were identified and released

based on the germplasm evaluation carried out at different centres. About 155 germplasm accessions have been effectively utilized for crossing programme at the Directorate of Cashew Research (DCR), Puttur and several of these were also supplied to other cashew research centres for hybridization programme and other studies. For instance, a total of 75 cashew accessions have been supplied to AICRP on Cashew Centers/ICAR Research Complex for Goa for evaluation and hybridization programme. A total of 107 accessions (65 during 2001 and 42 during 2002 fruiting season) in NCFGB have been utilized as parents under the ad-hoc research scheme "Network Programme on Hybridization in Cashew" which was in operation during 2000-2003. Leaf samples of 34 varieties and 153 gemrplasm accessions have been supplied to Division of Horticulture, UAS, Bengalurufor DNA Finger Printing of varieties and germplasm under the DST funded project. Leaf samples of 142 accessions have also been supplied to NRC DNA Finger Printing, New Delhi.

Presently, the hybridization programme is going on at DCR, Puttur and cashew research stations at Bapatla, Bhubaneswar, Vridhachalam, Madakkatahra and Vengurle. The review of performance of varieties and hybrids indicated that in the states where both selections and hybrids are released for cultivation, the performance of hybrids have been better than the selections. Hybrid vigour can easily be exploited in cashew because of the amenability of this crop for vegetative propagation. Recently, a program for development of varieties for cashew apple has been initiated at the Directorate with 14 selected accessions and this is expected to provide impetus for cashew apple utilisation.

Future thrust areas

Since there is a moderate amount of diversity available in Indian cashew germplasm due to limited introduction episodes, it is essential to introduce and enhance genetic variability from countries of Central and South America. The introduction of dwarf accessions from Brazil needs and subsequent development of dwarf hybrids needs special mention since dwarf types are very much required for high density planting systems to improve productivity. Uutilization of germplasm accessions in hybridization programs, exploitation of unique types such CNSL free and rich types are some of the areas that need attention in the ensuing days.

Table 1: Status of cashew germplasm holding in India

Centre	No. of accessions
ICAR- DCR Puttur	542
East Coast centres	
Bapatla	111
Bhubaneshwar	112
Jhargram	164
Vridhachalam	208
West Coast centres	
Goa	104
Madakkathara	142
Pilicode	99
Vengurla	346
Plains tract/otherscentres	
Darisai	23
Hogalagere	104
Jagdalpur	82
Kanabargi	3
Tura	59
Total	**2099**

Table 2: Germplasm accessions from DCR registered with NBPGR, New Delhi

Accession	**Traits of importance**
NRC-59 (VTH 196/18)	Big apple, bold nut size and high shelling percentage,
NRC-111 (Mardol-4)	Mid-season flowering, big apple and big nut size
NRC-116	Cashew Nut Shell Liquid (CNSL) free type
NRC-120 (Nairobi)	Early season flowering, bold apple and nut size
NRC-121 (Purple genotype)	Purple stem and leaves and high shelling percentage
NRC-140 (VTH 155 L)	Semi-tall, early season (Nov-Dec) and long flowering duration (120 days)
NRC 142 (VTH 578/1)	Wild relative with unique gene combination
NRC-152 (VTH 713/4)	Wild relative with unique gene combination
NRC-201 (Pl.No.1254)	Upright and compact habit, semi-tall type

Table 3: Range and mean of different characters in 478 germplasm accessions

Character	Range	Minimum	Maximum	Mean
Tree Height (m)	8.20	1.50	9.70	5.01
Tree Spread (m)	9.60	1.50	11.10	6.20
Nut Weight (g)	14.78	2.00	16.78	6.88
Sex Ratio	0.29	0.01	0.30	0.09
Apple Weight (g)	170.00	10.00	180.00	61.82
Shell Thickness (mm)	3.20	1.50	4.70	3.06
Flowering Duration (days)	88.00	42.00	130.00	82.54
Apple to Nut ratio	26.10	2.00	28.10	9.32
Shelling Percentage	27.30	15.30	42.60	28.50
Kernel Weight (g)	4.00	0.40	4.40	1.94
Leaf Area (sq.m)	131.30	37.00	168.30	87.33
Cumulative Yield per plant (kg)	27.24	0.29	27.53	10.49
Flowering Intensity (%)	82.50	14.30	96.80	65.78

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Improved cashew varieties and their recommendation

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Introduction

Cashew is a fast growing; ever green perennial tree well suited to the wet/dry tropical climate. The tree has a long productive life, perhaps up to 50 years, however in poor conditions the economic life of tree would be reduced. The cashew produces a nut containing a kernel, and also a fruit known as the cashew apple. The nut is processed for the kernel, which is sold as an edible nut and is the main economic product. The cashew apple has various uses; it can be eaten as fresh fruit, or processed into juice and other products. In Goa it is being exploited commercially for production cashew liquor called 'Feni'. There is also a by-product from processing the nut that is called cashew nutshell liquid (CNSL) which can be extracted from the spent shells of the nut during processing, and this product has various industrial uses.

The cashew tree cultivation has spread to many tropical countries. Top five cashew producing countries are Vietnam, Nigeria, India, Côte d'Ivoire and Brazil (FAOSTAT, 2013).The major export markets for the kernel are USA, Europe, Canada, Japan and Australia. China has also emerging as a major market. In addition India has a growing domestic market. The world production of cashew has doubled in the past 25 years; however world demand has increased at the same rate so that kernel prices have remained relatively stable over this period.

The present production of cashew in India 7.28 lakh tonnes whereas the requirement is 13-14 lakh tonnes which means that there is deficit of 50% in domestic production which is met by import of raw nuts from other countries. The lower production is due to the low productivity of cashew (772 kg/ha).This kind of situation warrants adoption of scientific strategies for increasing the domestic production in the light of declining import from cashew producing countries due to various reasons. The productivity is low particularly in Karnataka, Goa, Tamil Nadu, Andhra Pradesh and Odisha. The main factors for low productivity in these states are the large plantations under seedling origin and poor management practices.

Cultivation of high yielding varieties is the most important step in improving the productivity of cashew.

Cashew variety screening procedure

Cashew does not grow true to type from seed, and seedlings raised from seed or nuts vary in several characteristics including growth habit (tree size and canopy shape) and nut quality. All cashew seedlings should be planted in similar conditions and receive a consistent management, so as to isolate and measure the genetic characteristics. The selection process involves

- Monitoring of performance of the trees over a long enough period in order to obtain a good measure of the seedlings potential.
- Making selections based on the important criteria (nut yield/tree, nut weight, kernel weight, shelling percentage, export grade, time of bearing, tree shape)
- Cloning the selected seedling by grafting or budding to produce replicates of that variety. These replicate trees are then used as "sources of scions for the large scale production of the selected variety
- These varietal trees are then used for commercial plantings.

Development of high yielding cashew varieties

As a result of evaluation of germplasm collected and evaluation of the hybrid seedlings, a number of varieties were evolved and released from various cashew research centers. As cashew is propagated vegetatively through wedge grafting or soft wood grafting, the superiority of a hybrid or selection can be easily maintained and fixed. In all, 53 varieties have been released from different research centers and DCR (formerly NRCC). Among them 33 are selections and 20 are hybrids (Table 1). Some of salient features of these varieties are presented below.

Varieties released from Andhra Pradesh

The Andra Pradesh Horticultural University (Formerly Acharya NG Ranga Agricultural University) has released the following seven cashew varieties for cultivation in Andhra Pradesh based on trials conducted at Cashew Research Station, Bapatla.

BPP 1

This is a hybrid (H2/11) developed from the cross between Tree No.1 as female parent and Tree No.273 as male parent and was released in the year 1980. The average yield is 10 kg/tree. The percentage of perfect flowers is about 13 with a fruit set of eight fruits per panicle. Nuts are medium in size with a nut weight of 5g and the shelling percentage of 27.5. Kernel protein percentage is 19.8%. The apple is medium in size and yellow in colour with the juice content of 57%. Kernel grade is W 400. This hybrid is withdrawn from recommendation for cultivation.

BPP 2

This is also a hybrid (H2/12) with the same parentage as BPP 1, that is, T.No.1 x T.No.273. Released in 1980. The average yield is 11 kg/tree. The nuts are small with a nut weight of 4g and shelling percentage of 25.7. The percentage of bisexual flowers is 8 with the fruit set of 8 to 10/panicle. The protein content of kernels is 21.3%. Juice content in apple is 67%. Kernel grade is W 450. This hybrid is withdrawn from recommendation for cultivation.

BPP 3

This is a selection from the germplasm collected from Simhachalam in Vishakapatnam district of Andhra Pradesh and the variety was released in 1980. Bisexual flower percentage is 15%. The average yield recorded was 11 kg/tree. The nut weight is 4.8g with shelling percentage of 28.1. Protein content is 19.0%. The apple has juice content of 67%. Kernel grade is W 400. This selection is withdrawn from recommendation for cultivation.

BPP 4

This is the selection from germplasm accession of 9/8 Epurupalem and released in 1980. This variety has distinct light pink pigmentation in their youngest leaves. The bisexual flower percentage is about 8%. The average yield is 10.5kg/tree with a nut weight of 6g. Shelling percentage is poor (23%). Protein % of kernels is 18.1%. The apple colour is yellow and shape is conical. Kernel grade is W 400.

BPP 5

This is the selection from germplasm accession T.No.1. This variety was released in 1980. The bisexual flower percentage is 10%. The nut weight is 5.2g. The mean nut yield is

11kg/tree with shelling percentage of only 24. Protein percentage is also rather low (16.8%). Apple has juice content of 64%. Kernel grade is W 400. This selection is withdrawn from recommendation for cultivation.

BPP 6

This is also a selection from germplasm collection. Tree NO.56 was the source material for this variety released in 1980. The mean bisexual flower percentage is 8% and mean yield of nuts is about 10.5kg/tree. The nut weight is 5.2g and shelling percentage of this variety is also only 24. Protein percentage is 20.3%. Juice content of apple is very high (74%). Kernel grade is W 400.

BPP 8 (H 2/16)

It is a hybrid (H2/16) derived from the cross Tree No.1 x Tree No.39 and released in 1993 for general cultivation in Andhra Pradesh. It has been performing well in Orissa and West Bengal also. This variety is superior to all the other six varieties developed from Bapatla. The variety has mean yield of 14 kg/tree with better nut size (8.2g). Shelling percentage (29%) of this variety is also better than the rest of the varieties released from Bapatla so far. Kernel grade is W 210 (export grade).

Varieties released from Tamil Nadu

The Tamil Nadu Agricultural University released four varieties from its Regional Research Station, Vridhachalam.

VRI-1 (M 10/4)

This variety is a selection from germplasm collected from Vazhisodhanipalayam in South Arcot District of Tamil Nadu. It has a medium sized tree having setting of 5 to 7 fruits per panicle. It was released in the year 1981 and the mean yield is 7.2 kg/tree under Vridhachalam conditions. The nut size is small with 5g nut weight and shelling percentage of 28%. The kernel grade is W 320. This variety is withdrawn from recommendation for cultivation.

VRI-2 (M 44/3)

This is the only variety released at national level based on the multi-locational trial conducted at six coordinating centres. This national variety is a selection from the

germplasm (T. No. 1668) collected from Kattupalli village of Minjur block of Changelpattu district of Tamil Nadu and released in 1985. This variety is found to be "prepotent" - meaning that the variety is capable of giving good seedling progenies irrespective of male parents. This variety is found adaptable over wide range of soils and regions. The percentage of bisexual flowers is 10 with a setting of 5-8 fruits per panicle. The average yield is about 7.4 kg/tree. The nut size is small with 5.1g nut weight with shelling percentage of 28.3%. The kernel grade is W 320. The colour of the apple is pinkish yellow. This variety is withdrawn from recommendation for cultivation.

VRI-3 (M 26/2)

This is a selection from seedling progeny of a high yielding tree collected from a village Edayanchavadi in South Arcot District of Tamil Nadu and was released in 1991. It has 12.1% perfect flowers. The average yield of this variety is about 10 kg/tree, thus the increase over VRI-2 and VRI-1 being 35 to 39% respectively. The nut size is medium with 7.2g nut weight and shelling percentage of 29.1%. The kernel grade conforms to W 210 export grade. This variety is picking up fast among farmers of not only of Tamil Nadu but also of other states.

VRI-4

This variety was released in 2000. It is a selection from vazhisodanaipalayam, Cuddalore district. The special features of this variety are nut weight 6.63 g, kernel grade W 240, shelling out turn 28.5%, compact canopy and mid-season flowering type.

VRI (Cw)-5

It is a hybrid developed from the cross M 26/2 (VRI-3) x M 26/1. This was released in the year 2007. The canopy type is compact and branching habit is spreading. The average yield of this variety is about 13.2 kg/tree. The nut size is medium with 7.2g nut weight and shelling percentage of 30.5%. The kernel grade is W 210. The apple colour is pink with yellow tinge and the shape is round and the apple weight is ranging from 50.0 to 53.5 g. This is recommended for all the cashew growing districts of Tamil Nadu.

Varieties released from Orissa and West Bengal

In IX Biennial Workshop of AICRP on Cashew held in 1989 at Coimbatore, Bhubaneswar-1 for Orissa and Jhargram-1 for West Bengal were recommended for release.

Bhubaneswar-1

It is a selection from seedling progeny of WBDC V (Vengurla 36/3), a collection from Regional Fruit Research Station, Vengurla and released in 1989. Flowering season is from January to March with medium duration of 70 days. It has cluster bearing habit with about 12 fruits per bunch. This variety has average yield of 10 kg/tree with small nut size (4.6g nut weight). The shelling percentage is high (32%) with kernel grade of W 320. It has been found suitable for cultivation in the sandy and laterite soils of the East Coast.

Jagannath (BH 6)

It is a mid season flowering (Jan-Mar) variety having bold nuts with 8.6 g nut weight. The variety gives an average nut yield of 2.1 t/ha (10.5 kg/tree) and possesses high shelling percentage (32.5 %).

Balabhadra (BH 85)

It is an Early flowering (Dec-Feb) variety having bold nuts with 7.4 g nut weight. The variety gives an average nut yield of 2.0 t/ha (10.0 kg/tree) and possesses high shelling percentage (30.0 %).

Jhargram-1

It is a selection from T.No.16 originally collected from Bapatla. It was released in the year 1989. It has a medium compact canopy and intensive branching habit. It has on an average, 6 fruits per bunch and yield of 8.5 kg/tree with small nut size (5g nut weight). Shelling percentage is 30 and kernel grade is W 320.

Bidhan Jhargram-2

It is selection made from seedling plantation of H-2/15 of Regional Research Station, Bidan Chandra Krishi Viswa Vidyalaya, Jhargram, West Bengal. The variety has mid season flowering habit with 3-4 fruits per panicle. Apple is golden yellow with a weight of 63g and a mean juice content of 68.9 per cent. The average nut weight is 9.2g with a kernel weight of

2.85g and high shelling (32%). The kernel grade is W 180.The variety can yield 13.5 kg/tree in 7th harvest.

Varieties released from Chhattisgarh

The AICRP- Cashew centre located at Jagadalpur, under Indira Gandhi Krishi Viswa Vidyalaya(IGKVV), Raipur has released Indira Kaju-1, a cold tolerant cashew variety, the characters of which are as follows.

Indira Kaju-1

It is a clonal selection from natural pollinated seedling. Nut weight is 10.50g. It has field tolerance to tea mosquito bug and cashew stem and root borer. Shelling percent is 28.65% and colour of mature nut is grey. Average yield is 15.53 kg/tree. Tolerant to low temperature and recommended for Bastar Plateau Zone, Jashpur and Raigarh (Zone VII of Indian Agroclimatic Zone).

Varieties released from Maharashtra

Based on the evaluation of selections from germplasm and hybrid progenies in varietal evaluation trials conducted at Regional Fruit Research Station, Vengurla, the Konkan Krishi Vidyapeeth (KKV), Dapoli has released the following seven varieties for cultivation in Maharashtra. These varieties have been found to perform well in Goa also. Vengurla-1 and Vengurla-4 are doing well in Uttar Kannada district of Karnataka also. Varieties such as Vengurla-1, Vengurla-4 and Vengurla-6 are in great demand from farmers. Vengurla-7 which has been released in 1997 is suitable to Konkan region of Maharashtra and also adjoining cashew growing regions of Goa and Karnataka.

Vengurla-1

This is a selection from the germplasm (Ansur-1) collected from Ansur village in Vengurla Tehsil of Maharashtra. This was released in the year 1974. The average percentage of perfect flowers is about 8%. The average yield is 19 kg/tree. The nut weight is 6.2g with the shelling percentage of 31. It is early flowering variety. Colour of the apple is yellow. Kernel grade is W 240.

Vengurla-2

This variety was released in the year 1979. It is a selection from germplasm collected from West Bengal (WBDC VI : Vengurla 37/3). This selection has average perfect flower percentage of 8% and also has short flowering and fruiting phase. The average yield is about 24 kg/tree (in 20th year of age). But the nuts are small with 4.3g nut weight and shelling percentage of 32. Colour of apple is pinkish red. Kernel grade is W 320. This variety is withdrawn from recommendation for cultivation.

Vengurla-3

This is a hybrid developed from the cross Ansur-1 x Vetore 56 and was released in 1981. The percentage of perfect flowers is 25% with an average fruit set of 7%. Average yield is 14.4 kg/tree. This is a bold nut variety with the nut weight of 9.1g and shelling percentage of 27. Kernel grade is W210 (export grade). This hybrid is withdrawn from recommendation for cultivation.

Vengurla-4

This is a hybrid variety with the parentage of Midnapore Red x Vetore 56 and was also released in 1981. It is a cluster bearing type and with percentage of perfect flowers of 35 and fruit set of 6%. The yield of nuts is 17.2 kg/tree. The nut weight is 7.7g and shelling percentage is 31. The colour of the apple is red. Kernel grade is 210 (export grade).

Vengurla-5

This variety is a hybrid having the parentage of Ansur Early x Mysore Kotekar 1/61. This variety was released in 1984. Very high perfect flower percentage of 50.5% was recorded in this variety. But the fruit set is only around 3.3%. The average yield is 16.6 kg/tree. The nut size is small with 4.5 g nut weight. The shelling percentage is 30. This variety produces small golden yellow coloured apples. Kernel grade is W 400. This variety is withdrawn from recommendation for cultivation.

Vengurla-6

It is a hybrid of cross combination Vetore 56 x Ansur - 1 and released in the year 1991. The variety has average yield of 13.8 kg/tree with nut weight of 8g. The kernel grade is W 210. This variety is popular among farmers.

Vengurla-7

Hybrid 255 evolved at Regional Fruit Research Station, Vengurla under Konkan Krishi Vidyapeeth, Dapoli was recommended for release under the name "Vengurla-7" in the XIII Biennial Workshop of AICRP on Cashew held in November 1997. Vengurla-7 is a hybrid developed from the cross Vengurla-3 x M 10/4 (VRI-1). The percentage of perfect flowers is very high (40%). Average yield is 18.5 kg/tree. It is a bold nut type with nut weight of 10g and shelling percentage of 30.5. Kernel grade is W 180. The colour of apple is yellow with apple weight of 60g and with juice content of 75 per cent. Average weight of kernel is 2.9g. This variety is recommended for the Konkan region of Maharashtra and adjoining cashew growing regions of Goa and Karnataka.

Vengurla-8

It is a hybrid released in 2001 and yields 15-20 kg /tree. It has bold nuts with 86 nuts / kg. it is red apple variety with juice recovery is 85%.

Varieties released from Goa

Total of 2 cashew varieties were released from Goa state. Goa-1 was recommended for release in the XIV Biennial Workshop of AICRP on Cashew held at Bhubaneswar in October 1999. Thus this is the first time farmers of Goa are having opportunity to grow a cashew variety developed in their own state. Goa-2 was recommended for release in the National Group Meeting of Scientists of AICRP-Cashew held in Goa in November 2007.

Goa-1 (Balli-2)

Goa-1 was developed and released from ICAR Research Complex, Goa in 1999. It is the first cashew variety released from the state of Goa. It is a selection from accession Balli-2 which is originated from a tree located in Balli village of Quepem taluk of Goa. The average yield of Goa-1 is 7.0 kg/tree with nut weight of 7.6 g (range : 7.3 - 7.9 g) and the shelling percentage of 30.0 (range : 28.9 - 31.0%). Kernel weight is 2.2 g. The kernel grade is W 210. Apple colour is yellow and with average weight of 66.7 g and with average juice content of 68.0%. It is recommended to the state of Goa.

Goa-2 (Tiswadi-3)

Goa-2 was developed and released from ICAR Research Complex, Goa in 2007. It is a selection from Ela village of Tiswadi taluk of North Goa District. The average yield of Goa-2

is 5.5 kg/tree with nut weight of 9.4 g (range : 9.2 – 9.6 g) and the shelling percentage of 29.25. Kernel weight is 2.3 g. The kernel grade is W 210. Apple colour is yellowish orange with cylindrical shape and with average weight of 105 g. Juice content ranges from 68.0 – 72.0 per cent. It is recommended to the state of Goa.

Varieties released from Kerala

Kerala Agricultural University released eight varieties so far under AICRP-cashew programme. BLA 139-1 was released as Anakkayam-1 in 1985 for cultivation in Kerala. In 1987, three selections (BLA 39-4, NDR 2-1 and K-22-1) were released. In 1993 two hybrids (Kanaka and Dhana) and in 1995 one hybrid (Priyanka) were released. In 1999 one more hybrid (Amrutha) was released.

Varieties released by Cashew Research Station, Madakkathara

BLA 39-4 (Madakkathara-1)

It is a selection from seedling progeny of Tree No. 39 of Bapatla. The variety was released in 1987. The flowering season is from November to January. The mean yield is 13.8 kg/tree. The nuts are medium sized with 6.2g nut weight. Shelling percentage is 26.8. The kernel weight is 1.6g and kernel quality conforms to W 280. Apple colour is yellow with a weight of 52g. Reducing sugar content is 10.5%.

NDR 2-1 (Madakkathara-2)

This is a selection from germplasm collection made from Neduvellur in Kerala maintained at CRS, Anakkayam. This variety was also released in 1987. The mean yield 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. Apple colour is red and with weight of apple 63.3g. Reducing sugar content is 7.8%.

K-22-1

It is a selection from clonal progeny of Kottarakkara-22 (Layer 23) maintained at CRS, Kottarakkara and was released in 1987. This variety has a mean yield of 13.2 kg/tree. The nut weight is 6.2g and the shelling percentage is 26.5. The kernel weight is 1.6g with kernel count of W 280. The apple colour is red and weight of apple is 74g. Reducing sugar is 7.2%.

Kanaka (H 1598)

It is a hybrid of cross BLA 139-1 X H 3 - 13 released in 1993 from CRS, Madakkathara. It is an early variety. Average yield is 19 kg/tree with a mean nut weight of 6.8g. Shelling percentage is 31%. Kernel weight is 2.1g and quality of kernels conform to W 210 export grade. Colour of apple is yellow.

Dhana (H 1608)

It is a hybrid of cross ALGD-1 X K 30-1 released from CRS, Madakkathara in 1993. It has cluster bearing habit. The mean yield is 17.5 kg/tree with a shelling percentage of 28. Kernel weight is 2.2g conforming to export grade of W 210. Yellow is the apple colour.

Priyanka (H 1591)

This is a hybrid with parentage of BLA 139-1 X K 30-1 with jumbo nut size developed and released from CRS, Madakkathara in 1995. The yield of nuts is 16.9 kg/tree. The nut weight is 10.8g with kernel weight of 2.87g. Shelling percentage is 26.5. The export grade of kernels conforms to W 180. Colour of apple is yellowish red. Apple weight is 135g. Apple has 57.4% of juice.

Amrutha (H 1597)

This is a hybrid with parentage of BLA 139-1 x H 3-13 developed and released from CRS, Madakkathara in 1999. It has yield potential of 18.4 Kg/tree with nut weight of 7.2 g. Shelling percentage is 31.6 and with kernel weight of 2.2 g and kernel grade W 210. Colour of apple is yellow and apple weight is 76.0 g. Apple has 57.4% juice content. It is recommended to the state of Kerala.

Sulabha

It is selection released in 1996 with compact canopy and intensive branching. It is bold nut type with 9.8 g nut weight. The tree yields 21.9 kg of nuts with high shelling percentage (29.4%). The kernel weight is 2.88 g and grade is W 210. It bears light orange apples.

Damodar

It is hybrid released during 2002 with a parentage of BLA 139-1 X H 3-13. It has yield potential of 13.7 kg / tree with nut weight of 8.2 g. shelling percentage is 27.3. The kernel weight is 2.0 g and grade is W 240. It bears yellow red apples.

Poornima

It is hybrid released during 2006 with a parentage of BLA 139-1 X K -30-1. It has yield potential of 14.1 kg / tree with nut weight of 7.8 g. Shelling percentage is 31.0. The kernel weight is 2.6 g and grade is W 210. It bears yellow apples.

Raghav

It is hybrid released during 2002 with a parentage of ALGD -1 X K -30-1. It has yield potential of 14.7 kg / tree with nut weight of 9.2 g. Shelling percentage is 26.6. The kernel weight is 2.27 g and grade is W 210. It bears yellow apples.

Varieties released by Cashew Research Station, Anakkayam

Anakkayam-1 (BLA 139-1)

This is a selection from the seedling progeny of Tree No 139 of germplasm collection of Agricultural College, Bapatla, Andhra Pradesh. The variety was released in the year 1985. The variety has a short flowering duration. The yield is 12 kg/tree. The nut weight is 6g and shelling percentage is 28. Colour of apple is pink. Average apple weight is 67.5g. Reducing sugar content is 10%. Kernel grade is W 280.

Dharasree

It is hybrid released during 1996 with a parentage of T 30 X Brazil-18. It has yield potential of 15.0 kg / tree with nut weight of 7.8 g. Shelling percentage is 30.5. The kernel weight is 2.4 g and grade is W 240. It bears yellowish pink apples.

Akshaya

It is hybrid released during 1998 with a parentage of H-4-7 X K -30-1. It has yield potential of 11.0 kg / tree with nut weight of 11.0 g. Shelling percentage is 28.4. The kernel weight is 3.12 g and grade is W 180. It bears yellow apples.

Anagha

It is hybrid released during 1998 with a parentage of T 20 X K -30-1. It has yield potential of 13.7 kg / tree with nut weight of 10.0 g. Shelling percentage is 29.0. The kernel weight is 2.9 g and grade is W 180. It bears orange red apples.

Varieties released from Karnataka

A total of five varieties have been developed and released by ARS, Ullal (Ullal-1, 2, 3, 4 and UN 50). DCR (FormerlyNRCC) has released three varieties (Sel-1, Sel-2 and Bhaskara). Chintamani-1 and Chintamani-2 were developed and released by ARS, Chintamani, Kolar District of Karnataka for maidan tract of Karnataka.

Varieties released from ARS, UAS, Ullal

Ullal-1

This is a selection from the germplasm collected from Taliparamba in Kerala (8/46 Taliparamba) and released by ARS, UAS in 1984. The variety has 2-3% of bisexual flowers. 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%. The colour of apple is yellow. Kernel grade is W210.

Ullal-2

This is a selection from germplasm collected from Guntur in Andhra Pradesh (3/67 Guntur). This variety was also released in 1984. The variety is a late flowering type (December to March) with very short duration of harvest (85 days). The yield is about 9 kg/tree. The nut size is medium with 6g nut weight and shelling percentage is 30.5. Colour of apple is light red. Kernel grade is W 240. This variety is withdrawn from recommendation for cultivation.

Ullal-3

It is a selection from 5/37 Manjeri and released in 1993. 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. The colour of apple is red.

Ullal-4

It is a selection from 2/77 Tuni Andhra and released in 1994 for general cultivation. The average yield is 9.5 kg/tree. The nut size is medium with 7.2g nut weight. Shelling

percentage is 31%. Export grade of kernels conforms to W 210 counts/lb. The colour of apple is yellow and apple weight is 75g.

UN-50

This is a selection from Nileshwar 2/27 (T.No.25) and released in 1995. This is a medium duration variety. The average nut yield is 10.5 kg/tree. The nut weight is 9g and shelling percentage is 32.8%. The kernels are suitable for export with more than 85% of kernels coming under W 180 export grade. Apple colour is yellow.

Varieties from DCR (Formerly NRC-Cashew), Puttur

NRCC Selection-1

This variety was released in the year 1989. This is a selection from segregating progeny of germplasm 3/8 Simhachalam (VTH 107/3) originally a collection from AP. It is a late flowering type (December - February) with a flowering duration of 82 days. The number of fruits per bunch is 5. The yield, on an average, is 10 kg/tree. The nut weight is 7.6g. The shelling percentage is 28.8% and the kernel grade conforms to export grade of W 210. Apple colour is yellow. This variety is withdrawn from recommendation for cultivation.

NRCC Selection-2

This is a selection from the segregating seedling progeny of 2/9 Dicherla (VTH 40/1) originally a collection made from Andhra Pradesh. This variety was released in 1989. It has a mid season flowering habit (November - January) with a flowering duration of 74 days. The number of fruits per bunch is 3. The average yield is 9 kg/tree. The nut weight is 9.2g. The shelling percentage is 28.6% and kernel grade conforms to export grade W 210. Colour of apple is pink.

Bhaskara

This variety was released during March 2006 for coastal region of Karnataka. This 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. But the regular insecticidal spray against TMB is essential under severe out break situation. The number of fruits per panicle (bunch) ranged from 4 -13. The average yield on 13th year was 10.7 kg/tree with highest yield of 19 kg/tree. 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 apple colour is pinkish orange and juice content is 67.5%. This variety is very popular among the farmers of Dakshina Kannada District of Karnataka and also in neighbouring districts of Karnataka and Kerala.

H-130 (A jumbo nut hybrid)

H-130 is a jumbo nut hybrid, which yields 3 kg nuts / tree in 3rdyear of planting with cluster bearing (10-20 nuts/panicle), jumbo nut size (12-13 g) was released for west coast region.It is highly precious, early flowering type with long fruiting duration. It responds well to pruning and suitable for ultra-density planting system.The hybrid has high shelling percentage (29.9%) with big kernels (3.5- 5.0g) and kernel grade is W-130-150.

Varieties from ARS, Chintamani

Plains region is characterized by leveled land with very low rainfall. The soil is deep and red sandy loam in nature. The Kolar region has a coordinating centre at Chintamani and two varieties by name Chintamani-1 and Chintamani-2 were released from this Centre.

Chintamani-1

It is a selection from 8/46 Taliparamba, a germplasm collection from Taliparamba in Kerala and released in 1993 from ARS, Chintamani. This variety is recommended for plain region of Karnataka. Its flowering period is from January to April with 2-4 nuts per panicle. The average yield of this variety is 7.2 kg/tree as against the 2 kg/tree of the local varieties. The nut weight is 6.9g with shelling percentage of 31%. The kernel grade is W 210.

Chintamani-2

It is a seedling selection from ME 4/4 of ARS, Ullal and released in 2007 from ARS, Chintamani. This variety is also recommended for plain region of Karnataka. The canopy type is compact and with intensive branching. Its flowering period is from December to January. The average yield of this variety is 12.4 kg/tree. The nut weight is 7.9g with shelling percentage of 30%. The kernel weight is 2.35 g. The kernel grade conforms to W 210. The colour of the apple is red purple with average weight of apple of 70g. Juice content is 60%.

A National Group meeting was convened in 1988 to finalize production strategy of different plantation crops. This group suggested cultivation of several varieties of cashew in different states based on the varietal performance in different regions and their availability. Subsequently several cashew varieties have been released for general cultivation in different states. Some varieties developed in one state/region were found to perform well in other states/regions as well.

The state-wise varieties recommended are given below:

State	**Recommended varieties**
Karnataka	NRCC Sel-2, Bhaskara, H-130, Ullal-1, Ullal-3, Ullal-4, UN-50, Vengurla-1 (Uttara Kannada), Vengurla-4 (Uttara Kannada), Vengurla-7 (Uttara Kannada)
Karnataka (Plains region)	Chintamani-1, Chintamani-2 and Dhana
Kerala	BLA-39-4 (Madak-1), NDR-2-1 (Madak-2), K-22-1, Kanaka (H 1598), Dhana (H 1608), Priyanka (H 1591), Amrutha (H 1597), VRI-3
Maharashtra	Vengurla-1, Vengurla-4, Vengurla-6, Vengurla-7 , Vengurla-8
Goa	Goa-1, Goa-2, Vengurla-1, Vengurla-4, Vengurla-6, Vengurla-7
West Bengal	Jhargram-1, Bidan Jhargram-2, BPP-8
Orissa	Bhubaneswar-1, BPP-8, Dhana
Tamil Nadu	VRI-3, VRI (Cw) 5
Andhra Pradesh	BPP-4, BPP-6, BPP-8
Chattisgarh	Indira Kaju-1

Table 1.Varieties of cashew released from different cashew research centers in India

S.No.	variety	Hybrid /selection	Year of release	Nut weight (g)	Kernel weight (g)	Shelling %	Yield (kg/tree)	Export grade	Remarks
Directorate of Cashew Research, Puttur (Formerly NRCC)									
1.	NRCC Sel-1	Selection	1989	7.6	2.10	28.8	10.0	W 210	Withdrawn from recommendation
2.	NRCC Sel-2	Selection	1989	9.2	2.15	28.6	9.0	W 210	Short duration and bold nuts
3.	Bhaskara	Selection	2006	7.4	2.20	30.6	10.7	W 240	Escapes from the attack of TMB
4.	H-130	Hybrid	2018	12.9	3.5	29.5	3.0 (3^{rd} year)	W180	Response to pruning and suitable for UHDP
Cashew Research Station, Anakkayam, KAU,Thrissur									
5.	Annakkayam-1	Selection	1982	5.9	1.67	28.0	12.0	W 280	Early, vigorous and short flowering period
6.	Dharasree	Hybrid	1996	7.8	2.40	30.5	15.0	W 240	Mid season flowering, compact canopy
7.	Akshaya	Hybrid	1998	11.0	3.12	28.4	11.0	W 180	Bold nut type
8.	Anagha	Hybrid	1998	10.0	2.90	29.0	10.0	W 180	Bold nut type

Cashew Research Station, Madakkathara, KAU,Thrissur									
9.	K-22-1	Selection	1987	6.2	1.60	26.5	13.2	W 280	Compact canopy
10	Madakkathara-1	Selection	1990	6.2	1.64	26.8	13.8	W 280	Early flowering, compact canopy
11	Madakkathara-2	Selection	1990	7.3	1.88	26.0	17.0	W 210	Late variety, high yield
12	Kanaka	Hybrid	1993	6.8	2.08	30.6	12.8	W 280	Mid season flowering
13	Dhana	Hybrid	1993	8.2	2.44	29.8	10.7	W 280	Mid season flowering and cluster bearing
14	Priyanka	Hybrid	1995	10.8	2.87	29.6	17.0	W 180	Bold nut, mid season and drought tolerant
15	Sulabha	Selection	1996	9.8	2.88	29.4	21.9	W 210	Mid season flowering
16	Amrutha	Hybrid	1998	7.2	2.24	31.6	18.4	W 210	Mid season flowering
17	Damodar	Hybrid	2002	8.2	2.00	27.3	13.7	W 240	---
18	Raghav	Hybrid	2002	9.2	2.27	26.6	14.7	W 210	--
19	Poornima	Hybrid	2006	7.8	2.60	31.0	14.1	W 210	---

Agricultural Research Station, Ullal, University of Agricultural and Horticultural Sciences, Shimoga, Karnataka									
20	Ullal -1	Selection	1984	6.7	2.05	30.7	16.0	W 210	Long duration, Escapes from the attack of TMB
21	Ullal -2	Selection	1984	6.0	1.83	30.5	9.0	W 320	Short duration, small nuts
22	Ullal -3	Selection	1993	7.0	2.10	30.0	14.7	W 210	Short duration
23	Ullal -3	Selection	1994	7.2	2.15	31.0	9.5	W 210	Short duration
Agricultural research station, Chintamani, UAS, Bengaluru, Karnataka									
24	Chintamani-1	Selection	1993	6.9	2.10	31.0	7.2	W 210	Uniform and attractive nuts
25	UN-50	Selection	1995	9.0	2.24	32.8	10.5	W 180	Bold nuts and high shelling percentage
26	Chintamani-2	Selection	2007	7.9	2.35	30.0	12.4	W 210	---
Cashew Research Station, Bapatla, ANGRAU, Hyderabad, Andhra Pradesh									
27	BPP-1	Hybrid	1980	5.0	1.37	27.5	10.0	W 400	Flush colour is pinkish, semi tall and cluster bearing

28	BPP-2	Hybrid	1980	4.0	1.04	25.7	11.0	W 450	Withdrawn from recommendation
29	BPP-3	Selection	1980	4.8	1.34	28.1	11.0	W 400	--
30	BPP-4	Selection	1980	6.0	1.15	23.0	10.5	W 400	Poor Shelling %
31	BPP-5	Selection	1980	5.2	1.25	24.0	11.0	W 400	Early bearer and poor Shelling %
32	BPP-6	Selection	1980	5.2	1.44	24.0	10.5	W 400	Long duration
33	BPP-8	Hybrid	1993	8.2	1.89	29.0	14.5	W 210	Early bearer
Regional Research Station, Vridhachalam, TNAU, Coimbatore, Tamil Nadu									
34	VRI-1	Selection	1981	5.0	1.4	28.0	7.2	W 320	Suitable for coastal region
35	VRI-2	Selection	1985	5.1	1.45	28.3	7.4	W 320	Wide acceptability
36	VRI-3	Selection	1991	7.2	2.16	29.1	11.7	W 210	Early flowering
37	VRI-4	Selection	2000	6.6	--	28.5	--	W 240	Mid season flowering
38	VRI-5	Hybrid	2009	7.2	--	30.5	13.2	W 210	Cluster bearing

Regional Fruit Research Station, Vengurla, KKV,									
39	Vengurla -1	Selection	1974	6.2	1.39	31.0	19.0	W 240	Early flowering and medium size nuts
40	Vengurla -2	Selection	1979	4.3	1.0	32.0	24.0	W 320	Short duration, small nuts and high yield
41	Vengurla -3	Hybrid	1981	9.1	2.09	27.0	14.4	W 210	Bold nuts
42	Vengurla -4	Hybrid	1981	7.7	1.91	31.0	17.2	W 210	Cluster bearing
43	Vengurla -5	Hybrid	1984	4.5	1.0	30.0	16.9	W 400	Compact canopy
44	Vengurla -6	Hybrid	1991	8.0	1.91	28.0	13.8	W 210	More fruiting laterals
45	Vengurla -7	Hybrid	1997	10.0	2.9	30.5	18.5	W 180	Bold nuts
46	Vengurla -8	Hybrid	2001	11.6	--	---	17.5	W 180	Bold nuts

Cashew Research Center, ICAR Research Complex, Goa									
47	Goa -1	Selection	1999	7.6	2.2	30.0	7.0	W 210	
48	Goa -2	Selection	2007	9.4	2.3	29.2	5.5	W 210	Yellow and big apple
Regional Research Station, Jhargram, BCKV, Kalyani, West Bengal									
49	Jhargram-1	Selection	1989	5.0	1.5	30.0	8.5	W 320	
50	Bidhan Jhargram-2	Selection	2014	9.2	2.85	32.0	13.5	W 180	Bold nuts
Orissa University of Agriculture and Technology, Bhubaneswar, Odisha									
51	Bhubaneswar -1	Selection	1989	4.6	1.47	32.0	10.5	W 320	Cluster bearing and high shelling percentage
52	Jagannath	Hybrid	2008	8.6	--	32.5	10.5	--	Mid season flowering
53	Balabhadra	Hybrid	2008	7.4	--	30.0	10.0	--	Early variety
Cashew Research Centre, Jagadalpur, Indira Gandhi Krishi Viswa Vidyalaya(IGKVV), Raipur, Chattisgharh									
54	Indiara Kaju-1	Selection		10.5	--	28.6	15.5	--	Cold tolerance

Quality planting material production in Cashew

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Introduction

Cashew is one of the major dollars earning horticultural crop. In India, cashew is mainly grown in Kerala, Karnataka, Goa and Maharashtra along the west coast, Tamil Nadu, Andhra Pradesh, Odisha and West Bengal along the east coast and also spreading in non-traditional areas like Bastar region of Chattisgarh, Jarkhand, Gujarat and North- Eastern hill region. At global scenario, though India occupied second largest area under cashew cultivation (18.76 %), but contributes only 16.33% in production. India is lagging behind in productivity of raw cashew nuts (761.2 kg/ha) compared to Vietnam (3041.2 kg/ha.) (FAO, 2017). In India, the established processing capacity of raw nuts is around15-20 lakh tones, where the domestic contribution is around 7-8 lakh tones. But presently, domestic requirement also has grown up tremendously besides export earnings. Thus, presently India has been importing raw nuts from African countries to the tune of 9-12 lakh tones to meet the demand of domestic cashew processing industries. Of later, the import possibility from many of the other countries is dwindling, as several countries have setup processing facilities.

Factors for low productivity

The main factors associated with low productivity are non-uniform seedling progenies, cultivation under degraded sites, severe infestation of cashew stem and root borer (CSRB) and tea mosquito bug (TMB). Among these, seedling progenies of non descript origin is one of the prime factors for low productivity in cashew because of their high degree of heterozygosity. Hence, vegetative propagation is considered as suitable method to develop uniform and healthy cashew plantation. Different methods of vegetative propagation namely layering, grafting, and budding have been tried in cashew at Directorate of Cashew Research and various cashew research stations in country. The studies indicated the superiority of softwood grafting over other vegetative propagation methods. Hence, this technique has been recommended for commercial multiplication of quality planting material in cashew. As a result of area expansion, the demand for quality planting material is gaining in linear phase

which required to be attended with immediate effect. The ICAR- Directorate of Cashew Research located in Puttur, Karnataka in India has worked a year around for supply of quality softwood grafts to farmers. The present requirement of cashew planting material in the country is around 75-80 lakh grafts per annum.

Advantages of soft wood grafts

- Soft wood grafts are true to type in nature but seed propagated plants are highly heterozygous in nature
- Soft wood grafts are precocious and early bearing over seedlings
- Use of grafted plants helps to develop uniform shape and size to plantations
- Helps to induce dwarfness
- Helps to establish uniform orchards
- Responds well for package of practices

Establishment of scion bank

Scion bank should be established with recommended cashew varieties adapting a closer spacing of 3 × 3 m in order to get continues supply of scion sticks. The plant should be manured with recommended dose of NPK (750 g N, P_2O_5 – 125 g and K_2O- 120g per plant) fertilizers during monsoon season to get adequate number of scion sticks. The tender shoots should be protected from Tea Mosquito Bug and other sucking pest by giving timely spray of insecticides. The canopy of plants in scion bank should be maintained at a reachable height by regular pruning and purity of the variety is verified by allowing a branch to flower and fruit in each plant in the initial year for verification. The pruning of trees may be carried out in scion bank during September-October. Establishment of nursery requires resources such as nursery area, water source, minimum nursery implements and most importantly the scion bank (budwood orchard) of elite cashew varieties.

Closer view of Scion bank

Selection of scion and precuring

Non-flowered lateral shoots of current season growth (3-5 months old) which should be about 10-12 cm long, straight with pencil thickness, brown coloured dormant plumpy terminal buds can be selected as scion stick. The selected shoots are precured a week before by clipping of leaves leaving behind petiole stubs. The pre cured scions should be detached from mother tree before terminal bud sprouts and collection should be done early in the morning to avoid desiccation.

3-4 months old scion shoot Pre cured scion shoot

Production of healthy rootstocks for grafting

Seed nuts selection

Seed nuts are collected during the peak harvesting period (March and April). The seed nuts of 6-7 g can be selected and sun dried for 2-3 days. Preferably seed nuts can be collected from a single variety and floaters be separated out. Such graded seed nuts can be stored for 4-6 months in gunny bags under ambient condition without much exposure to heat and cold.

Sowing of seeds

Seed nuts should be soaked in water for 12-24 hours before sowing in order to get better and uniform germination. The soaked seed nut are sown in poly bags sized 25 X 15 cm size containing pot mixture of red soil, sand and FYM at 1:1:1. The seed nut is dibbled in friable pot mixture facing stalk-end upwards. During summer, mulching with paddy straw may be done till germination takes place. Watering should be done regularly during summer months and alternate days at rainy days to maintain sufficient soil moisture. Seed nuts usually germinate after 10-15 days of sowing depending on season. About 2-3 months old, 25-30cm height seedlings can be selected as rootstock for grafting.

View of poly bags covered with paddy straw

Healthy rootstocks ready for grafting

Softwood grafting technique

Top portion of the selected root stocks are decapitated at the height of 15-20cm from ground level, retaining four bottom leaves. A cleft of 6-7cm deep is to be made in the middle of decapitated portion. A scion stick of 10cm length, matching with root stock thickness can be selected and given a wedge shape cut of 6-7cm length at the cut end of the scion. The wedge of the scion is inserted into the cleft of root stocks and the graft joint is firmly tied with 30 X 2cm, 100 gauge polythene strips.

The grafts are capped with 20 X 4cm, 200 gauges thick polythene tubes to avoid drying of scion portion. After 2-3 weeks the polythene caps are removed gently and the grafts are moved to open condition for hardening. The grafts with success of 70-80% can be obtained after 3-4 weeks of hardening.

Sequential steps in softwood grafting

After Care/ Management of cashew grafts in Nursery

- Grafts should be watered daily during dry periods and excess watering should notbe done during rainy season.
- During summer months (March-May) grafted plants should be protected from scorching sun by providing partial shade (35-50%) with the help of shade nets.
- During heavy rains excess water should be drained out.
- Need based bordeaux mixture spray (1%) or carbendazium 0.1% may be done during rainy season as a prophylactic spray to control fungal diseases.
- Shoots arising from leaf axils on the rootstock (below the graft union) should be removed regularly.
- The polythene strip should be removed from graft union after 3-4 months after grafting to avoid girdling.
- Grafts produce flower panicles during flowering season (November-December) irrespective of age. Such panicles should be removed as and when observed.

Overview of cashew grafts hardening in the nursery

Plant protection measures

- The germinated seed nuts are attracted by rodents and birds. Prophylactic application of 5% malathion dust or 0.05% chlorpyriphos spray can solve this problem.
- Heavy watering during rainy season results in collar rot or damping off of seedlings. This can be overcome by need based drenching the soil with 1% Bordeaux mixture or 0.1% carbendizim. Covering the poly bags with laminated shade nets before rainy season.

- Tender and newly emerge shoots are highly susceptible to tea mosquito bug, leaf eating caterpillars and other sucking pests. Quinolphos or monocrotophos at 0.15% spray at shoot emergence stage can reduce this infestation.

Graft standards for sale

- More than 5 months old grafts are ideal for field planting
- The height of grafted should be more than 45 cm
- The grafted plant should have at least 4-5 fully matured leaves
- The grafted union should be at a height of 15-20 cm from the collar region
- Grafts should be healthy and erect growing
- The polythene strip should be removed from graft union before sale
- The graft joint should be perfect without any girdling or constriction
- The side shoots arising from rootstock should be removed before sale

Varieties recommended for different states

State	Suitable varieties
Tamil Nadu	Vridhachalam-3, Vridhachalam-5
Kerala	Dhana, Kanaka, Madakkathara-2 , Priyanka, Vridhachalam-3
Andhra Pradesh	BPP-4, BPP-8, Dhana, VRI-3
Karnataka	Chintamani-1,NRCC-2, Ullal-1, Ullal-3, Ullal-4, UN-50, Bhaskara, Vengurla-4, Vengurla-7, Vridhachalam-3, Madakkathara-2
Maharashtra	Vengurla-4,Vengurla-7, Vengurla-9
Goa	Goa-1, Goa-2, Vengurla-4,Vengurla-7
Odisha	Bhubaneswar-1, Bhubaneswar-2, Dhana, BPP-8
West Bengal	Jhargram-1, BPP-8
NEH region	Priyanka, Ullal-4, NRCC-2, Vengurla-4

Role of ICAR-DCR in cashew research

ICAR-Directorate of Cashew Research, Puttur is pioneer institute for cashew research. The institute was identified as National active germplasm site (NAGS) for maintaining more than 539 different accessions collected from various parts the country. The organization has a

tremendous role in production and supply of elite planting material. Every year around 2-5 lakhs cashew grafts are produced and distributed to different cashew growing states. Training programmes on nursery management, production technology, pest and disease management and post-harvest, value addition and processing are conducted to different group of beneficiaries.

List of approved cashew nurseries in Karnataka

The demand for planting material is rising up every planting season due to attractive prices of raw cashew nuts in recent years. In Karnataka and kerala many of the rubber growers are replacing the rubber plantations with cashew. In the recent years, stipulate for elite planting material has crossed several lakhs. With the increasing demand of cashew grafts, many of the government and private firms have came up in taking the action of quality planting material production and the list is furnished below.

1. ICAR-Directorate of Cashew Research, Puttur, Karnataka
2. Agricultural Research Station, Chinthamani
3. Horticultural Research Station, Ullal, Mangaluru
4. Karnataka Cashew development corporation Ltd., Lady Hills, Mangaluru
5. Regional Research Station, Brahmavar

Besides, several cashew nurseries in plantation corporations, state horticulture departments, agricultural and horticultural universities and several DCCD, Kochi recognized nurseries in the private sector are also producing planting material for local need.

Conclusion: Application of standardized nursery techniques will help for rapid multiplication of genuine quality planting material in cashew. Use of quality softwood grafts from certified nurseries will helps the farmers to establishment of uniform orchards with early and precocious bearing, which leads to higher the productivity.

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Integrated nutrient management in cashew

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Introduction

Cashew (*Anacardium occidentale*) is an important horticultural crop in India, contributing to foreign exchange. In India, cashew is mainly cultivated along the coastal region of India. The important cashew growing states are Maharashtra, Karnataka, Kerala, Goa along the west coast and Andhra Pradesh, Odisha, Tamil Nadu, Puduchery and West Bengal along the east coast. It is also grown in other non-traditional areas such as Bastar region of Chhattisgarh and Kolar (Plains) regions of Karnataka, Gujarat, Jharkhand and in NEH region. The total area under cashew cultivation in India during 2016-17 is 10.41 lakh ha with a production of 7.79 lakh tones and average productivity of 745.6 kg ha-1. The productivity of cashew in India is only 745 kg ha-1 in the year 2014. Of the several factors associated with low productivity, poor soil fertility and lack of adequate care are the major factor limiting production. Being a hardy, fast growing drought tolerant tree, cashew is predominantly cultivated as a rainfed crop in soils of low fertility and highly degraded lateritic hillocks. In traditional farming, the cashew trees seldom receive nutrients and water. Continuous non application of fertilisers and manures lead to multi-nutrient deficiencies in soil. The experimental studies shows that cashew respond very well to fertiliser application.

Soil characteristics of cashew growing areas in India

The soil survey studies conducted at predominant cashew growing areas revealed depletion of soil nutrients due to non replenishment of nutrient removal by the cashew trees. Organic carbon rated as low in 2.7% samples in Puttur, Karnataka, in 20.0% samples in Vengurla, Maharashtra, 81.4% samples in Bhubaneswar and 92.9% samples in Bapatla. Available nitrogen was recorded as low in 94.3% samples in Puttur, 37.1% samples in Vengurla, 94.3% samples in Bhubaneswar and 75.7% samples in Bapatla. Cashew orchards in Pilicode, Kerala were found to be high in organic carbon and available nitrogen. The percent samples rated as low in available potassium was 65.7% in Puttur, 41.4% in Vengurla, 58.6% in Bhubaneswar, 22.9% in Bapatla and 17.1% in Pilicode. The soils were deficient in available phosphorus.

The soils were also deficient in calcium and magnesium. The micronutrients such as iron and manganese were sufficient. However the soils were generally deficient in zinc (22.9 to 57.14% samples in different regions) and copper (8.57 to 32.9% samples in different regions). These results indicate growing nutrient deficiencies in soils under cashew cultivation along west coast and east coast. Under such situation, soil test based nutrient management can not only improve the growth and productivity of cashew, but also arrest soil degradation.

Nutrient management in cashew

Like any other crops and organism, cashew too requires additional nutrient inputs for producing potential yield. Being a perennial tree crop, cashew removes considerable amount of nutrients from soil. A 30 year old cashew tree removes 2.847 kg N, 0.75 kg P_2O_5 and 1.265 kg K_2O. If the continuous removal by cashew tree is not balanced by application of manures and fertilisers, the yield and quality of produce will be affected, apart from deterioration of soil health. The response to nutrient application varies from location to location, based on initial soil nutrient status and management practices followed. Integrated use of organic manure, inorganic fertilisers and micronutrients provide sustainable yield while maintaining soil health.

Management of soil acidity

Cashew growing soils are generally acidic. Under high acidic soil conditions, nutrients such as phosphorus, calcium, magnesium, boron and molybdenum become unavailable, and nutrients such as iron, manganese and aluminium increase to toxic levels to affect plant growth. For correcting soil acidity, liming is to be undertaken with lime, dolomite or other liming materials. Testing of soil for pH will give an idea of soil acidity. However, for finding out lime requirement special test are to be carried out, which can be done in any soil testing laboratory. Liming based on soil test is to be done while establishing plantation and periodically based on soil test. Lime may be applied any time of the year, however, to increase the efficiency, lime is to be applied immediately after cessation of heavy rains since moisture is essential for lime-soil reaction. For new plantations, apply lime 2-3 months before planting. For established plantations, once in 3-5 years will be sufficient. The ground liming materials can be either incorporated into the soil or be broadcasted as per the lime requirement. The top-dressed lime gets leached into the soil with rainfall. Incorporation of

liming materials gives faster results. The time of application is April – May before the onset of monsoon.

Manuring

Since the cashew growing soils are deficient in organic matter, application of 10-15 kg farmyard manure or compost per grownup tree is recommended. This has to be undertaken in August-September, during the receding periods of monsoon. This can be applied in the circular trench along with the application of fertilizer discussed below.

In the absence of FYM, green manuring can be adopted as an alternative. Green manure crops such as glyricidia, sesbania and sunhemp can be grown along boundaries and in between two rows of cashew. Application of green manure increase organic matter content in soil. It also improves soil structure and help to reduce runoff and soil erosion. Wherever available the poultry manure can be used in place of FYM by applying at the rate of 10 kg per tree per year.

Management of major nutrients

The general nutrient recommendation for various cashew growing regions is presented in Table 1. These fertiliser doses are to be adjusted based on the soil test results, age of the plant and spacing followed. The recommendation is for normal spacing. 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 contributed from the decomposing cashew biomass fall out. It again re-iterates the need for soil test based site specific nutrient management.

Table 1 Recommended dose of fertilizers to cashew in different states

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

Time and methods of application

Fertiliser is to be applied after cessation of heavy rains and after weeding and clearing the base of individual trees. 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. Flushing and early flowering phase (September to December) is the period of increased root activity aiding enhanced absorption of nutrients from soil. Therefore effort should be made to coincide the fertiliser application with this phase. During flushing phase there is heavy internal demand for nutrients as the tree is entering re-productive phase. Hence proper fertiliser application is essential during this growth phase. Preferably the fertilizers to cashew are to be applied in two split doses; one at the onset of the monsoon and the second during the post-monsoon period, ensuring adequate soil moisture availability. If only single application is possible due to labour constraint or other reasons, then this can be done during post monsoon period when sufficient soil moisture is available. Circular trenches of 25 cm deep and 15 cm wide are opened at distance of 0.5, 0.75, 1, 1.5 m away from trunk during 1st, 2nd, 3rd and 4th year after planting and onwards respectively in laterite soils in heavy rainfall areas in west coast. In loamy soils of low rainfall east coast fertiliser can be applied in 50 cm circular strips. The trench should be closed immediately after the application of fertilizers and

green leaves can be spread as mulch. During 1st, 2nd, 3rd, 4th and 5th year of planting 1/5th, 2/5th, 3/5th, 4/5th and full quantity of recommended dose is to be applied.

Management of micronutrients

Among 17 essential nutrients, the nutrients that are required by plant in small quantities are called as micronutrients. These include iron, manganese, zinc, copper, boron and molybdenum. The functions of these nutrients in cashew are summarised below (Table 2).

Table 2. Micronutrients and their role in plants

Micronutrient	Role in plant
Iron	It plays a major role in synthesis of chlorophyll and photosynthetic activity within the plant and plays major role in nitrogen assimilation.
Manganese	Manganese play role in chlorophyll synthesis, and are important in functioning of many enzymes in plants.
Zinc	Zinc is required for protein synthesis and for the formation of growth regulating compounds in plants.
Copper	It is important in chlorophyll formation. It is also a component of different enzymes in plant.
Boron	In plants B is required for cell division and elongation. It plays a major role in flower and seed production and hence directly related to yield.
Molybdenum	Important in protein synthesis.

The widespread occurrence of micro nutrient deficiencies in cashew growing areas is to be tackled by adequate supplemental application of micro nutrient fertilisers either through soil application or foliar spray.

Micronutrient fertilisers

Commonly used micronutrient fertilisers are listed below in Table 3; however, the list is not exhaustive.

Table 3. Micronutrient fertilisers

Micronutrient	Source	Content (%)
Iron	Ferrous suphate heptahydrate	20
	Fe-EDTA	12
Manganese	Manganese sulphate	30.5
	Mn-EDTA	5-12
	Manganese chloride	17
Zinc	Zn-EDTA	12
	Zinc sulphate monohydrate	33
	Zinc suphate heptahydrate	21
Copper	Copper sulphate penthydrate	24
	Copper sulphate monohydrate	35
Boron	Borax	10.5
	Boric acid	17
	Di-sodium octaborate tetrahydrate	20
	Solubor (for foliar application)	19
Molybdenum	Ammonium molybdate	52
	Sodium molybdate	39

Rate and method of application

Foliar application

Table 4 illustrates the recommended rates of micronutrient fertilisers for cashew. A grown up cashew tree requires about 5 litre of spray solution. The foliar spray is to be carried out at start of flushing, panicle initiation and fruit setting stages.

Table 4. Rate of micronutrient for foliar application

Nutrient	Fertilizer to be used	Rate (g/litre)
Iron	Ferrous sulphate	5
Manganese	Manganese sulphate	5
Zinc	Zinc sulphate hepta hydrate	5
Boron	Boric acid	1
	Solubor	1
	Borax	1
Molybdenum	Ammonium molybdate	1
Copper	Copper sulphate penta hydrate	1

Soil application of micronutrients

The general rates for soil application of micronutrients are available. The rate is 5 kg/ha for Zn, 2 kg/ha for B, and 1 kg/ha for Cu, 2.5 kg/ha for Mn and 0.5 kg/ha for Mo. This rate is as per nutrient basis, and while applying this has to be converted on fertiliser basis, based on the micronutrient fertilise to be used by the farmer. It is better to provide the micronutrient by including canopy coverage area in calculation. At any cost excess application of micronutrients to soil should not be done as it will adversely affect other nutrients, crop growth and yield. Soil application is only required once in two years. Since the quantity of micronutrient to be given per tree is very small, it is better to mix it with sand while applying. Precautions in micronutrient soil application in soil.

- Apply only once in 2 years.
- Zinc fertilisers should not be applied along with phosphatic fertilisers.
- Apply only if deficiency is detected in soil testing and apply just the recommended dose.

Manuring and fertilisation in high density planting systems

Under high density planting the rate of fertilisers are to be adjusted based on the number of trees per unit area. For some regions, specific fertiliser recommendations are available for high density planting. For tree density of 400 plants/ha, 75:25:25 kg N, P_2O_5 and K_2O per ha per year is recommended.

Nutrient management under organic farming in cashew

Soil fertility and nutrient supply are one of the important factors deciding yield. It is reported that only 20% of the cultivated area under cashew receives the nutrient application. Although cashew plantations are reported to produce 1.38 to 5.20 t ha^{-1} of cashew leaf litter biomass with reported composting efficiency of 65%, these are not adequately recycled in cashew plantations. The leaf litter are removed to facilitate picking of nuts during harvest season. During other periods these may be burned or composted. However, the prepared composts are applied to other crops such as arecanut, coconut etc. These practices year after year lead to depletion of soil nutrients. Chemical fertilisers though easier way to increase growth and yield, nowadays there is more preference for organic cashew by some of the consumers. Also, there is also growing concern of increasing cost of fertilisers due to government policies and environmental concerns.

Software and Mobile App for aiding the growers in nutrient management in cashew

One of the major constraints in realizing the potential yield in cashew is the limited attention given by growers on nutrient management in cashew. The application of the right quantity of required fertilizer at the right time is vital for the judicious management of resources and for achieving the maximum benefit and income. Due to the wide variability in field conditions, and availability and choice of fertilisers, the farmers cannot correctly determine the right quantity of fertiliser to be applied and they may have to depend on scientists and extension personnel to get information on the correct doses. For empowering the farmers to take informed decision by themselves, a software and a mobile App for nutrient management in cashew was prepared under the project funded by RKVY-RAFTAAR at ICAR-Directorate of Cashew Research, Puttur.

Software on Cashew nutrient manager

This software is available in both English and Kannada. It is available on the ICAR-DCR website for calculating fertilizer requirement, lime requirement, foliar application of major and micronutrients. The deficiency symptoms of major and micronutrients commonly observed in the field also included in the software. The farmers can click on the images and understand the symptoms and find out the options to correct the deficiency. The software also lets the farmers download the soil health card issued by ICAR-DCR, Puttur. The link to the software is https://cashew.icar.gov.in/soil

The use of fertilizer calculator module

- The user needs to provide the no. of trees in the plantation. Or this will be automatically calculated if the user gives spacing followed in the plantation and total area.
- The full recommended dose is required from 5th year onwards under normal density planting and from 3rd year onwards under high-density planting. Columns are provided to enter this information in the software.
- There are options to calculate fertilizer if the user follows the high-density planting either with general fertilizer recommendation or special recommendation of fertilizer.
- If soil test reports are available, this information can be added. Based on soil nutrient status, the fertilizer rate will be adjusted automatically.
- The user can choose the rate of fertilizer recommended for his/her area in the state from the drop down menu.

- The type of fertilizer can be selected as per farmers' choice, or even a new fertilizer can be used in the calculation, providing the percentage content of nutrients, which will be available on the fertilizer bag.
- The user can generate the report with information on fertilizer rate per tree basis and the quantity required for the plantation.

The use of lime calculator module

To calculate the lime requirement, the user has to get the soil tested for Lime requirement and use the lime calculator. The user has to enter the information such as pH value (obtained after testing the soil for lime requirement), the radius of the tree canopy, the liming material available for use, and the no. of trees per unit area or spacing.

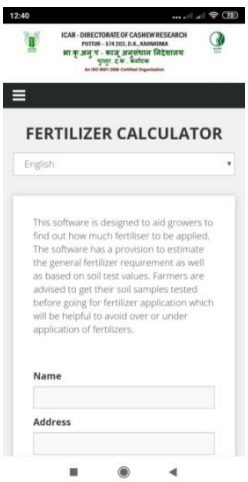
The use of foliar nutrition calculator module

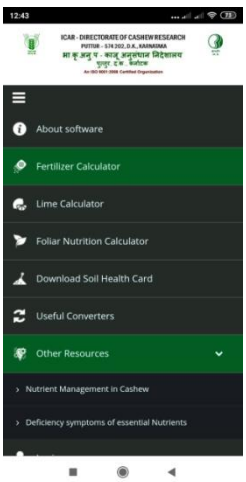
For calculating, the user has to enter the following information.

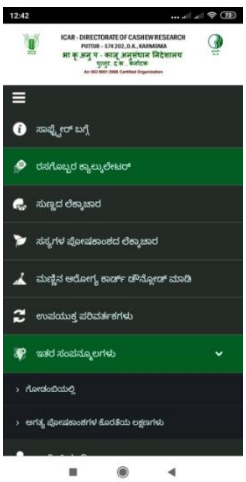
- Choose the nutrient to be applied as a foliar spray
- Enter information on no. of trees or spacing & area in the plantation
- Provide the age of tree and capacity of the tank being used for spraying/mixing fertilizer.

Mobile App on cashew nutrient manager

The mobile app version of the software on the cashew nutrient manager was developed. The App has got bilingual functionality (English and Kannada). The app can be downloaded from the Google play store at https://play.google.com/store/apps/details?id=com.icarcashew.dcr_cashewnutrientmanager







Conclusions

Like any other crops, nutrient management is important in cashew also. The studies have indicated the potential to increase yield by nutrient application in cashew. Being primarily grown in lateritic acidic landscapes of low fertility, liming and nutrient application found to significantly improve the net farm income.

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Strategies for soil and water conservation, and irrigation management in cashew

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Introduction

Cashew is one of the important foreign exchange earning crops and is traditionally grown in the coastal region in India. The major cashew growing states in the west coast are Maharashtra, Goa, Karnataka and Kerala. Along the east coast, the major cashew growing states are Tamil Nadu, Andhra Pradesh, Odisha and West Bengal. The non-traditional areas of cashew cultivation are Bastar region of Chhattisgarh and Kolar (Plains) regions of Karnataka, Gujarat, Jharkhand and in NEH region. In India, cashew is generally grown as a rainfed crop mainly along the coastal areas in low fertile soil. Majority of cashew orchards in India are not irrigated. The productivity levels of cashew are low in India compared to other producer countries. The research studies showed that the mean rainfall distribution in cashew area ranged from low rainfall (1500-2000 mm in Gujarat) to high rainfall (2700 to 3500 mm in West coast and NEH region). In India, the vegetative development of cashew occurs during rainy season, and the reproductive phase during the dry season. Although cashew is grown in high rainfall environment, it experiences severe moisture stress during January to May with the highest water deficit during March to May. Incidentally the critical growth phases such as flushing, flowering and nut formation in cashew also occur during these periods. Any form of stress biotic and abiotic stresses during these periods adversely affects the flowering and fruit set and results in premature nut drop and finally reduces the yield and productivity of cashew. Lack of moisture availability during fruiting season is one of the several factors associated with the low yield in cashew. Studies have shown that supplemental irrigation can significantly improve the productivity and yield of cashew. This bulletin addresses various issues in water management in cashew. The bulletin highlight the importance of water management in cashew, different options available to address the issue of irrigation, water conservation and water management for increasing the yield.

Cashew (*Anacardium occidentale* L.), is native to Brazil and was introduced to India by Portuguese travelers as a soil binding crop, to control soil erosion in coastal areas during 16th century. Sooner its commercial importance and adaptability to adverse soil and environmental conditions were recognized and its cultivation on commercial scale occurred along the east and west coast of India. Export of cashew kernels and cashewnut shell liquid bring foreign exchange to the country. In India, cashew is cultivated on a wide range of soil types such as sandy to sandy loam, laterite soil, loam and red lentisols. Due its drought hardiness, cashew is widely cultivated in degraded hillocks and slopy lands, where profitable production of other crops are not possible. Majority of cashew growing soils are low in soil fertility in terms of nitrogen, base status, cation exchange capacity and micronutrients such as zinc and boron. Due to heavy precipitation in the coastal areas where cashew is grown, the basic cations are washed out causing increased soil acidity. The high soil acidity in turn decreases the nutrient uptake by the plant, making some of the nutrients unavailable for cashew.

Water requirement of cashew

In India, the vegetative development of cashew occurs during rainy season, and the reproductive phase during the dry season. Although cashew is grown in high rainfall environment, it experiences severe moisture stress during January to May. Incidentally the critical growth phases such as flushing, flowering and nut formation in cashew also occur during these periods. Any form of stress biotic and abiotic stresses during these periods adversely affects the flowering and fruit set and results in premature nut drop and finally reduces the yield and productivity of cashew.

Water management in cashew

The cashew growing regions are characterized by high intensity rainfall over a short duration which lead to runoff and soil erosion. Cashew experience moisture stress during December/January to May which coincide with flowering and fruit setting phase of cashew, leading to flower drying and immature nut drop. Moreover the traditional areas of cashew cultivation lack access to water sources for irrigation purposes. Research studies indicate that cashew though a hardy crop respond well to water and manure management. In areas with no access to irrigation water, the water deficit to the crop can be managed to some extent by the adoption of region specific soil and water conservation practices. Adoption of such practices

is part of cashew production technology in case of slopy areas to prevent surface runoff and soil erosion.

Soil and water conservation practices

Cashew plantations are raised on landscapes which are unsuitable for many other crops, and generally lack source of water for irrigation. Arranging irrigation in such landscapes will be difficult and costly. Adoption of proper soil and water conservation techniques *in-situ* in such sloppy and degraded landscapes play very important role in preventing further soil degradation by controlling soil erosion, conserving soil moisture and improving tree growth and productivity in a sustainable manner. Among different soil and water conservation techniques studied, modified crescent bunds, staggered trenches with coconut husk burial and reverse terrace are recommended for cashew orchards. The other popular soil conservation practice recommended for cashew is terrace with catch pits. These practices were found beneficial to harvest pre-monsoon rainfall and increase the cashew yield to the tune of 32-35%. Other benefits are reduction in runoff velocity and soil loss, increased soil moisture retention and ground water recharge. With the adoption of such soil and water conservation practices, barren / sloppy lands can be brought under cashew cultivation in order to increase the farm income and land productivity.

Different technologies for in-situ soil and water conservation recommended for cashew are detailed below. The adoption of these practices should be done in accordance with the local conditions, topography, water holding capacity and infiltration characteristics of soil.

Trenches

Continuous contour trench: These trenches are taken in sloppy areas (7 to 8% slope), running through entire field length along the contour. The trench dimension recommended is 0.5 m x 0.6 m.

Modified crescent bund: The modified crescent bund consists of a crescent shaped bund of 6 m length, 1 m width and 0.5 m height at 2 m radius, which is to be taken at upstream of the cashew terrace which will help to retain water as well as litter.

Modified crescent bund for soil and water conservation in cashew orchards

Staggered trench: The staggered trenches of size 5 m length, 1 m width and 0.5 m depth are to be taken between two rows of cashew or in the middle of 4 plants, across the slope, in which coconut husks can be buried to enhance water retention.

Reverse terraces: The recommended dimensions for reverse terraces are 2 m length, 2 m width and 0.7 m depth, which are constructed so as to be inclined from periphery to the centre.

Reverse terrace for soil and water conservation in cashew orchards

Catch pits: The recommended dimensions for catch pits are 3 m length, 0.5 m width and 0.5 m depth, which are constructed upstream of cashew planted terrace, to catch and retain the runoff and to increase percolation.

Terrace with catch pits for soil and water conservation in cashew in steep slopes

Tree base terrace: Formation of tree base terrace at 2 m radius around the plant, taken over three years of planting shall be beneficial for moisture conservation. It is made by taking soil from the upper side of the slope and filling at the lower portion. The upside shall be taken in such a way that it form a catch pit to deposit soil and conserve moisture.

Bioengineering measures

Coconut husk burial: Adoption of coconut husk burial techniques with soil and water conservation techniques like modified crescent bund, staggered trenches etc. improve the water retention in soil for longer periods. This practice of coconut husk burial can be adopted around cashew plants also. Husks are to be buried in trenches of 3.5 m length, 1 m width and 0.5 m depth, opened across the slope between two rows of cashew. In such trenches 3 to 4 layers of husks can be buried with convex side of first layer of husk touching ground. The last layer of husks should be placed with convex side upper side. Thin layer of soil and leaf materials can be placed between layers of husks. Then the trench can be filled with soil, leaving about 10 cm depth.

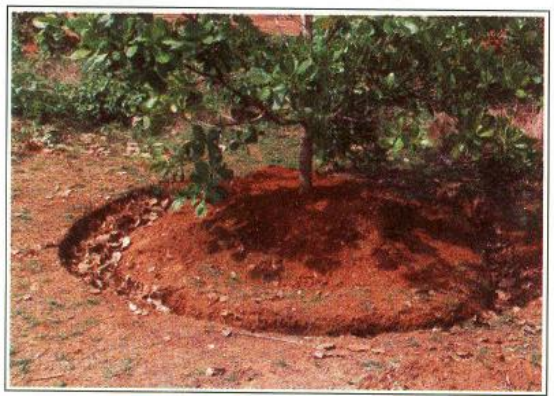
Coconut husk burial for soil and water conservation in cashew orchards

Use of bigger pits and mulching: This practice is to be followed during the establishment of cashew plantations. Pits of 1 m^3 size are to be dug open at recommended spacing following other soil and water conservation measures such as terracing. These pits are to be filled with topsoil, organic manure and rock phosphate at recommended rate up to 2/3rd depth. Plant the graft at centre of this pit and proper mulching to be done.

Trenches with vegetative barriers: Inclusion of vegetative barrier along with continuous contour trenches and staggered trenches (in reversely sloppy areas) can substantially reduce runoff and soil loss. *Stylosanthes hamata, Vetiveria zizanioides* are some of the recommended vegetative barriers. Apart from helping to reduce run off and soil loss, the vegetative barriers can be harvested to provide additional income.

Green manuring and mulching: Growing green manure crops like *Glyricidia* at vacant spaces and borders provide material for mulching. Mulching the tree basin with green mulch helps to conserve the soil moisture.

Circular trench with leaf litter and coconut husk: This practice is generally recommended for east-coast areas, wherein coconut husks and leaf litter are buried in circular trenches of 0.3 m width and 0.5 m depth opened at 2 m away from the cashew trunk.



Circular trench with leaf litter and coconut husk

Supplementary/Protective irrigation

While establishing the new plantations, the planted cashew grafts requires enough soil moisture for establishment and hence it is recommended to plant the cashew grafts during the monsoon season. Under drought situation, the newly planted grafts need to be watered once in every 3 to 7 days, to ensure the root ball of the graft is kept moist, but not water logged. Once established, due to the deep tap root system, the cashew trees can survive the moderate dry season without irrigation, but with effect on yield. Cashew is known for its drought hardiness and generally grown as unirrigated, however the yield can be increased if irrigated. Wherever source of irrigation water is available, providing supplementary irrigation can benefit in improving the nut yield.

Providing irrigation @200 litres per tree at 15 days interval during November to March increases the nut retention and yield. For yielding trees, protective irrigation is to be given only after the plant enters flowering phase, during nut set and nut development stages.

By providing black polythene mulch the quantity of irrigation to be provided can be reduced to 60 L/tree once in fortnight

Drip irrigation

In drip system of irrigation water is applied through a network of pipelines and applied to the root zone of crop drop by drop by use of emitters or drippers. In this system water is applied based on ET demand of the crop and root zone is always maintained at field capacity levels.

Drip irrigation allows water saving to the tune of 40 to 70% in comparison to other methods of irrigation and 25-80% increase in yield. The water requirement in cashew is decided based on the climatic condition, canopy area and growth phase of the plant. Based on canopy coverage and daily water evaporation, the water requirement of cashew can be calculated as follows.

To meet 20% CPE

Age of tree: 5 years

Canopy spread or diameter: 4 m [mean of EW and NS length of canopy]

Ground coverage of canopy: $\pi r^2 = 3.14 \times 2 \times 2 = 12.56\ m^2$

Daily CPE = 5mm; 20% CPE = 1 mm

The 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 m^3.

1 m^3 = 1000 L

0.01256 m^3 = 12.56 L/tree/day

Advantages of drip irrigation

- It reduces direct loss of water by evaporation, seepage and percolation.
- Slow application rates facilitates easy infiltration to the soil.
- It reduces water consumption by weeds and grasses.
- It allows watering in the root zone of plant.
- Yield increases due to optimum soil moisture status at root zone.
- It can be adopted in undulating areas, where surface methods of irrigation is not possible.
- Increased water use efficiency.

Disadvantages of drip irrigation

- The drippers are clogged with soil/mineral particles and algae.
- The soil moisture is limited and depends on discharge of drippers, dripper spacing and the soil type.
- The rodents and insects may damage some of teh components of drip system.
- The initial investment and annual maintenance cost are higher compared to other irrigation methods.

Drip irrigation schedule for cashew

In cashew drip irrigation can be started from the second fortnight of December to end of March. However for new plantations, irrigation can be continued upto end of May. For well-established normal density plantations, the rate of drip irrigation recommended is to meet 60% of the evaporative demand. In general, this can be met by providing 4 drippers each of 6 L/h capacity, running for 1.5 hours (that provide 36 litres of water per tree per day) during the months of December and January. The general recommendation during February and March under normal density planting is to provide 48 L/tree/day (4 drippers of 6 L/h capacity, running for 2 hours). These rates are for grown up trees. The drippers should be installed at the base of the tree located at 1 m equidistance from the base of the tree.

In case of high density planting system drip irrigation is to be given to meet 20% of the evaporative demand. This is provided by installing two drippers each of capacity 2 L/h at the base of the tree located at 1 m equidistance from the base of the tree, running for 1 h 45 minutes (giving 7 litre water per tree per day) during December and January and running for 2 h 15 minutes (giving 9 L water per tree per day) during February and March.

Irrigation should be started only after flowering and stopped before starting the harvest. When drip system is planned right from the establishment of plantations, two drippers can be placed at 0.5 m away from the base of the tree on both sides on the lateral pipe, and another two drippers 1 m away from the base of the tree on both sides of the cashew tree. Microtubes of 1.5 to 2 m length can be connected to the drippers to facilitate changing the water dripping points near the root zone as the tree grow up over different years.

Fertigation

It is the technique of applying plant nutrients by dissolving them in irrigation water mainly through drip system. It helps to deliver the correct quantity of water and nutrients to plant roots zone. Fertigation ensures almost 90% use efficiency for the applied fertilisers, as it enables applying the nutrients at the most nutrient demanding stage of crop, at right place (at the zone of highest root activity) and right time. The right combination of water and nutrients is to be used to obtain desired results through fertigation. The advantages of fertigation are as follows.

- Higher nutrient use efficiency.
- Less pollution of water bodies through leaching of fertiliser nutrients.
- Savings of water, nutrients, energy, labour and money

- Effective application of micronutrients.
- Reduced weed growth.
- Increased yield and quality of the produce.

The disadvantages in fertigation is given below.

- Chances of non-uniform distribution of fertilisers to different trees in case of any fault in the drip irrigation system.
- Clogging of emitters / laterals pipes due to precipitation of chemicals.

Fertilisers used in fertigation

The fertilisers used in fertigation should be readily soluble in water, compatible with other fertilisers, low content of insoluble matters and low corrosiveness. The general thumb rules on solubility are given below.

- All ammonium, nitrate, potassium, sodium and chloride salts are soluble.
- All sulphates are soluble except for calcium sulphate.
- All oxides, hydroxides and carbonates are insoluble.
- Urea, MOP and chelated micronutrients are generally soluble.
- Phosphates, sulphates, calcium, magnesium and trace elements may lead to precipitation and blocking if mixed or used with hard water (high in calcium and magnesium). For example, ammonium sulphate causes precipitation of calcium sulphate and magnesium as sulphate.
- Tracer elements such as Mg, Zn, B, Fe, Cu etc ., are difficult to apply through drip irrigation because they need in very low quantities, may reacts with salt in water and causes clogging.
- However, chelated form such as Fe- EDDHA, Fe- DTPA can be used, on chelation the solubility increases.
- Custom made liquid fertilizer designed for fertigation are also available in the market, however this may be costly.

When fertilisers are solubilised by mixing together, they may react and tend to precipitate, if they are not compatible. Such fertilisers are better applied separately through fertigation on different days/time or different fertilisation tanks. Examples of such incompatible fertilisers

are Ammonium sulphate and potassium chloride; calcium nitrate with phosphates or sulphates or DAP, MAP; Phosphoric acid with iron, zinc, copper and manganese etc.

Fertigation recommendation in cashew

It has been reported that fertigation can save 50% in the fertilizer requirement and doubled the cashew yield. Under fertigation only 50% of the recommended dose of fertilizer be given through drip and remaining may be applied in the form of castor cake (4 kg/tree/year in case of normal density planting system or 2 kg castor cake per tree per year in case of high density planting system). The application of organic manure or castor cake may be done during August in pits dug out near water dripping point located 1 m distant from the base of the trees. The recommended dose of fertilizer need to be given in equal splits at weekly interval starting from the month of October to February. The required quantity of fertilizers are to be dissolved in water and applied through drip system.

Immediately after cessation of monsoon rains, the flushing phase get intensified in cashew and fertilizer application is highly essential during this phase. However, since flowering induction in cashew needs dry period, irrigation is not recommended during these periods. So to meet the nutrient demand 25% of the recommended dose needs to be applied as basal dose as soil application. Rest of the dose may be applied in equal split doses at weekly intervals starting from the month of October upto February. For young and establishing plantations irrigation is to be given at 100% CPE.

However under the actual field conditions, the no. of drippers, flow rate, availability of labour to run the system daily, age of the cashew trees, its development stages etc vary widely and user need to customize his/her requirement. Similarly in designing fertigation schedule the field conditions vary widely under each farmer’s field and a general recommendation may not be useful. The availability of fertilizer, soil conditions, density of planting, age of the tree etc needs to be taken into consideration while formulating a fertigation schedule. To empower the users to do drip/fertigation calculations and scheduling at their convenience by inputting their specific needs and resources, a software and mobile App is being developed by ICAR-Directorate of Cashew Research, Puttur and will be shortly available on ICAR-DCR website and Google Play store.

Maintenance of drip system

Daily maintenance

- Start the pump and allow developing stable pressure.
- Clean all the filters as per the protocol.
- Open the bye pass valve meant for sending water to the drip system to obtain desired pressure in the system.
- Traverse the field and check for leakage or damage to any components. Rectify the defects by replacing the parts, removing the folds and kinks in the laterals. Check the position of drippers and microtubes and keep them in correct location if misplaced.
- Check the drippers for uniform discharge of water. Open and clean the filters if required. Do not pull the emitter from laterals as it will lead to enlargement of hole and leakage.
- Remove the end stops and flush the laterals for about 1-2 minutes.
- Flush each submain at the end of irrigation to remove the debris. This is important, since dirt is accumulated in mains and submains and if not flushed off, this may directly go the dripper and clog the pores.

Fortnightly maintenance

Clean the filters

Sand filter: Clean the sand filter by backwash, after adjusting the flow using bypass valve such that sand doesnot come out. Carefully stir the sand thoroughly while backwashing and also break the lumps if any. Continue this until clean water flows out. If the sand is not filled upto the mark indicated, refilling with new sand may be required. Since the sand filter uses special crushed silica, ordinary sand will not serve the purpose.

Screen filter: Remove the filter from the assembly, remove the rubber seals from both ends and clean with a light brush in running water.

Disc filter: Remove the filter from the assembly, remove the rubber seals and clean in running water.

Monthly maintenance

If required perform acid treatment to remove precipitated salts from drippers, microtubes and laterals. Perform chlorine treatment to remove algal growth, slime and bacterial growth.

1. Clogging of emitters is one of the major problem in drip irrigation systems. Take out the emitter/micro tube from lateral pipe and shake it or blow it to remove the trapped dirt. Open able types of emitters can be opened and clean with accessories such as needle.

2. Leakage in the lateral, main and sub-mains: Cut the damaged part and connect it with joiner/connector.

3. Flush and clean the filters by opening and cleaning the screen

4. Flush the sub-mains and laterals by releasing the end caps.

5.Lubricate the movable screws and parts of the system both after using and when not using.

Care during rainy season

Before the onset of rainy season, back wash by flushing the system after removing the end cap of the lateral pipes. Replace the end cap of lateral pipes, roll the lateral pipes in circle and place near sub main pipe at a high elevation.

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Canopy management - a tool for increasing productivity in Cashew (*Anacardium occidentale* L.)

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Introduction

Cashew is a tropical nut tree introduced from Brazil during 16th century as a forest species to mitigate soil and water erosion. The commercial cultivation of cashew started during late 19th century, when the relishing and nutritive status of cashew nut was explored. Every year cashew growing area has been increased exponentially not only for delicious nut but also for reasonable income with minimum crop management practices. Cashew is a vigorously growing woody perennial tree. Naturally grown cashew trees produce unconditional branches results irregular canopy shape. Sometimes, the condition of too many branches at one direction results lodging of trees. In such kind of orchards, taking up intercultural operations in later years become difficult and those cris-crossed branches affect the quantity of light interception which results in low yield and poor quality fruit development. Light is an important natural phenomena for plant growth, development, yield and production of quality fruits. The green leaves exposed to sunlight produces photo assimilates such as carbohydrate and sugars which are translocated to the needy and interior plant parts *viz.*, shoots, buds, flowers and fruits. Since, trees shape determines the light interception, maintaining the shape of tree through proper canopy management (training and pruning) practices are essential.

Canopy management

Canopy is the physical composition of tree comprising of the stem, branches, shoots and leaves. While, the canopy density is determined by the number and size of the leaves, its architecture is determined by the number, length and the orientation of stem, branches and shoots. Canopy management deals with the development and maintenance of their structure in relation to the size and shape for the maximum productivity and quality. The basic concept in canopy management of a perennial tree is to make the best use of the land and the climatic factors for an increased productivity in a three dimensional approach. Tree vigour, light, temperature and humidity play a vital role in the production and quality of the fruits. The

major objective is to achieve maximum productivity in a shortest period without adversely affecting tree health and bearing of the orchard.

Principles of canopy management

The canopy management lies in the fact, as to how best we manipulate the tree vigour and use the available sunlight and temperature to increase the productivity and quality and minimize the adverse effects of the weather parameters. Some basic principles of canopy management are as follows.

1. Maximum utilization of light.
2. Avoidance of the buildup of micro-climate congenial for the disease and pest development.
3. Convenience in carrying out cultural operations.
4. Maximizing the yield, productivity and quality.

Benefits of a canopy management

1. Canopy management enhances productivity
2. Improves the fruit quality
3. Facilitate cultural operations
4. It helps for the proper management of pest and diseases

Different tools for canopy management in Cashew

1. Training

Training is a method of regulating plant growth in a desired direction during early years of planting, to form a definite canopy shape. Such type of initial training provides good architecture to the plants and further helpful in inducing good flowering and nut production.

In cashew, the training system and the diameter of canopy to be maintained is depended on spacing. In general, two types of training systems are being practiced in cashew a) Modified leader system b) Open centre system.

a) Modified leader system

In this system, cashew grafts are allowed to grow as single stem up to a height of 75 to 100 cm by removing side sprouts. Then lateral branches are allowed to grow at desirable direction by de-topping. De-topping height varies from 2.5 to 4 m depends on spacing. Under normal spacing (8m × 8m), de-topping at 4 m from ground level is recommended. Whereas, for high density planting (5m × 5m), de-topping at 2.5 m from ground level is recommended. Removal of cris-cross branches and trimming of branches has to be resorted to get dome shape canopy and the same should be maintained in later years by imposing mild pruning.

This kind of canopy helps in reducing week shoots and water shoots development. Modified training system is suitable for both normal and high density planting system.

b) Open centre system

Cashew grafts are allowed to grow straight up to 50-60 cm from ground level. The terminal growing point is pinched off to form lateral branches. The branches are regulated to grow in four directions at equal distance. Because of fast vegetative growth canopy spreads rapidly. To avoid this, canopy centre needs to be opened once in a while to support more light interception to the interior plant parts. This encourages flowering at inner and outer surface of canopy thus increases the yield.

2. Pruning systems in cashew

Cashew plantation under normal or less spacing, requires regular pruning to avoid unnecessary supply of photo assimilates to unproductive shoot *i.e.,* water shoots and week branches. In cashew, trimming of exhausted branches induce productive growth and helps to promote the yield. In high density planting system, pruning operation plays a vital role to accommodate the canopy within the allotted space. Pruning and canopy shaping along with suitable special operations need to be taken up every year after harvest of crop. Cashew trees

enter a distinct resting period (quiescent stage) after harvest (May– June) till next flush production time (September - October). The lateral shoots which bears flowers/fruits are formed in the terminal of leader shoot after resting period. The past season leader shoots can produce only one lateral from its terminal. Pruning enhances the production of lateral shoots, thus the yield can be increased. Pruning intensity and time varies for different specific agro-climatic regions. The details of pruning pertaining to ***East coast*** region are furnished in the below table.

Region	**Best Pruning method**	**Month of Pruning**	**Collective operations if any**	**Percentage of yield increase**	**Suitable varieties**
Karnataka	Leader shoot pruning (Secondary shoots) - 50% to 60% canopy	July	-	34.02	H-130, VRI-1, VRI-3 Vengurla-4 Ullal-1 VTH-30/4
	Leader shoot pruning (Secondary shoots) - Whole tree	August	-	53.85	VTH-539
Tamil Nadu	Lateral shoot pruning (Tertiary shoots) – whole tree	August	Two Foliar sprays New flush stage (August) -NPK 19:19:19@ 1% Flowering stage (Dec)	44.69	VRI-3
Odisha	Branch thinning (3 branches)	July	-	37.92	Vengurla-4
West Bengal	Leader shoot pruning (Secondary shoots) Whole tree	July	-	53.51	Vengurla-4

Advantages of training and pruning

- Harvesting and utilization of maximum solar energy by regulating plant growth for betterment of yield and quality of nut and apple
- Development of stronger framework of branches with equal distance at desirable direction
- Equi-distant branches enhances resistance against strong wind in wind prone areas
- Trimming of tangled and low lying branches facilitates the intercultural operations
- Less vegetation restrict the micro-climate congenial for pest infestation
- Maximum exposure of ground helps to disinfect pest and disease inoculum during summer
- Removal of dried branches, dead woods, cris-cross branches reduce the effect of shade and extra burden on trees
- Thinning out of dead branches reduce the chance of secondary infection

Precautions and aftercare during training and pruning

- Training must be made in live tissue to facilitate good callus formation for rapid healing
- Sharp tools should be used for implementing training or pruning to avoid damage to bark/phloem
- After training or pruning, 10% Bordeaux mixture paste swabbing for large cut ends or 1% Bordeaux mixture spray for pruned shoots is recommended

Secateur

Pruning saw

Pole tree pruners

Pruning shears

Chain saw

Telescopic power tree pruner

Tools used for pruning

Training and pruning done through manual methods is cumbersome in cashew. There are tools available to make the operation simple and easy.

Secateur: Use to prune lateral shoots and small twigs of 1.5 to 3 cm diameter

Pruning saw: Use to prune small woody branches of 5 to 10 cm diameter

Pruning shears and Pole tree pruner: Use to prune 10 to 20 cm diameter upto its reachable height

Chain saw: Power or fuel operated chain saw use to prune woody shoots of any size

Telescopic power tree pruner: Use to prunewoody branches of smaller size upto its reachable height

Conclusion

Now a days increasing productivity is one of the major target assigned to meet out the demand on production, productivity and processing needs of cashew. Though many technologies are available rejuvenation and closer spacing is widely adapted for the concept

of doubling farmers' income. Further, more farmers and growers from within the country and abroad are coming forward with queries for taking up this technology in their fields. More awareness about the technology and financial assistance from government agencies can bring revolution in cashew cultivation thereby achieving the production target of raw nuts in the country.

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High Density Orcharding in Cashew

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Introduction

High density planting (HDP) or Ultra density planting (UDP)is a system of planting in a lesser space than traditional spacing to accommodate more number of plants per unit area to increase the productivity in any kind of horticultural crops preferably with little modification in their packaging practices especially canopy management, nutrient and irrigation requirements. The concept of HDP is always associated with training and pruning operations, where the initial frame work of the plants is to be strengthen with the earlier and excessive vegetative growth are controlled with the later.

Concept of HDP and UDP

- Maximum utilization of natural resources like solar radiation and land
- To increase the productivity and quality of the produce
- To avoid congenial micro-climate suitable for survival or breeding of pest and disease inoculum by proper pruning operation

Land preparation

The plating pits are prepared with 1 m^3 size at a distance of 5 × 5 m (HDP) 3 × 3m (UDP) in plains. In case the land is slope, pits are preferably taken up by making contiguous reverse terraces against the slope. The $^{2}/_{3}^{rd}$ depth of the pits are filled with friable and fertile soil and remaining $^{1}/_{3}^{rd}$ can be applied with 5 kg of well decomposed farm yard manure (FYM).

Season and method of planting

Grafts of selected cashew variety are planted right at the centre of the pit preferably during the monsoon season (August - September). Planting can be done throughout the year if irrigation facilities are available. The soil should be compacted without air pockets around the root zone followed by life irrigation. Stalking should be provided to the grafts to support

straight growth and mulching with green manures can be made to retain adequate moisture for longer period especially during summer and water scarcity regions. This will help to reduce the number of irrigations.

Initial stage of ultra density orchard

Plant spacing

The plant spacing for conventional method, high and ultra-density planting system for cashew has furnished here.

Comparison of planting density at different methods of planting

Sl. No.	Methods of Planting	Recommended Spacing	Accommodation of number of plants per hectare
1	Conventional method/ low density planting	8 X 8 m or 7 X 7m	156 or 238
2	High density planting	5 X 5 m or 4 X 4m	400 or 625
3	Ultra Density planting	3 X 3 m or 2.5 X 2.5 m	1111 or 1600

Varieties suitable for HDP and UDP

All the available varieties are not suitable for high and ultra-density planting. The variety which responds well for pruning is to be selected. Therefore, selection of variety is very important aspect in high and ultra-density planting systems. The cashew varieties having precocious flowering and positive response to pruning are VRI-3, NRCC Sel-2, Ullal-1, Ullal-4 and K-22-1 are most suitable for this kind of planting. The recent hybrid H-130 is most suitable for the purpose having high precocity and good response to pruning. It has very bold nuts (13 g) and long flowering duration. The complete allotted space can be covered in 3rd year of planting and potential yield of the unit land can be realized from 3rd to 4th year of orchard life onwards. The yield in farmer's plot harvested in this method was up to 3 kg/plant

in third year of planting. Even if a yield of 2 kg per plant can bring more than 3 tonnes per ha area which will be much superior over existing orchards having National average yield less than 750 kg/ha.

Training and Pruning

The cashew grafts are allowed to grow without side sprouts in the main stem for upto 40-50 cm from the ground level to ensure the stronger trunk in later years. The growing tip are pinched or nipped off to promote side branches / primary branches and subsequent secondary branches and laterals. Symmetrical and wider angle primary braches at the number of 3-4 are allowed in all four directions. The flowering and fruiting may start from first or second year is depended on the precocious bearing nature of cashew varieties. Pruning is a year wise operation and required to be carried out immediately after harvest (June-July). The recommended height of pruning during first and subsequent years is 1 m from ground level.

Aftercare during training and pruning

- Training must be made in live tissue to facilitate good callus formation for rapid healing
- Sharp tools should be used for implementing training or pruning to avoid damage to bark/phloem
- After training or pruning, 10% Bordeaux mixture paste swabbing for large cut ends or 1% Bordeaux mixture spray for pruned shoots is recommended
- As a preventive measure, the pruned trees are to be sprayed with 0.2% λ-cyhalothrin twice or thrice in the initial 24 months of pruning
- The tender shoots should be protected against Tea mosquito bug attack by spraying λ–cyhalothrin 0.06% (6 ml in 10 L of water)


Pruning and training of plants in ultra-density

Manuring and Fertilizer Application

The annual dose of fertilizers to cashew is to be applied in to two split doses. First split dose at onset of monsoon period and second split dose during post monsoon period when the soil moisture condition is at optimum level. Fertilizers are to be applied 60 cm away from the main stem by making 10-15 cm deep trenches. The fertilizer dose can be modified depending on the soil type and crop requirement based on soil test results. The general recommendation for the crop is as follows.

Table on Fertilizer recommendation for different aged plants

Sl. No.	Age of plants	Urea	Rock phosphate	Muriate of potash (MOP)	Organic Manure
1	One	100 g	150 g	50 g	4-5 kg
2	Two	250 g	200 g	100 g	5-10 kg
3	Three and above	400 g	300 g	200 g	10-20 kg

Plant Protection measures

There are no major diseases in cashew but some pests cause severe infestation to the crop *i.e.,* Tea Mosquito (TMB), Cashew stem and Root Borer (CSRB), leaf eating caterpillar and leaf minor. The infestation of TMB is severe in ultra-density planting due to emergence of enormous new shoots and panicles and the infestation of CSRB was very less due to less bark growth and stem thickness due to frequent pruning of plants.

1. Tea Mosquito Bug *(Helopaltis antonii)*

The mosquito bug is considered to be the most serious pest of cashew in India, and causes more economic loss to the crop than any other pest. It will cause damage to all the parts such as tender shoots, leaves, floral branches, developing nuts and apples. The TMB can be controlled by spraying 0.06% Lambda cyhalothrin, or 0.15% profenophos or 0.15 % monocrotophus. For better management three sprays is required one at the time of vegetative flush, second at the time of panicle emergence and third at the time of fruit setting.

2. Cashew Stem and Root Borer (*Plocaederus ferrugincus*)

This is another major pest in normal density planting but in ultra-high density orchards it was observed very low infestation may be due to less bark growth and stem thickness which is due to frequent pruning of plants. For the control of stem and root borer early detection of incidence is very important. The affected bark should be removed along with the grubs and then swabbing affected area with chlorpyriphos 2 ml/lit.

3. Leaf eating caterpillar

This pest causes more damage during the emergence of new flush. It can be controlled by spraying 0.06% Lambda cyhalothrin or Profemophos 50 EC @ 2 ml/lit.

4. Leaf miner

The caterpillars of this silvery grey moth mine through the tender leaves and severely damage them at the time of new flushes. For controlling spray 0.05 per cent Phosphamidon.

Harvesting and Yield

In ultra-density planting, plants start flowering during first year of planting**.** If plants are healthy and vigorous harvesting can be done during first year otherwise panicles can be removed in first year for better growth of plant. The 2nd year plants yield 1-1.5 kg nuts per plant and 2-3 kg per plant during 3rd year and above. Nuts are harvested from fully developed fruits or nuts are collected from the fallen fruits.

Conclusion

The bumper harvest was possible by adopting the technology with specified cashew varieties and management practices developed by the Directorate and adopting the same in their fields. A large number of farmers from Karnataka, Kerala, Tamil Nadu and Andhra Pradesh have adopted this technology successfully. Further, more farmers and growers from within the country and abroad are coming forward with queries for taking up this technology in their fields. More awareness about the technology and financial assistance from government agencies can bring revolution in cashew cultivation thereby achieving the production target of raw nuts in the country within a short span of 4-5 years.

Future thrust

There is need for more research on time and intensity of pruning and screening of all commercial varieties for suitability for HDP and UDP. Manure and fertilizer requirements, specific pest management techniques and complete package of practices for the technology need to be developed by experimenting with different cultivars.

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Establishment and management of cashew orchards

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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.

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.

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.

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 minimizes 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.

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.

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 especially 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 runoff 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 way 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 premonsoon 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.

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Role of plant growth regulators in Cashew

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Introduction

The global population is expected to reach 10 billion people by 2050 which will increase the demand for greater agricultural productivity to feed the massive population and require greater conservation of arable lands to offset the negative climate impacts of the growing population. Historically, new technologies have enabled the agricultural industry to adapt to the demand for greater productivity and fortunately, agriculture innovation continues to support growers in their efforts to produce higher yields in a more profitable and sustainable manner. Natural and synthetic plant growth regulators, an innovative technology, have been used as a part of the process to enhance crop productivity and quality.

What are Plant Growth Regulators?

Plant growth regulators (PGR), often referred to as plant hormones, are natural or synthetic substances that are used to alter the growth and/or physiological processes of a plant. They do so by acting as "chemical messengers for intercellular communication" within the plants they are applied to. PGRs are either sprayed onto the plant or applied to the plant or its seed. They are transported throughout the plant via vascular tissues called xylem and phloem and then released at the target cells. They can also move between cells through plasmodesmata, which are microscopic channels that create pathways between cell walls. A natural PGR is produced by the plant itself, while 'synthetic' ones are created in a laboratory.

The five Families of Plant Growth Regulators

PGRs are categorized into five main groups—auxins, gibberellins, cytokinins, abscisic acid, and ethylene. PGRs alter plants in different ways depending on which group they belong to.

Auxins

Cells tend to grow more rapidly in areas where auxins are highly concentrated—typically the shoot and root tips. These PGRs promote cell elongation and affect rooting processes, tropic responses, and bud development. They travel down from the growing tip to inhibit lateral

growth and maintain apical dominance, in which the central stem of a plant in stronger than its branches.

Cytokinins

Cytokinins regulate plant growth and development by promoting cell division, known as cytokinesis, and affecting morphogenesis, the biological process that controls the development of a plant's shape. They are naturally produced in the roots and move up through the xylem, a transport tissue in vascular plants, to promote lateral growth. Auxins and cytokinins pair together to strike a balance between the growth of the central stem and lateral branches.

Gibberellins

Gibberellins mainly function to promote stem elongation and stimulate flowering, though they affect other processes like adventitious root growth. Though there are over 80 different members of the gibberellin family, only gibberellic acid (GA_3) and GA_4+ GA_7 are used in plant tissue culture.

Abscisic Acid

Abscisic Acid (ABA) regulates seed germination and plays a significant role in somatic embryogenesis, in which a plant or embryo is artificially derived from a single somatic cell or group of somatic cells. Additionally, when a plant is exposed to drought, freezing, or environmental pollutants, it will produce more ABA to regulate the plant's reaction to water stress and encourage higher levels of absorption from the surrounding soil.

Ethylene

Known as the aging and/or ripening hormone, ethylene is not required for normal vegetative growth. It can, however, affect the development of root and shoots and is widely used for commercial purposes, specifically to speed up fruit ripening.

Plant Growth Regulators and Agriculture

Most of the PGRs used in commercial agriculture, including the sale of nursery stock, are produced in a laboratory, meaning they are synthetic. They can either stimulate or inhibit different kinds of growth in plants, giving farmers more control over how their crops grow and what they yield.

Crop	Chemical/ Dosage	Response
Rice	Kinetin, GA_3 and Triacontanol (1000 ppm)	• Grain filling and partitioning • Delayed senescence
Cotton	IAA, NAA (30 ppm), CCC (cycocel)	• Increase grain yield, Decrease boll shedding • Increase photosynthetic rate and yield • Increase number of bolls, boll weight and lint yield
Sunflower	Benzyl adenine (BA) (250 ppm) GA+BA(150ppm)	• Increase yield and Achenes weight and number
Groundnut	Mepiquat chloride (125 ppm) (2,3,4-D-chlorophynoxy triethyl amine)	• Increased grain yield and chlorophyll synthesis and decrease chlorophyllase activity • Stimulation of assimilate transport in germination
Sugarcane	Ethephon Glyphosine	• Reduced growth rate and regulate ripening
Tapioca	Ethrel (250 ppm) CCC (1000 ppm)	• Early tuberisation • Increase the weight of storage roots
Pigeonpea	Ethrel (40 ppm) and GA3 (20 ppm) CCC(0.64 mM)	• Increase grain yield • Respond well for RWC, chlorophyll and stomatal conductance
Carrot and Potato	GA_3 (50 ppm)	• Induction of flowering in long day and seed setting

Plant Growth Regulators and Horticulture

Ripening of fruits

Crop	Chemical	Dose	Response
Mango	Ethephon	1000 ppm	Accelerated fruit ripening and improves surface colour
Citrus	Ethrel	1000 ppm	Induce yellow colour within seven days
Banana	Ethrel	1000 ppm	Accelerated ripening by two days
Papaya	Ethephon + NaOH	2000 ppm	Ripening within 24 hours
Sapota	Ethephon + NaOH	500 ppm	Ripening within two days

Flowering and fruit set

Crop	Chemical	Dose	Time of spray and number of spray	Response
Coconut	2,4-D	30 ppm	One month after opening of spathe, through micro sprayer	Fruit setting percentage increased to 32.5% against 23% in control
Banana	2,4-D	25 ppm	Within a week after opening of last bud	Prevents seediness in poovan
Mandarin orange	2,4-D or NAA	20 ppm, 100 ppm	Spray at flowering.	Increase fruit set
Thompson seedless		25 ppm	Dip cluster at calyptra falling stage	Increase fruit set
Pine –apple	Planofix 10 ppm +2% urea 0.04% sodium carbonate +20 ppm ethrel	50 ml/plant applied in to the crown 200 to 300 ppm	At 35-40 leaf stage Sprayed during fruiting	Induced uniform flowering to increase the fruit size
Snake gourd	Ethrel	100ppm	4 times 10 –15 days	Increase in yield

Bitter gourd Bottle gourd			after sowing at weekly intervals	
Ribbed gourd Pumpkin	Ethrel	250ppm	4 times 10-15 days after sowing at weekly intervals	Increase in yield
Sweet potato	Ethrel	250ppm	At fortnight interval from 15 days after planting	Increased tube

Plant growth regulators and cashew

Cashew is a polygamous tree and produces male and hermaphrodite flowers in different phases during flowering. The yield of cashew is very low owing to the production of low percentage of hermaphrodite flowers, poor fruit set, immature fruit drop and low fruit retention. Flowering in cashew is seasonal, producing flower buds in varying phases starting from September to March depending upon the cultivars and climatic conditions. Though, cashew produces innumerable flowers, only 1-2 per cent of the flowers set fruit and reach maturity. Fruit set and their retention are the major limiting factors for low yield in cashew which need due attention. The nuts those develop after pollination start drying followed by dropping, leading to very low percentage of matured nuts. Therefore, growth regulators are gaining importance in cashew cultivation for overcoming problems associated with plant growth, fruit set, development and, final retention.

Seed Germination

Seed germination and dormancy are important processes affecting plant overall performance. These processes are influenced by a range of factors, including plant hormones. The plant hormones, including ABA, IAA, cytokinins, ethylene, gibberellins and brassinosteroids, can positively or adversely affect seed germination, while interacting with each other. Germination rate (speed of germination) can be used as tool in breeding programme for evaluation of seedling vigor. In cashew, Shanmugavelu et al., (1970) reported the effect of plant growth regulators on nut germination. Studies revealed that GA_3 induced better nut germination in cashew than other chemicals. Studies by Laxmipathy et al., (2014) revealed that application of 200 ppm GA_3 was mainly attributed to enhanced germination, early seedling emergence, highest vigor index and better seedling growth in cashew.

Regulation of seedling and root growth

Cashew is commercially propagated through soft wood grafting where early attainability of seedling height can reduce the cycle of propagation. Young seedlings of cashew usually do not produce lengthy tap root and secondary roots and hence seedlings suffer heavy causalities especially during summer. The possibility of inducing better root and shoot development by treating cashew seeds or seedlings with plant growth regulators to reduce mortality was also investigated by Shanmugavelu and Rangasawamy et al., (1970). They reported that 500 ppm GA_3 treatment resulted in 77% higher shoot growth but failed to induce root growth. Auxins like NAA at 100 ppm and 500 ppm recorded 92% higher root growth and production of secondary roots in cashew seedlings where as GA_3 did not influence the production of secondary roots of cashew. GA_3 treatments also resulted in increased shoot and root biomass in cashew seedlings focusing its role in cell elongation and increase in cell number (Brain et al., 1959). The most striking response of GA on cashew is the stem elongation. The number and length of cells in the cortex and pith regions were influenced by GA treatment. Therefore, it appears that stem elongation is predominantly due to cell elongation supplemented with cell division in the cortex and pith region.

Propagation

Cashew is a cross pollinated crop and therefore, the seedling progenies obtained through seed propagation are heterogeneous due to segregation. Conventional vegetative propagation methods such as air layering, mound strolling, or cutting have been attempted in cashew but the multiplication rate is inadequate to meet ever increasing requirement. However, the performance of this crop obtained through conventional vegetative propagation methods is poor and breeding desirable plant traits has also become difficult due to its out-breeding nature. Therefore, vegetative propagation offers opportunity in maintenance of desired characteristics of mother tree and hence it becomes the preferred choice for raising cashew propagules (Oliveria et al., 1989). 49.72 per cent of semi hard wood cashew cuttings from the 4 month old seedlings rooted with the number of roots per cutting ranged from 15.3 with 1000 ppm NAA treatment to 4.5 with no growth regulator treatment and the length of the longest root ranged from 8.5 cm with IAA at 500 ppm to 17.7 cm with IBA at 2000 ppm.

Control of plant growth

Cashew is a fast growing woody perennial, covers the allotted space under high density planting, within a short span of 6-7 years. Controlling excessive vegetative growth for increased or sustained productivity is the major principle of high density planting (Santram, 1996). In cashew, due to non-availability of dwarf clones, dwarfing root stocks or a pruning technology for the management of vigorous canopies, use of growth retarding chemicals such as paclobutrazol assumes significance. Reduction in shoot growth by Paclobutrazol (PBZ) occurs primarily as a consequence of reduced internode elongation. Misra and Singh, (1991) found that reduction in growth was observed in cashew when Paclobutrazol was applied to young grafted plants at nursery stage. Application of 50 ppm PBZ as soil drench could restrict vegetative growth up to six months. Nayak et al, (2010) reported the regulation of plant growth by PBZ application. Paclobutrazol when applied as soil drench at the rate of 2.0, 4.0, 6.0 and 8.0 g per plant reduced plant height and canopy spread. Similar studies conducted by Meena et al., (2014) also reported the regulation of growth and yield of cashew varieties by PBZ application when applied @ 1, 2 and 3 a.i. per plant as soil drench. They found that the application of PBZ reduced plant height, canopy spread and intermodal length. The application of PBZ at pre-flushing stage was effective in increasing number of flushes with yield increment up to 51.78 %.

Sex ratio, flowering and fruiting

Flowering in cashew is seasonal and produces innumerable flowers but only 1-2 per cent of the flowers set fruit and reach maturity. Production of more number of pistillate flowers and reduction in nut drop can be accomplished by the use of plant hormones. It has been reported that foliar sprays of Gibberellic acid (GA_3), 1- Naphthalene acetic acid (NAA) and Ethylene increased the production of perfect flowers and improved sex ratio in cashew (Puhual et al., 1993; Kumar et al., 1995; Aliyu et al., 2011). Cashew trees sprayed with 50 ppm Ethrel had significantly the highest number of flowering panicles per square, number of perfect flowers per panicle and sex ratio (Gawankar et al., 2010). Etylene is believed to be the chemical which causes natural initiation of flowering. A significant increase in the number of flowering panicles per square meter with Ethrel 50 ppm in case of Bhaskara was reported by Lakshmipathi et al., (2014). They also reported improvement in sex ratio by foliar application of Ethrel at pre- bloom stage. Gawankar et al., (2010) indicated that the number of staminate flowers was related to the number of lateral per square meter. Higher number of laterals in water sprayed trees could have resulted in higher number of staminate flowers. Singh et al.,

(1992) reported that foliar application of Ethrel @ 100 ppm increased the number of perfect flowers in cashew. Improvement in the sex ratio with the application of Ethrel was mainly due to increased number of perfect flowers. Ethrel may also have exerted its effect on sex expression by manipulating endogenous auxin levels corresponding to a reduction in staminate flowers as reported by Mariappan et al., (1995). Kumar et al., (1996) reported that number of perfect flowers per panicle was positively correlated with yield in cashew. A similar correlation was observed by Lenka et al., (2001). Dorajeerao et al., (2001) reported that clones having broader sex ratio were high yielder.

Fruit set and their retention are the major limiting factors for low yield in cashew which needs due attention. The nuts that develop after pollination start drying followed by dropping, leading to very low percentage of matured nuts. Preliminary studies on improvement of sex ratio, fruit set, fruit retention and yield by using plant growth regulators have indicated beneficial effects in cashew. Increase in the percentage of fruit set by 55 per cent in cashew with foliar application of 10 ppm NAA was reported by Murthy et al., (1975). Lashmipathy et al., (2014) reported that spraying of 50 ppm Ethrel increased the number of fruits set, number of fruits retained per panicle, nut weight (g), nut yield (kg) per tree and reduced fruit drop per panicle in cashew. Increased fruit set and fruit retention due to application of Ethrel and other growth regulators could be attributed to the increased number of bisexual flowers and reduced pre mature fruit drop. Reduced fruit drop in cashew due to application of growth regulators was also reported by Konhar and Arun Mech, (1988). Aliyu et al., (2011) found that highest fruit set and improvement in fruit retention was recorded from twigs treated with GA_3. This remarkable response in cashew twigs treated with GA_3 over other exogenous hormones suggests hormone-specific nature of cashew tree (Davenport, 2003).

Influence on nut yield

Correlation analysis for yield attributing characters using different plant parameters has been attempted by several workers. Nut yield (kg) per tree was found to be most significantly and positively correlated with number of flowering laterals per square meter, total number of laterals per square meter, duration of male flowers, duration of hermaphrodite flowers, number of male flowers per panicle, number of hermaphrodite flowers per panicle, total number of flowers, number of fruits set per panicle, number of fruits retention per panicle and nut weight (Lashmipathy et al., 2014 and Kumar et al., 1996). Similar correlation was also reported by Lenka et al., (2001).

Among the various factors influencing cashew yield, the narrow sex ratio is of primary importance. Therefore, growth regulators are gaining importance in cashew cultivation for overcoming problems associated with fruit set, development and, final retention. Improvement in sex ratio with application of growth regulators was mainly due to increased number of bisexual flowers. Both auxin and ethrel had stimulating effect on the physiological changes in the tissues influencing the flowering characters (Salisbury and Ross, 1986). Increased nut yield by Ethrel application has been reported in cashew by Mohan and Rao, (1995); Gajbhiye et al., (2007); Gawankar et al., (2010) and Lashmipathy et al., (2014). Increased nut yield with application of growth regulators could be attributed to increased number of bisexual flowers, fruit set, fruit retention and total number of nuts per tree (Veeraragha vathatham and Palaniswamy, 1983). Aliyu et al., (2011) showed that application of exogenous hormones can improve fruiting/yield significantly through the flowering components (Days to flowering and Hermaphrodite flowers per panicle) in cashew. The significant reduction in the period of flowering will considerably enhance flowering synchronization in cashew. These two events coupled with the increased number of hermaphrodite flowers were likely responsible for higher fruit set through improved pollination. PBZ has been reported to exert influence on partioning the photosynthates to the sites of flowering and fruit production consequent to the reduction of vegetative growth. In this context, Meena et al., (2014) reported that PBZ treatment increased nut yield per plant but nut length, width, weight and volume decreased. The maximum yield increment of treated plants (51.7%) was associated with PBZ @ 2.0 a.i. per plant. A significantly higher fruit set and fruit retention in PBZ treated plants had favourable impact on culminating higher nut yield per plant.

Plant growth regulators (PGR) application methods

1. **Application in Powder form:** PGR powders dissolved in organic solvent mixed with moistened charcoal powder, soybean flour or wheat flour and prepare a uniform paste. The paste is allowed to stand until the solvent evaporates.
2. **Application in Lanoline paste:** Most of the roots promoting PGR are readily soluble in lanoline; a lanoline paste which promotes advantageous roots in plant is made by mixing PGR in lanoline and allowing it to cool.
3. **Soaking Method:** Measured quantity of PGR is dissolved in alcohol then dilute with distilled water to make required quantity and concentration of solution (20-2000 ppm). Cuttings are soaked in solution for 24 hours before planting.

4. **Aerosol Method:** This method is popular in green houses, where the PGR solution is released through a small aerosol bottle / cylinder. Liquid gases soon evaporate leaving the PGR chemical in the air.
5. **Spraying method:** The most common method of applying growth regulators is spray applications. When using plant growth regulators as a foliar spray, it is important to achieve thorough, consistent and uniform coverage. To accomplish this with most chemicals, it is recommended to apply 2 quarts of spray solution per 100 square feet. Failure to apply these chemicals properly can lead to inconsistent results.
6. **Root feeding method:** It is the method of pressurized soil injection to deliver important plant growth regulators into the plant's root zone. The goal is to develop the feeder roots that are vital in helping the plant to survive during periods of stress.
7. **Injection of solution into internal tissues:** It is the injection technique to supply the required plant growth regulators into intact plant tissues.

Precaution in Application of Plant Growth Regulator

- Use growth substances at an appropriate stage of plant growth
- Growth substances should be sprayed preferably in the afternoon
- Spray should be uniform and wet both the surface of leaves
- Add surfactant or adhesive material like Teepol, Tween-20
- Solution should always be prepared in distilled water only
- Fine spray can be ensured by hand automizer
- Use always fresh solution of chemicals
- Avoid spraying in windy hours

Constraints in the Use of Growth Regulators

- Sensitivity of each plant species or cultivars to a given chemical treatment prevents easy predication of the biological effects.
- Screening for PGR activities entails high costs and much difficult. Some synthetic plant growth regulators causes human health hazards
- The cost of developing new PGR is very high due to which they are very much costly.
- It's difficult in identification of proper stage of crop at which the growth regulators should be applied
- Lack of support from agricultural researchers in public and private sectors

- Lack of basic knowledge of toxicity and mechanism of action

Future perspectives

Future perspectives for the use and application of plant growth regulators in agriculture are promising, especially in the case of agricultural and horticultural crops. A major challenge would be to understand how the information conveyed by these growth regulators is integrated during plant growth. Controlling the hormone dose/response ratio remains a challenge, since the hormone levels attained should be moderate in order to maintain a balance between the positive effects and the negative effects of plant hormones on growth and development. The need of today world is high output yield and enhanced production of the crop as well as fertility of soil to get in an eco-friendly manner. Although the use of PGRs is encouraged in the modern production system of Agricultural and Horticultural crops and also helpful in altering various growth characteristics but their unjudicial use can threaten the environment and also effect the consumer acceptability, as commercial available PGRs formulations consists of synthetic growth regulators. The synthesis of ecological safe formulation of PGRs and their usage in optimum dosage will enhance their acceptability by the growers as well as consumers. The second way is to use alternative approaches for alteration of growth characteristics in crops including the genetic engineering, gene silencing, manipulation of environmental factors especially temperature, light, and water stress technique to control growth of plants.

Given the growing awareness pertaining to healthy eating, nutrition, and organic foods, the worldwide surge in organic farming techniques has been one of the most significant growth drivers of the plant growth regulators market in the recent years. The fact that the plant growth regulators are defined as any organic compounds with low concentrations (1-10 ng /nl) in inhibiting, promoting, and modifying plant growth & development, has further accelerated the use of PGR as an substitute to synthetic chemicals in organic farming.

Conclusion

The use of plant regulators in agriculture and horticulture is a trend with great advantages. The regulation of complex growth and plant developmental process requires the coordination and integration of many signalling events during plant growth. The PGRs would be favorable as a good technique to the production of the diverse agricultural and horticulture plants in nursery, field, and greenhouse. The application of the PGRs could be an effective approach

for reducing the negative impact of stress on plant growth. In addition, the manipulation of the hormonal balance can bring gains to the crops of the different agricultural and horticultural plants.

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Management of Cashew Stem and Root Borer (CSRB) – major pest of cashew

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Introduction

Cashew is prone to significant losses in raw cashew nut yield due to insect pest incidence during various stages of the crop. Moderate to severe loss of the crop yield may occur depending on crop stage as well as intensity of insect pest damage. Out of these pests, two major insect pests cause considerable yield loss in most of the cashew growing regions of our country; viz., a) Cashew Stem and Root Borers (CSRB) scientifically known as *Plocaederus ferrugineus* and *Plocaederus obesus* and b) Tea Mosquito Bug (TMB) scientifically known as *Helopeltis antonii*.

Cashew Stem and Root Borers

Cashew stem and root borers (CSRB) infest the vital bark portion of yielding cashew trees and lead to gradual death of such infested cashew trees, if timely pesticidal intervention and alternate management practices are not adopted. The pest population of CSRB builds up over the years resulting in cumulative loss of tree population. Thus, productivity in a given location gets drastically reduced over the years as high yielding trees succumb to the pest. The other major pest is the tea mosquito bug (TMB)which displays seasonal occurrence in tune with the crop phenology; the adults and nymphs of TMB constantly suck plant sap and this results in drying up of shoots and flower panicles, leading to considerable yield loss during that cropping season. However, intensity of the pest damage varies over the years.

Cashew stem and root borers (CSRB)

The pest complex comprises of three species; *Plocaederus ferrugineus* and *Plocaederus obesus* which are primary pests infesting the healthy trees and *Batocera rufomaculata* which is a secondary pest and infests already infested and weakened cashew trees. The insect damage is generally noticed by cashew farmers at later stages, during which any pest management practice will not be effective and this is one of the main reasons for inadequate

management of the pest. The larval stages feed on the bark portions of the main stem, primary branches and roots, by forming irregular tunnels which enlarge as the larvae grow in size. The pest has concealed nature of feeding i.e., it is hidden below the bark which appears deceptively normal externally. On chipping off the damaged bark portions the cashew farmers can notice presence of different age groups of CSRB larvae below the bark, while the pupae and un-emerged immature adults occur inside the heartwood or in root forks of the infested cashew trees. The adult insects belong to the "longicorn beetle" group of insects which have long antennae and are active only during the night. Hence, adult beetles are seldom noticed in the cashew plantations during day time.

Symptoms of pest damage:

During initial stages of pest attack, small quantities of slightly pinkish-brown chewed fiber occurs on the bark surface; while the presence of exuded gum and brownish frass (*i.e, chewed cashew bark fiber and excreta*) at the base of the CSRB infested tree, are seen during the progressive and moderate stages of pest attack. During severe pest incidence, the canopy of infested tree turns yellowish prematurely and start falling off. In subsequent stages of attack, the twigs and branches dry off and the bark on the trunk starts splitting. At this stage, substantial quantity of chewed fibers and gum are seen at the base of the CSRB infested tree.

Seasonality of pest incidence

Though the pest incidence is noticed all-round the year, the adult emergence (as indicated by the back dating the age groups of field collected CSRB grub) stretched between Oct. to May in different cashew growing zones. Generally different stages of the pest are noticed in infested cashew trees all-round the year. However, young and old larval stages of the pest occur during the late summer months and throughout the monsoon months while, pupal stages of the pest are noticed during post monsoon months only. During the onset of rainy season the healthy cashew trees turn dark green, whereas, the CSRB infested trees retain the yellowish canopy, which is a definite indicator of the pest infestation in those trees. The initial incidence symptoms of the pest overlaps with the nut collection period. Hence, during the nut collection period, detailed observation of the main tree trunk at collar region reveals the initial infestation symptoms; if any, which needs to be treated suitably prior to onset of monsoon.

Nature of pest damage

The adult female beetles lay ovoid eggs (which resemble rice grains) inside the crevices of the bark of stem, branches or exposed roots. Nascent grubs hatch from these eggs in 5 – 7 days and immediately start boring into the bark. The grubs feed voraciously for a period of 8 to 10 months and grow rapidly in size and fill the tunnels with chewed fiber and excreta. Their feeding method by irregular tunneling interferes with movement of sap leading to premature leaf fall, drying of branches and gradual death of the infested cashew tree. Full grown larvae make deep zig-zag tunnels in the heart wood and form a hard cocoon made of calcium secretions. The pupal stage lasts for 60 – 90 days and after transformation the pre-mature adult beetles lie quiescent and are inactive for 30 to 60 days till emergence. The emerged beetles are highly nocturnal and mate later on and continue the life cycle.

Pest management techniques

Several systemic insecticides and botanicals have been evaluated as swabbing and stem injections for their efficacy in managing the pest at various research centers, for over a few decades. Any insecticidal treatment imposed on the infested trees without removing the pest stages will not be effective in resurrecting and saving the tree.

All 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 tracked. The pest larvae will be present in the zone where the frass is lighter in color both in the stem and in the roots; these need to be removed and destroyed by skillful chiseling of the tunnels in the infested portion. 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 chloropyriphos (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.

The treated trees need to be observed regularly at 15 to 20 days interval for any fresh symptoms of pest incidence and if fresh pest infestation symptoms occur, the treatment should be repeated. It is very critical not to damage more than 50 per cent of the bark circumference, as this will lead to girdling and subsequent death of the treated cashew tree. In case, more than 50 per cent of the bark circumference has been damaged or the leaf canopy has turned yellowish, such trees need not be treated, as they do not recover. Such trees need

to be uprooted and searched for presence of pest stages in those trees both in collar and root zones and they should be destroyed. Such uprooted trees should be shifted out of the plantation and can be used as firewood. Adopting this method of plant protection is termed as "phytosantiation" which aids in minimizing the pest load in a given area. Both methods when adopted simultaneously on a community basis will surely lead to lower incidence of pest in the following years.

Prevention of the spread of pest infestation

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

i) Reduction density of CSRB pest population in a given location and
ii) Rescuing the CSRB infested cashew trees during initial stages of infestation, itself.

To achieve these aspects, all the cashew trees need to be surveyed at regular intervals for any initial symptoms of pest incidence, the initial stages of infestation of CSRB infested trees should be taken up during the nut collection period and marked suitably. Treatment of all such initially infested trees should be done AT A TIME during post monsoon and premonsoon months as the soil will have sufficient moisture to facilitate the digging of root zone and if possible preferably on a community basis following the methods 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. 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.

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Management of Tea Mosquito Bug (TMB)– major pest of cashew

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Introduction

Tea Mosquito Bug (TMB) *Helopeltis* spp. (Hemiptera: miridae) is one of the major pests of cashew affecting its tender shoots, panicles, nuts and apples. Both nymphs and adults feed by sucking the plant parts, injecting polyphenol oxidase (salivary enzymes). Typical feeding damage by *Helopeltis* spp. appears as a discolored necrotic area or a lesion around the point of feeding. The infestation by TMB results in a burnt appearance of the trees. Four species of TMB, *Helopeltis antonii* Signoret, *Helopeltis bradyi* Waterhouse, *Helopeltis theivora* Waterhouse and *Pachypeltis maesarum* Kirkaldy are found in India. Among them, *H. antonii* is the dominant species. Each insect can damage up to 3 or 4 shoots or panicles leading to heavy loss in yield. Under outbreak situations, a damage of 25-30 per cent and even 100 % 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. 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 standardized using cashew shoot as a host material.

Host range

TMB is polyphagous in habit and the nymphs and adults of feed on a wide variety of crop plants such as eucalyptus, mahogany, neem, cocoa, cinchona, guava, drumstick, black pepper, Singapore cherry, cotton, *Lawsonia inermis* (mehendi) and Allspice. During off season, the activity is mainly confined to these hosts and some weed plants like *Chromolaena odorata*, *Macaranga peltata*, *Melastoma malabathricum*, *Calycopteris floribunda* etc and the pest migrates to cashew during flushing, flowering and fruiting period of cashew. But, cashew is the most preferred host for TMB during the cropping season.

Distribution of the pest

The pest is distributed in most of the cashew growing regions of our country including Kerala, Karnataka, Goa, Maharashtra, Tamil Nadu, Andhra Pradesh, Gujarat, Chhattisgarh and Orissa. The pest is severe in West coast regions compared to East coast regions. 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 *P. mesarum* are also causing similar damage to cashew in certain areas.

Nature and symptoms of damage

Both nymphs and adults suck the sap from tender leaves, shoots, panicles and immature nuts and apples by insertion of stylets which induces exudation of resinous gummy substance. Certain toxic secretions viz., proteolytic enzymes are released during feeding into cashew which 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 or burnt 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.

Seasonality of pest incidence

The build-up of the pest commences during October - November synchronizing with the emergence of new flushes, after the cessation of the South-West monsoon. In general, the activity is minimum during the monsoon period (June - September). The population reaches a peak during January, when the trees are in full bloom. However, the activity of this pest is seen upto May in cashew. In young plantations, the pest is noticed continuously with a higher intensity during January till March.

Reactions of cashew types

Though all the germplasm accessions and related varieties are potentially susceptible to this pest, a cashew variety "Bhaskara", developed at Directorate of Cashew Research, Puttur escapes TMB damage due to non-overlapping of the cropping period with that of peak pest population. This variety is a selection identified during 1982 from severely of TMB infested location, at 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 case of pest damage on first batch of panicles due to TMB, subsequently, the trees of this variety flower again ensuring the chances of good yield during the same season.

Association of TMB with disease incidence

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 matured 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 of TMB

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* cuspis Rajmohana and Srikumar (Scelionidae), *Chaetostricha* sp. (Trichogrammatidae) and *Gonatocerus* sp. nr. *bialbifuniculatus* Subba Rao. In the East coast, *Ufens* sp. is the only parasitoid observed on TMB eggs. However, the attempts to multiply these endo-parasitoids

under laboratory conditions were not successful, as these require large number of live TMB eggs alone for the development.

Around 120 species of spiders have been recorded in cashew plantations. The species like *Hyllus* sp., *Telemonia dimidiate, Oxyopes swetha*, *Phidippus* sp. and *Matidia* sp. have been observed predating on TMB. Besides, 17 species of reduviid bugs (including *Sycanus collaris* (Fab), *Sycanus galbanus*, *Sphedanolestes signatus* Dist., *Endochus inornatus* Stal., *Irantha armipes* Stal., *Panthous bimaculatus* and *Occamustypicus* Dist. have also been recorded as predators of TMB. Ants of the species *Crematogaster wroughtonii* Forel (Formicidae) and *Oecophylla smaragadina* Fabricius predate on nymphs of the pest. In addition, there are praying mantids, pentatomid bugs and other predatory insects that predate on TMB in cashew. Similarly, *Aspergillus flavus* and *A. tamarii* are reported as entomopathogens on TMB. Specific strain of *Beauveria bassiana* is also found causing mortality of TMB in certain months. However, detailed information on the effectiveness and methodology of application needs to be further developed.

Management using botanicals

A few plant products have been tested for their insecticidal activities against TMB. The aqueous emulsions of pongamia oil (3%) was found to cause high mortality of TMB up to 7 days after spraying followed by neem oil (3%). Besides, neem seed extract was also found to cause mortality of TMB but at less than 50% level. Similarly, seed extracts of *Annona reticulata* and *A. squamosa* were found to cause less than 50 % mortality of TMB, but not *Strychnos nuxvomica*. In another experiment, 5 % leaf extracts of *A. reticulata, Tephrosia vogelii* and *S. nuxvomica, Butea frondosa, Adathoda vasica* were found not effective against TMB. The commercial neem pesticides like Nimbecidine, Godrej Achook, Limanool and RD-9 Repellin at 1% were not effective in causing mortality of TMB, but have noticeable ovipositional deterrence effect similar to Pongamia oil and neem oil.

Insecticidal management

Proper surveillance for pest damage symptoms during flushing, flowering and fruiting period is very essential for the management of this pest as the pest has a short life cycle and can inflict serious damage in a few days. Whenever, the incidence of pest is noticed on 5-10 per cent of the flushes, the first round of pesticide spray should be given. The second round of the spray should be invariably completed within 2-3 week, if the TMB population still persists. If panicle damage is severe (> 50%) because of delayed insecticidal application, further sprays

will not result in improved yields. Hence, it is absolutely necessary to keep a constant surveillance of the pest especially during first month of flushing to initiate timely insecticidal intervention. The third spray can be a need based on in case pest population persists even after the second spray. Never should the same insecticide be used for spraying again for subsequent spray.

The present recommendation for chemical management of TMB is as follows:

First spray	:	λ-cyhalothrin (0.003% i.e., 0.6 ml/lit) or Imidacloprid (0.6 ml/lit), or Acetamiprid (0.5 g/lit) or Profenophos (0.05% i.e., 1.5 ml/lit) - at flushing stage
Second spray	:	λ-cyhalothrin (0.003%) or triazophos (0.05% i.e., 1 ml/lit) - at flowering stage.
Third spray (if pest persists)	:	λ-cyhalothrin (0.003%), or profenophos (0.05 5 i.e., 1.5 ml/lit) - 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 (4.0 - 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.

Spraying should be done in the early hours of the day (7 - 11 am) or in the evenings (3 - 5 pm). Spraying should be taken up immediately when initial symptoms of TMB damage are noticed. If it rains immediately after spraying, the spraying has to be repeated and entire canopy area should be sprayed. Approximately, 6-8 litres of solution is required for a tree of 15 -20 years depending upon the canopy.

Empty chemical containers 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 persons who attend to spraying of insecticide.

Recent approaches in semio-chemical pest management

Extensive trials on presence of sex pheromone system in TMB have indicated that the females release pheromones which induce quick and intense response from males in field condition. Hence, collaborative trials are in progress to characterize and synthesize the sex pheromone components for developing sex-pheromone traps which can be used to monitor and trap the insect population during the cropping season. This approach reduces the dependence on insecticides which lead to residue related issues and avoids any possibility of environmental pollution.

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Minor pests, diseases of cashew and importance of pollinators

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Introduction

Cashew, an insect pollinated tree crop is widely grown in tropical climates. It is known to be damaged by more than 300 insect pests and diseases worldwide limiting its productivity. Nearly 50 % of annual crop loss results due of pests and disease problems in different cashew growing regions if suitable control measures are not taken up timely. Among the pests, tea mosquito bug and cashew stem and root borer are the primary pests, while others are regional specific and are considered important in certain occasions. Depending on the climate, location, age and management measures of the plantation, each geographic region has its own distinctive pest complex. Documentation of pest diversity across different cashew growing regions is necessary to formulate effective management strategies. This topic presents details on minor pests of cashew, diseases and pollinators of cashew.

Minor pests of cashew

Among the insect pests damaging cashew, tea mosquito bug and stem and root borer are the major pests, while, shoot tip caterpillars, thrips, leaf miner, leaf and blossom webbers, apple and nut borers are also the important pests of cashew in certain regions. Some of these pests may be problematic in certain regions. In general, management actions taken for managing TMB could manage these pests also, but separate spraying may be required during certain periods to prevent economic loss.

(a). Shoot tip caterpillar

During active growth period, damage to shoot tips of cashew trees is caused by the shoot tip caterpillars. This pest is regularly reported from the east coast tracts.. The pale yellowish green caterpillar (*Anarsia epotias* Meyr., F: Gelechiidae) with black head webs together the tender leaves and feed within it at the early stage. Later on, they bore in to the terminal shoots and tunnel inside up to 2-3 cm. A gummy substance oozes out from the infected tips and finally the attacked shoots dry up. The egg, larval and pupal period lasts for 3-4 days, 12-16

days and 7-10 days respectively and the life cycle is completed in 25-29 days. Similarly, the tiny, yellowish to greenish-brown larvae of *Hypotima* (=*Chelaria*) *haligramma* M. (Lepidoptera: Gelechiidae) also damage shoot tips by folding the fresh leaves and feed within. Tender shoot tips are bored occasionally up to 25-35 mm, leading to drying up of shoot tips. These both larvae also damage inflorescences in the subsequent period.

(b). Leaf miner

The leaf miner, *Acrocercops syngramma* M. (Lepidoptera: Gracillaridae) is a pest of cashew during post monsoon period all over the country. Young plants are more prone to attack. Caterpillars mine and feed below the epidermal layer of the tender leaves and tender shoots causing extensive leaf blisters which later dry up causing distortion, browning and curling of the leaves. As the attacked leaf ages, the holes develop due to drying out of the damaged portion. During the developmental period they are dull white in colour and turn pinkish before pupation. After full development, larvae fall off to the soil for pupation and silvery grey adults emerge after 7-9 days. The life cycle of this pest is 20 to 25 days. Larval parasitoids *viz*., *Chelonus* sp. (Braconidae), *Sympiesis* sp. (Eulophidae), *Chrysocharis* sp. (Eulophidae) kills the miner larva up to 40 % in field conditions.

(c). Leaf thrips

Thrips are minute, fragile, slender, active insects and adults have fringed wings. Foliage thrips (Thysanoptera: Thripidae) *viz*., *Selenothrips rubrocinctus* (Giard), *Rhipiphorothrips cruentatus* Hood and *Retithrips syriacus* (Mayet) attack cashew. The adults and immature stages of thrips colonise the lower surface of leaves. The thrips destroys the cells on which it feeds causes leaf distortion, unsightly dark coloured droplets or blotches of excrement can be seen on the leaf surface. The infested leaves become pale brown and crinkled with roughening of the upper surface. Honeydew excreted from thrips gives rise to black sooty mould. In severe cases, shedding of leaves and stunting of growth results. If infestation occurs on cashew seedlings, whole seedling may dry up. *S. dorsalis* breeds on a number of annual crops and it is observed on *Calycopteris floribunda* Lamk. (Combretaceae), throughout the year which is a quite common shrub in all the cashew plantations.

(d) Leaf folder and leaf rollers

Several caterpillars fold and/or roll the tender cashew leaves emerging after post monsoon and feed within. Light yellowish larvae of *Caloptilia tiselaea* M. cause damage by folding the tender leaves terminally. Larvae of *Anigraea albomaculata* damage tender leaves by making spindle shaped folds. While larvae of *Macalla albifusa* Hamps. join the leaves one above the other by silken threads and feed on them. Larvae are very active and wriggle out when disturbed and the damaged portion dries up gradually. In few places, larvae of *Sylepta auranticollis* Fabricius during their early stages roll the tender leaves and scrape the green matter, later they defoliate the entire leaves.

(e). Leaf beetles

During South West monsoon, the red coloured chrysomelid leaf beetles, *Monolepta longitarsus* Jal. (Coleoptera: Chrysomelidae) damage cashew to certain extent. These appear abundantly especially in young trees and skeletonise the leaves which gradually dry up. Tender shoots are also attacked and shoot terminals finally dry off. When nursery seedlings are attacked the entire seedlings dry up. Tapioca, *Terminalia arjuna* (Roxb.) *paniculata* Roth (Combretaceae) are alternate hosts of this pest.

(f). Apple and nut borer

Several lepidopteran, coleopteran, dipteran and hemipteran pests damage apples and nuts of cashew during different developmental stages. Among them, *Thylocoptila paurosema* M. and *Hyalospila leuconeurella* R. (Lepidoptera: Pyralidae) are important. Dark pink larvae initially damage flowers and later bore inside the tender nuts and developing apples resulting in shrivelling and premature fall. In the developed green nuts and apples, caterpillars tunnel near the junction of apple and nut and the boreholes are plugged with frass and excreta. There are 5 larval instars lasting 15- 33 days. The fully grown larvae drop to the ground for pupation and emerge as moths. The larvae of *H. leuconeurella* bore through the apple from one end to the other end and remain inside the apple till the fruit drops and when nuts are attacked they get deformed. On *H. leuconeurella*, a chalcid, *Brachymeria* sp. and an Ichneumonid *Cremastus* sp. have been recorded as parasitoids. Besides, *Lamida moncusalis* Wlk.,*Orthaga exvinacea* Hamps.and*Euproctis* spp. occurs as external feeders on tender fruits and apples.

(g). Leaf and blossom webber

Cashew shoots bearing fresh flushes and flowers are attacked by *Lamida* (= *Macalla*) *moncusalis* Wlk. (Lepidoptera: Pyralidae) and *Orthaga exvinaceae* Hamps. (Lepidoptera: Noctuidae). Of these, *L. moncusalis* is a major pest in East Coast tracts. Symptoms of infestation are presence of webs on terminal portions, with clumped appearance, and drying of webbed shoot/ inflorescences. The caterpillar is dark green with yellow longitudinal bands and pinkish dorsal lines. The egg, larval, pre-pupal and adult stages last 4-7, 16-22, 9-15 and 3-6 days respectively. The life cycle is completed in 32- 47 days.

(h). Flower thrips

Flower thrips such as *Rhynchothrips raoensis* G., *Haplothrips ganglbaueri* (Schmutz), *H. ceylonicus* Schmutz, (Thysanoptera: Phlaeothripidae),*Thrips hawaiensis* (Morgan), *Frankliniella schultzei* (Trybom) and *Scirtothrips dorsalis* H., (Thysanoptera: Thripidae) cause premature shedding of flowers, scabs on floral branches, apples and nuts. The infestation on developing nuts results in the malformation of nuts and immature fruit drop.

(i). Mealy bug

Mealy bugs, *Ferrisia virgata*, *Planococcus lilacinus*, *Planococcus citri* and *Phenococcus solenopsis* are serious in certain cashew pockets. They are soft bodied, having milky white coating on the body. The nymphs and adults suck sap from the tender plant parts results in withering of growing shoots, inflorescence and developing fruits. It can be seen on the lower surfaces of tender leaves, twigs, inflorescence panicles and fruit peduncles. Besides causing direct damage, the bugs excrete copious amount of honey dew on which sooty mould develops which impairs normal photosynthetic activity. To manage this pest, the infested portion along with mealy bug colonies should be pruned and destroyed. Fallen leaves under the tree canopy should be collected and burnt to avoid further spread of the pest. Two parasitoids *viz*., *Aenasius advena* Campere (Encyrtidae) and *Blepyrus insularis* Cameron were recorded on *F. virgata*.

Other minor pests

Apart from these pests, there are several chrysomelid beetles (importantly *Monolepta longitarsus* Jacoby, *Neculla pollinaria* Baly), lepidopteran caterpillars (*Lymantria* sp. (Lymantridae), *Metanastria hyrtaca* Cram. (Lasiocampidae), *Euproctis* spp. (Lymantridae) defoliate cashew mostly during post monsoon flushing period. In few regions, leaf folders,

leaf rollers, aphids cause damage to tender cashew shoots. Besides, there are several minor pests damaging flower buds and flowers. Most of these pests occur at very low population level, for which, management measures are generally not required.

Management of insect pests of cashew

- Generally, the plant protection measures taken up against tea mosquito bug usually take care of the infestation of most of foliage pests, hence spraying for other pests is required only under severe infestation.
- Surveillance and regular monitoring of the pest situation is essential so as to decide on management strategies.
- Removal of weeds in cashew plantations should be taken care, as weeds like *Chromolaena odorata, Terminalia paniculata, Getonia* sp. and are not only competitors of cashew but also serve as host plants for some of the cashew pests.
- In young cashew plants, wherever possible, removal of different stages of pests like egg laden leaves or shoots, caterpillars, pupa or cocoons gradually reduces the pest population.
- Removal and destruction of mealy bug and aphid infested plant parts helps to minimize their infestation and spread. Spraying of dichlorvas 76 WSC 0.2% (@ 2.5ml / lit) or dimethoate 30 EC 0.05% (@ 1.75ml / lit) in combination with fish oil resin soap @ 20 g per litre of water reduces mealy bug incidence effectively.
- Under unsprayed conditions, an array of predators*viz*., spiders, ants, reduviids, coccinellids, neuropterans, hemipteran bugs and praying mantises take care of many of the minor pests of cashew.
- Red ants (*Oecophylla smaragdina*) are the potential biocontrol agents in cashew plantations that feed on bugs, caterpillars, hoppers, moths etc. Red ant colonized old cashew trees are generally free from pests. Trees harbouring ant nests especially red ants should be spared of spraying to allow them to take care of pests naturally.
- Botanical insecticides are good biological weapons that can be best integrated with insecticides. Neem (*Azhadirachta indica*) oil @ 3-5%, Karanj (*Pongamia pinnata*) oil @ 2%, Fish Oil Rosin Soap and neem seed kernel extract @ 1% are some of the botanical preparations effective against many of the foliage pests of cashew like leaf miners and leaf feeding caterpillars. While using botanicals, emulsifiers (soap water/ bar soap 0.5 % @ 5g/lit or teepol @ 0.1 %) should be used in the spray fluid.

- Rotation of insecticides between sprays is advised to prevent development of resistance to any particular pesticide. Spraying should be taken up before 9 am or after 4 pm in order to save cashew pollinators.

Diseases of cashew

Cashew is infected by fungal and algal diseases. Of which, damping off, anthracnose, inflorescence blight and powdery mildew are considered important in few cashew growing regions. However in general, the intensity of damage caused by the diseases is not severe compared to insect pests attacking cashew. Few important diseases, their damage symptoms and the management measures are given here under.

i. Nursery diseases

(a) Damping off

It is caused by *Pythium* spp., *Phytophthora* spp., *Fusarium* spp. and *Rhizoctonia solani*. The disease occurs in nurseries where drainage conditions are poor. Collar region of infected seedlings appear swollen with a band of blackened tissues around the stem. Affected plants turn pale and eventually topple over or rot. In severe cases, the leaves show water soaked translucent areas which enlarge and coalesce subsequently. Close spacing, continuous nursery growing, cool, wet, highly organic and neutral to basic soils favour damping off diseases. Spraying of Ceresan WP at 0.1 % or Bordeaux mixture 0.5- 1.0 % will effectively manage this disease.

(b). Seedling blight

It is caused by *Fusarium* sp., *Pythium* sp., *Phytophthora palmivora*, *Cylindrocladium scoparium*. It occurs in nurseries having ill-drained conditions. The disease is characterized by tiny yellowish spots on leaves of root stocks which gradually increase in size. The surrounding tissues turn brown and then become ash coloured, leaf tips dry up consequently. Leaves turn yellow, wither and drop. Collar region becomes fibrous and roots discolour decayed or shred off. Ultimately, the seedlings wilt and dry up.

Spraying of Bavistin @ 500 ppm (a.i.) just before the onset of monsoon as a prophylactic measure inhibits the growth of the pathogen. Soil drenching with copper oxychloride (0.3 %) @ 3g/lit or Bordeaux mixture 1 per cent or Mancozeb (0.3 %) are effective in controlling this disease.

(c). Foot rot

This disease is caused by *Phytophthora palmivora* resulting in yellowing of leaves, rotting of roots, discoloration in collar region, wilting and finally mortality of plants. Application of Trichoderma, drenching as well as spraying of copper oxy chloride @ (COC) 3.0 g/ lit or Ridomil MZ @ 3 g/ lit or Potassium phosphonate (Akomin) @ 3 ml/ lit has shown good control over this disease.

ii. Diseases of cashew plantations

(a). Anthracnose

The young plantations of cashew are vulnerable to attack of TMB serving as predisposing factor for the entry of the fungus *viz.*, *Botryodiplodia theobromae* and *Colletotrichum gleosporioides* causing dieback. The fungus infects young shoots, tender leaves, panicles, tender nuts and young apples. Affected leaves become crinkled, dry up and fall off.Affected twigs show elongated dark brown to black lesions which ultimately dry up. In inflorescence, small dark spots are formed on main stalk and lateral branches of the panicle. These flowers eventually wither and drop off. The nuts show black necrotic spots, while the apples turn black and mummified. Mature fruits develop black irregular or roundish spots and stains that are often sunken and gradually start rotting. Effective control can be obtained by spraying Bordeaux mixture 1 per cent or Mancozeb 0.2 per cent or Copper oxychloride 0.3 per cent after removal of infected portions. Spraying of 0.2 % Dithane M-45 also minimizes this disease. Combined application of insecticide and fungicide is effective and economical.

(b). Gummosis

This disease is caused by *Ceratocystis* sp., *Pellicularia salmonicolor* and *Diplodia natalensis*. The disease is characterized by exudation of a reddish brown liquid from the main stem and branches, which later turn black. Longitudinal cracks also appear on the affected region from which gum exudes. The inner tissues of the affected portions turns reddish brown having small cavities filled with reddish fluid and the affected branches dry gradually. Chiselling out the affected part and application of Bordeaux paste (10 %) or swabbing the cut portion with Copper oxy chloride helps in controlling this disease.

(c). Inflorescence blight

This is a common disease during monsoon caused by *Colletotrichum gleosporioides* and *Phomopsis anacardii* in association with TMB. The disease is characterised by drying up of floral branches. Reddish- brown, shiny, minute water soaked lesions develop on the main and secondary rachis. The lesions turn pinkish brown, enlarge and soon turn scabby. Gummy exudation can be seen on the affected regions. The adjoining lesions coalesce resulting in drying- up of inflorescences with a scorched appearance. The nuts and apples of the affected inflorescences show rotting and shrinking. During cloudy weather, incidence of this disease is aggravated.Combined application of Copper oxychloride 0.2 per cent and any insecticide that control TMB such as lambda-cyhalothrin 0.003 % is recommended.

(d). Pink disease/ die-back

Pink disease is of minor importance caused by *Pellicularia salmonicolor*. It is prevalent during rainy season especially south- west monsoon. Affected branches initially show white patches on the bark and a film of silky thread of mycelium develops on the branches. Later, the fungus penetrates into deeper tissues and interferes with transport of nutrients. As a result, the shoots and branches wilt and dry up from the tip downward and hence called as die- back. Later the fungus develops a pinkish growth which represents the spore mass. In advanced stages, the bark splits and peel off, while, the leaves turn yellow and fall off. Control measures of this disease include, pruning of the affected branches or shoots below the spot of infection and destroying them, protecting the cut surfaces with the application of Bordeaux paste (10 %) and giving prophylactic sprays of Bordeaux mixture (1 %) or any other copper fungicide during October-November.

(e). Powdery mildew

Powdery mildew is caused by *Oidumanacardii*. A floury, whitish film formed of mycelial hypha and conidiospores of the fungus develops on affected tender foliage, inflorescence and young nuts. Initially, leaves show discolouration, later extensive irregular dark patches appear. When heavily affected, old leaves curl and dry prematurely, while young ones remain undeveloped and misshapen, besides flower buds and flowers wither and fruits fall prematurely. The disease usually appears during December- January. To control this disease, spraying twice with Wettable sulphur @ 0.2 per cent at pre- bloom and full-bloom is

recommended. Spraying with Carbendazim @ 1 g /litre is also also effective in checking the disease.

(f) Sooty Mould

This disease is caused by the fungus, *Capnodium* spp. Black fungal growth appears on the leaf lamina as a coating and the affected leaves dry up. Infestation is common with the incidence of sucking pests like aphids and mealy bugs on leaves, shoots and panicles. Spraying of fish oil rosin soap 1.5 kg/ 100 litre of water followed by 1 % Bordeaux mixture or 2 % starch controls the associated insects as well as the disease.

Importance of Pollinators in Cashew

Fruit set in cashew is mainly influenced by the activity of pollinators. In cashew, inflorescences develop on current season lateral shoots. Each inflorescence has both staminate (male) and hermaphrodite flowers (bisexual) in it. Pollen grains are sticky in nature, thus wind pollination is difficult and because of position of style in the hermaphrodite flowers, self pollination is very difficult.

In general, cashew flowers are visited by diverse group of insects like ants, thrips, butterflies, flies, wasps and bees. Insect visitors documented on cashew flowers at ICAR-DCR include 40 species belonging to 13 families of three insect orders. Many of the dipterans are just visitors of cashew flowers, and not pollinators. Similarly, wasps like sphecids and vespids move among cashew flowers frequently which might be for nectar as well as prey insects. Similarly, several ant species move over the cashew inflorescence throughout the day period in abundance, but the major need is for EFN at the base of flowers and buds as well as the honey dew from certain sucking pests attacking cashew inflorescences.

Based on the abundance and foraging activity, eight bee species are considered as main pollinators of cashew, *viz.A. c. indica, A. florea, Braunsapis picitarsus, Ceratina hieroglyphica, Tetragonula* sp., *Lasioglossum* sp., *Pseudapis oxybeloides* and *Seledonia* sp. Most species of bees visited the flowers simultaneously, and activities of *A. c. indica, A. florea* and *Tetragonula* sp. are noticed throughout the observation period. Peak foraging period of pollinators coincides with peak anthesis of hermaphrodite flowers and high pollen build-up in male flowers, which is very much advantageous for effective pollination in cashew. Since pollen was the foraging reward for most of the bee species, fresh male flowers were mostly preferred. Most bees collected pollen followed by nectar in the same male

flower or nectar followed by pollen. Nevertheless, it is observed that the same hermaphrodite flower was visited by multiple bee species consequently, thus effecting pollination.

Pollinator exclusion studies by bagging experiments indicated that bees are efficient pollinators of cashew increasing fruit set. Thus, sufficient pollinator population is required to realize good yield of cashew, as hermaphrodite flowers need to be pollinated within 4 hours of peak stigma receptivity. Encouraging bees especially the native bees by their conservation and identifying cashew genotypes with high pollinator attraction are important to enhance the productivity of cashew.

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Cashew Nut Processing

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Introduction

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 throughout 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.

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Cashew apple processing

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Introduction

The cashew apple was given priority over cashew kernel during the initial introduction era due to its wider and attractive spectrum and ready consumption. Cashew apple is a reservoir of minerals and vitamins especially vitamin C and polysaccharides, protein and fibre and hence acts as the best thirst quencher and instant energy supplier to the exhausted travelers. But there are certain limitations such as poor shelf life, susceptible to microbial infection and tannin content which hinders the extensive utility and commercialization of cashew apple and their products. Hence despite of processing, cashew apple is left over as a plantation waste along with other recyclable cashew biomass to improve the physio-chemical and biological properties of the soil. Though the leftover cashew apples improves the soil physico-chemical and biological properties, the *in-situ* decomposition emits unpleasant odour in the plantation and hence, proper disposal or value addition of cashew apple is essential. This paper provides the details on proper utilization, industrial and homestead valorization of cashew apple.

Botany of Cashew apple

Cashew belongs to the family *Anacardiaceae* having drupe fruit type. Cashew apple is actually a swollen fruit stalk derived from a tissue called thalamus or receptacle hence considered as *false fruit* and the distinct layers like exocarp, meso and endocarp are absent in cashew apple. The development and maturity of cashew apple are coherent with the nut maturation. The cashew apple can reach up to an average length × breadth of 11 × 5 cm which is 8 to 10 times more than that of respective nut size. The matured cashew apples are spherical or cylindrical or pyriform in shape. During maturation and ripening, the firm, fragile and green, immature cashew apples are turned to soft and juicy with the different colours (red, orange and yellow) depending on the varieties (Berry and Sargent, 2011).

Cashew apple valorization

Non-alcoholic beverages

Cashew apple juice

Freshly harvested cashew apples are washed in running water and ensured to be free from soil debris or microbial spoilage. The juice extraction can be achieved through basket press, screw press or hydraulic press. Poly Vinyl Pyrollidone is added at the rate of 10 g or defatted soy-meal 180-200 g per 8 to 10 lit of cashew juice and passed through muslin cloth for clarification. After 20 to 40 min the clear supernatant is added with sugar at the rate of 0.5 kg per litre of juice and preservatives such as sodium benzoate and citric acid 6 g each (Sobhana *et al.,* 2011).

Cashew apple squash

The procedure for preparation of juice and squash is similar. But the consistency of squash can be achieved by adding more sugar and citric acid. Freshly harvested cashew apples are washed in running water and ensured to be free from soil debris or microbial spoilage. The juice extraction can be achieved through basket press, screw press or hydraulic press. Poly Vinyl Pyrollidone is added at the rate of 10 g per 8 to 10 lit of cashew juice and passed through muslin cloth for clarification. After 20 to 40 min the clear supernatant is added with sugar at the rate of 3 kg per litre of juice and preservatives *viz.,* 6 g of sodium benzoate and 100 g of citric acid. The squash can be diluted with three times of water and serve (Sobhana *et al.,* 2011).

Cashew apple syrup

The clarified cashew apple juice is added with 2 kg of sugar per 1 lit of juice and kept under moderate heat. The mixture is frequently stirred till the sugar completely dissolves. Dissolve 15 g of citric acid in a small quantity of the above syrup. Add this to the large quantity with continuous stirring. The syrup can be diluted with five times of water and serve (Sobhana *et al.,* 2011).

Ready to serve beverage (RTS)

The required amount of water with sugar (200 g sugar / 1 L water) and citric acid (5g) are boiled with continuous stirring. Amount of 200 ml clarified cashew apple juice and 100 ml of

any fruit juice are added after switching off the flame. The content is cooled and packed in aseptic condition (Sobhana *et al.,* 2011).

Cashew apple sauce

Cashew apple sauce is an important byproduct made out of well ripe less firm cashew apples. The cashew apple pulp has removed for lumps and added with ingredients such as onion powder, garlic powder, red chili powder, salt and vinegar. The ingredients are mixed thoroughly with cashew pulp and cooked till it reached sauce consistency. The consistency can be confirmed with drop test method.

Alcoholic beverages

Cashew apple feni

The cashew apple feni is prepared through fermentation and distillation process. Matured and ripened cashew apples are collected, juice extracted, fermented and subjected to the distillation process. By distillation method, the concentration of alcohol can be adjusted to the required level. Cashew feni has been awarded the Geographical Indication registration in 2009 as a special alcoholic beverage from Goa. The hydrocarbons, volatile and mineral constituents of cashew feni are ethanol (42.85%), acetic acid (12.28%), ethyl acetate (55.97%), acetaldehyde (18.28%), furfural (3.22%) and copper (1.04%) (Sobhana *et al.,* 2011).

Cashew apple wine

The required quantity of cashew apples is cleaned in running water for removal of debris and immersed in 5% salt solution for 2-3 days for tannin reduction. The apples are then exposed to steam of 15 lb for 15 min. This can be done using a pressure cooker or autoclave. The steamed apples are crushed using squeezer or grinder to collect juice and filtered through muslin cloth. The preservative sodium metabisulfite is added at 1g/litre juice to arrest the microbial growth. Sugar @ l kg and tartaric acid @ 6g are added to the juice with continuous stirring till it reaches 17°Brix. The bacterial culture *Saccharomyces cerevisiae var. bayanus* is added to the prepared mixture at the rate of 2% (v/v) and the fermentation process is to be carried out at room temperature (28±3°C) for 6 days. The TSS of final product stage is 2–3°Brix (Sobhana *et al.,* 2011).

Cashew apple vinegar

Cashew apple vinegar preparation consists of two stages a) alcoholic fermentation, b) acidic fermentation. Yeast @ 2.0 g in 20 ml coconut water is added and kept for 12 hours to make starter solution. To clarify the cashew apple juice, cooked and cooled sago gruel @ 5g is added along with starter solution into 1 lit of extracted unclarified cashew apple juice. This solution is kept for twelve days for alcoholic fermentation in narrow-mouthed plastic bottles, with cotton plugging. After twelve days, the fermented supernatant juice is separated through filtration (to obtain alcoholic ferment) into a wide mouth glass container or clay pot and added with thrice the quantity of mother vinegar for acidic fermentation. This container is kept tied with a muslin cloth, allowing air passage, for 15 days. The clear juice portion is filtered to a clean stainless steel vessel and pasteurized by keeping in boiling water for 10 minutes, cooled and bottled on the 16th day to get vinegar with 5 to 6% acidity. For continuous vinegar production, the filtrate can be used as mother vinegar (Sobhana *et al.*, 2011).

Osmo-dehydrated products

Cashew apple sweet candy

Whole cashew apples or cashew apple slices are soaked overnight (10-14 hr) in sucrose solution of concentrations ranging from 50-70°Brix, enriched with 2%. Calcium chloride and 0.6% potassium metabisulphate (KMS) at ambient conditions. The apple slices in solution should be frequently turned upside down manually or through agitator to ensure complete immerse, which will otherwise lead to microbial infection. The sugar solution concentration can be maintained at 60°Brix for 3-4 days. The cashew apple slices are separated from sugar solution and spread over a clean dry stainless steel tray for air drying. Dehydration using cabinet dryer at 50°C for 3-4 hr is advisable for rapid dehydration process. When whole apples are used, slits on four sides can be made using bamboo splints to encourage osmosis.

Cashew apple spice candy

Whole cashew apples or cashew apple slices are soaked overnight (10-14 hr) in salt mixed with turmeric powder, chilli powder, pepper powder, 2% calcium chloride and 0.6% potassium metabisulphate (KMS) at ambient conditions. The apple slices in solution should be frequently turned upside down manually or through agitator to ensure complete coating of spice mixture, which will otherwise lead to microbial infection. The slices should be retained in spice mixture for at least 2 days. The cashew apple slices are spread over a clean dry

stainless steel tray for air drying. Dehydration using cabinet dryer at 50°C for 3-4 hr is advisable for rapid dehydration process. Cashew apples slices are more preferred for this method than whole apple processing.

Cashew apple chew

Well ripened firm and freshly harvested cashew apples were washed and air dried for 5 to 10 min. cashew apples (500 g) are cut into cubes of desirable size and mixed thoroughly with spice mixture made of Cumin, Clove, Cardomom, cinnamon and sugar (optional). The mixture was spread as single layer over a clean dry stainless steel tray for dehydration under 28-30°C for 3-4 days for moisture removal. Frequent stirring or turning of sliced cashew apples is essential to avoid microbial infection. The sweet spice mixture acts as an osmolyte and the released aqueous solution from cashew apple are again impregnated into spice coated cashew slice to increase the retention of vitamin-C. This can be taken as such like a mouth freshener or along with betel leaves (Preethi and Shamsudheen, 2019).

Cashew apple fig

Whole fresh and firm uniform sized cashew apples are selected and washed with running water. The apple base and distal end are removed by chopping and soaked in sugar solution of concentrations ranging from 50-70°Brix and 0.6% potassium metabisulphate (KMS) as preservative. If whole apple is used, gentle slits are made on four sides of cashew apple using bamboo splint or stainless steel knife to encourage osmosis. The sugar solution concentration should be maintained at 60°Brix for at least 3-4 days. The apple slices in solution should be frequently stirred to ensure complete immersion, to avoid microbial infestation. After 3-4 days, the sugar solution is drained off and the separated cashew apples are dehydrated using cabinet dryer at 40-45°C temperature for 7-8 hr (Preethi and Shamsudheen, 2019).

Cashew apple crisp

Cashew apple crisp is an important extruded product prepared out of cashew apple pomace powder. The methodology for preparation of cashew apple pomace powder has been standardized by ICAR-DCR, Puttur. By converting the perishable cashew apple pomace to powder form is helpful to store the raw material for diversified uses during off season. Corn flour (CF) and rice flour (RF) are the major ingredients in extruded product preparation. These ingredients are predominantly poor in minerals, proteins and fibre. Hence, to enrich the product with bio minerals, protein and fibre, cashew apple pomace powder (CAPP) was

added as one of the ingredient along with commercially available corn flour and rice flour. The optimised quantity of cashew apple pomace powder ranged from 5-25% for successful exit of extruded products (Preethi and Shamsudheen, 2019).

Biochemical characters of wet cashew apple products developed at ICAR-DCR, Puttur

The directorate has developed four self-stable cashew apple based products namely Cashew RTS, Cider, Jam and Jelly.

CashLime

Cash lime is a cashew apple and lemon juice blend RTS/Nectar prepared using cashew apple pulp. The nutrient rich drink can be stored under refrigerated conditions for maximum of five months with maximum retention of nutrients and biochemical quality parameters (TSS- 10.5°Brix, vitamin C - 72 mg/100 ml, Tannins - 76 mg/100 ml, Total Phenols - 58 mg/100 ml, CUPRAC Assay - 186 mg/100 ml and FRAP Assay - 123 mg/100 ml) compared to fresh one (TSS- 12°Brix, vitamin C - 86 mg/100 ml, Tannins - 76 mg/100 ml, Total Phenols - 72 mg/100 ml, CUPRAC Assay - 242 mg/100 ml and FRAP Assay - 169 mg/100 ml) whereas the samples stored at room temperature began to lose its quality after two months of storage.

Cashew Apple Cider

Cashew apple cider was analyzed for its functional nutrient value and shelf life. The product was stored at refrigeration temperature and room temperature as well. Based on biochemical behavior of the products at both the storage conditions, it was observed that the product stored at refrigeration temperature could retain maximum of its nutrients till completion of 24 months (vitamin C - 109 mg/100 ml, Total Phenols - 137 mg/100 ml, CUPRAC Assay – 84 mg/100 ml and FRAP Assay - 246 mg/100 ml) compared to fresh one (vitamin C - 220 mg/100 ml, Total Phenols - 205 mg/100 ml, CUPRAC Assay - 98 mg/100 ml and FRAP Assay - 452 mg/100 ml) whereas the samples stored at room temperature were found stable with maximum nutrient retention up to 12 months of storage without any detrimental change in sensory quality of the product.

Cashew Apple jam

Jam being a self-stable processed product due to its high TSS content (68°Brix) could retain maximum of its nutrients (vitamin C - 83 mg/ 100 ml, Tannins 103 mg/100 ml, Total Phenols -119 mg/100 ml, CUPRAC Assay 372 mg/100 ml and FRAP Assay 169 mg/100 ml) even

after five months of storage at room temperature compared to fresh preparation (TSS-68^{o}Brix, vitamin C - 121mg/100 ml, Tannins - 112 mg/100 ml, Total Phenols - 134 mg/100 ml, CUPRAC Assay - 403 mg/100 ml and FRAP Assay - 200 mg/100 ml).

Cashew Apple Jelly

The trend of nutrient retention of jelly was found similar to that of jam. Jelly was also stored at room temperature and was observed for change in its nutrient content during storage. Jelly also being a self-stable processed product like jam. Due to its high TSS content (65.5°Brix) it could retain maximum of its nutrients (vitamin C - 91mg/100 ml, Tannins - 90 mg/100 ml, Total Phenols - 107 mg/100 ml, CUPRAC Assay - 282 mg/100 ml and FRAP Assay - 122 mg/100 ml) even after five months of storage at room temperature compared to fresh preparation (vitamin C - 142mg/100 ml, Tannins - 93 mg/100 ml, Total Phenols - 117 mg/100 ml, CUPRAC Assay - 316 mg/100 ml and FRAP Assay - 152 mg/ 100 ml).

Limitations of cashew apple utility in product development

Pre-harvest factors

Pest infestation

The pest and disease of cashew apple have received attention in the recent past, after the realization of its commercial importance for value addition and processing. There are a few pests that infest either cashew apple or cashew nut or both such as cashew apple and nut borer (CANB), thrips and fruit flies. The female adults of CANB lay eggs on the cavity space at apple and nut junction at tender stage and later bore and feed the tender apple and nut resulting in its premature fall. In general, one borer in apple and three to four borers in nut was observed. In both apple and nut, CANB was located near to the junction and not at the distal end of apple cavity. **Thrips:** Thrips rasp the wax layer of cashew apple and suck the sap causing net like cork over the apple body. Sometimes, the cracks over the corky surface cause secondary infestation by fruit flies and microbes (Maruthadurai *et al.*, 2012).

Cashew apple cracking

The etiology for cashew apple cracking is ambiguous. The reports say that cashew apple cracking is varietal specific (eg. NRC selection - 2) and inherited to progenies when this is used as one of the parents in breeding programmes. Few reports say that cashew apple oriented towards southern and western sides are more prone to cracking (70% to 80%) than the northern and eastern side. The incidence was less noticed in the apples borne in inner

branches, whereas the apples in the upper branches exposed to sunlight are prone to apple cracking. The micro or macronutrients may also have a marked effect on cracking (Preethi *et al.*, 2019).

Cashew apple and nut drying

The etiology for cashew apple and nut drying is unknown. Genetic inheritance or nutrient deficiency/toxicity or disease infection may be the reason for cashew apple and nut drying.

Microbial infection

The delicate nature of skin facilitates the entry of pathogens.

Post-harvest factors

Physiology of cashew apple

Though cashew apple follows non-climacteric respiration pattern, high respiration rate (62 to 72 ml kg^{-1} hr^{-1}) and steady increase in ethylene expression rate was observed (200 to 400 ml kg^{-1} hr^{-1}). Drastic reduction in ethylene release rate and emission of volatile compounds at the post-harvest stage is unique to cashew apple. A sudden increase in abscisic acid at pedicel and all over the cashew apple at the later phase of development tends to reduce the retention capacity and firmness.

Post-harvest spoilage

Due to delicate nature of skin, cashew apples are prone to quick pre and postharvest attack of fruit flies which facilitates the entry of fungal inoculums such as *Rhizopus*, *Aspergillus* and *Colletotrichum*. To avoid the pathogen entry and to disinfect apple surface, quick dip with 0.25% citric acid or 0.3% ascorbic acid or 0.1% sorbic acid is recommended before fresh consumption or product development.

Tannin content

Tannins are referred to as an anti-nutritional factor that interfere with the assimilation of proteins in the body, resulting in non-availability of nutrients. The acrid feeling while consuming fresh cashew apple or cashew apple juice is owing to the presence of tannins (35%). Hence, tannin reduction and de-tanning is an important step prior to going for any product out of cashew apple.

De-tannification using bio-products

Bio-products available in nature are the cheapest and safest source of detannification. Cassava starch is readily available and effectively reduces tannin at the rate of 39.8%, but requires more than 8 hr for clarification which leads to fermentation (Jayalekshmy and John, 2006). Hence, refrigeration with clarification is recommended in this method to avoid fermentation. Rice gruel is a rapid (20 to 40 min) and effective clarifying agent but the quantity of gruel to be added at the rate of 1:2 (Juice: Gruel) leads to dilution of fruit juice and alter the taste. Some recently identified de-tanning agents such as defatted soybean meal, dried potato starch and bajra starch (rich in starch and iron) were tested for their efficiency in tannin reduction at ICAR-Directorate of Cashew Research, Puttur and found to be more efficient to reduce tannin at the rate of 34.3%, 28.6% and 24.0%, respectively.

De-tannification using chemicals

Poly vinyl pyrolidone (PVP) is one of the most effective chemicals that precipitates tannin in cashew apple juice (34 to 35%). But PVP is very expensive and not readily available in the market. Gelatin powder is the most common and readily available de-tanning agent (35 to 36%). It works well even within the range of 3 to 10g for one litre of cashew apple juice. Enzymes like tannase can also be used as best tannin precipitant but its sourcing and affordability is a dispute.

Steaming and blanching

These are the integral operations in processing for the inactivation of enzymes and sterilization of apple surface. Steaming of cashew apples (0.4 N/m^2) for 5 to 15 min or boiling in salt water (40 to 50°C) for 15 min reduces the tannin content in cashew apples.

Microfiltration

This method is also in practice but requires tedious pre-treatments like the use of clarifying agents prior to filtration and is expensive as well.

Conclusion

Cashew apple and their products have a potential market in the domestic and international forum. Though there are some limitations, certain physical and chemical processing steps are to be followed to bring out quality and palatable cashew apple products with significant nutritive properties.

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Intellectual property (IP) management in ICAR system and ICAR – DCR technologies available for commercialization

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Cashew (*Anacardium occidentale* L.) is a tree nut crop introduced from Brazil to India by the Portuguese in the 16th Century. Over the years, cashew became a crop with high economic value and is earning considerable foreign exchange for the country as a result of systematic cultivation and research. National Research Centre on Cashew (NRCC) was established in the year 1986 to carryout research on cashew crop improvement, production, protection and processing. NRCC was upgraded into Directorate of Cashew Research (DCR) in 2009. As result of a number research projects carried out over the years the institute has come up with number of technologies such as cashew varieties/hybrids, processing machineries, crop production and protection techniques and cashew apple based products.

ICAR-DCR is now transferring the technologies which are suitable for commercialization to private enterprisers and startups so that the benefits of these technologies reach the consumers and also motivates inventors through recognition for their invention. Thus it promotes right balance between interest of inventors and wider public interest and also fosters public private relation. Among the technologies, H-130 high yielding bold nut cashew hybrid which helps to increase productivity of cashewnuts. Cashew apple based technologies enable utilization of crop produce (which otherwise goes waste) will give additional income to the farmers and cashewnut processing related technologies will strengthen the processing industry. Thus these technologies are beneficial to cashew farmers, rural women and youth and cashew industry.

Intellectual Property &Technology Management (IP&TM)

Intellectual Property rights (IPRs) have become an integral part of research management in R&D institutions. Keeping it in mind, ICAR has institutionalized a three-tier IP management mechanism and framed guidelines for management IPs and commercialization of technologies developed by the research institutes of ICAR. The Intellectual Property and

Technology Management (IP&TM) Unit is at the helm of the three tier system which manages all the matters related to intellectual properties and technology commercialization. Every institute of ICAR is empowered to take up license contracts or commercial agreements with potential clients for the commercial transfer of its technologies. To meet this objective each institute is institutionalized with an Institute Technology Management Unit (ITMU) unit which acts as a facilitating and supporting unit, further to support the ITMU in recognition of technologies for commercialization and IP management, ITMC is constituted at each institute. Between the IPTM and ITMU, a middle-tier Zonal Technology Management (ZTM) unit consisting of 10 subject specific ITMU units is instituted to support the ITMU units under it in the matters related to the IP management and technology commercialization. At ICAR-DCR, ITMU shoulders the responsibility of commercialization of technologies developed by ICAR-DCR, Puttur.

Objectives of Institute Technology Management Unit (ITMU)

- To identify the commercialize-able technologies developed in the institute
- To manage the IP portfolios of the institute: Patenting of technologies, Copyright, Trademark and varietal registration etc.

Technology recognition and commercialization process

Step 1: Research project (IRC/RAC): The scientists working on different aspects of cashew production and processing at ICAR-DCR, Puttur develop the technologies through research projects, and the results of these are presented in the Research advisory committee (RAC) and Institute research Council (IRC) of the Institute. The technologies suitable for commercialization are identified by the ITMU and Inventor is asked submit the Technology Disclosure form (TDF).

Step 2: Technology Disclosure form (TDF): Inventor gives detailed information about technology including, protocol, cost of the technology, suitability of patenting, business plan etc.

Step 3: Assessment and recognition (ITMU/ITMC): ITMU does the prior art search about the technology details for duplication or availability of similar products and potential market etc. After the prior art search, the TDF is put before the ITMC for assessment and recognition of technology. If the technology is found suitable for

commercialization the ITMC recognizes the technology for commercialization or return the TDF if further improvements are required or rejected if it cannot be commercialized.

Step 4: Identifying potential licensees and Licensing: ITMC and inventors decide about the licensing process. The ITMU unit identifies and invites the potential licensees and showcases the technologies with the help of the inventors. Upon acceptance of technologies by the potential licensees a Memorandum of Understanding (MoU) is signed between the licensee and Institute.

Step 5. Licensing: After MoU Licensing process continues and license terminates after a specified time and the technology can be relicensed for another term.

Types of Licensing:

1. Exclusive licensing: License is given to only one individual or firm.
2. Non-exclusive licensing: License is given to more than one firm.

Duration of licensing: 3-10 years depending on the nature of the technologies

Licensing mainly involves

1. Plant material- Provide grafts for establishing mother blocks in the nurseries.
2. Food products- Provide the detailed protocol and demonstration of technology.
3. Machineries- Provide the engineering drawings and demonstrate working of the machine.

Technologies developed by ICAR-Directorate of Cashew Research (DCR)

Currently, 12 technologies developed by scientists of ICAR-DCR have been recognized for commercialization which can be classified into the following three main categories.

a. Cashew planting material: high yielding varieties and hybrids
b. Cashew apple based products
c. Processing machineries: Small scale /cottage processing machineries

A. Cashew Variety/Hybrid

1. H-130: a new jumbo Cashewnut hybrid

- H-130 is a new high yielding, bold nut cashew hybrid developed and released from ICAR-Directorate of Cashew Research, Puttur.
- It is highly precocious and cluster bearing type.
- This cashew hybrid has both bold nut and cluster bearing character.
- The tree bears bold nuts (10-14 g) and big size yellow colour apples (75-120 g). The shelling percentage is 29.5 and kernel grade is W180.
- Responds well to the pruning, can be used in High Density Planting (HDP).

Tenure of License: Ten years from the day of signing licensing agreement

Potential licensees: Nursery owners and people interested in starting Cashew nursery.

B. Cashew Apple Based Products

Cashew apple a juicy fruit, can be an additional profit earning source for cashew farmers but due to lack of suitable technologies in handling cashew apple during harvest and post-harvest management about 8-10 Tons of cashew apple per hectare goes waste without utilization. These cashew apples are rich source of vitamin C which has an anti-scurvy effect and also possess anti-bacterial properties. It has also been proven to be effective in treating stomach ulcers and gastritis.

In spite of having high nutritional value, neither the fresh cashew apples nor the juice is consumed due to astringency. ICAR-Directorate of Cashew Research has developed several cashew apple technologies which are free from astringency and helpful to get additional income to cashew farmers and create employment opportunities in cashewnut growing areas of the country.

Tenure of License: Three years from the day of signing licensing agreement

Potential licensees: Self-help groups (women), rural youths, small scale food processing industries etc.

2. Cashew apple RTS (Cashlime): Unfermented beverage

Cashlime is a cashew apple and lemon juice blend RTS/Nectar prepared using cashew apple juice. The nutrient rich drink can be stored under refrigerated conditions for five months with retention of nutrients and biochemical quality parameter.

Tenure of License: Three years from the day of signing licensing agreement

Potential licensees: Self-help groups (women), rural youths, small scale food processing industries etc.

3. Cashew apple cider: Fermented beverage

Cashew apple cider is a fermented beverage with alcohol content of 3.5-6.0%. Traditional cashew apple fermented beverage i.e. Feni has alcohol content of 42% which may have adverse effect on health. Whereas mild alcohol containing cashew apple cider can have beneficial effects.

Tenure of License: Three years from the day of signing licensing agreement

Potential licensees: Self-help groups (women), rural youths, small scale food processing industries etc.

4. Cashew apple Jam

Cashew apple jam is an antioxidant rich functional food. ICAR-Directorate of Cashew Research has standardized protocol for astringency free cashew apple jam, which could be stored for 6 months at room temperature.

Tenure of License: Three years from the day of signing licensing agreement

Potential licensees: Self-help groups (women), rural youths, small scale food processing industries etc.

5. Cashew apple Jelly

Cashew apple jelly is an attractive semisolid product of cashew apple juice and sugar. Jelly making is a good way to preserve fruit flavors throughout the year which is enjoyed by all. It is also an easy-to-prepare product without much special equipment.


Potential licensees: Self-help groups (women), rural youths, small scale food processing industries etc.

6. Cashew apple crisp

Cashew apple crisp is an important extruded product prepared out of cashew apple pomace powder. This is similar to crispy snacks available in the market but enriched with natural fibers, proteins and biominerals which are beneficial to the human health. The methodology for preparation of cashew apple pomace powder has been standardized by ICAR-DCR, Puttur. Converting the perishable cashew apple pomace to powder form helps in storing the raw material for diversified uses during off season.

Tenure of License: Three years from the day of signing licensing agreement

Potential licensees: Snacks industries, Self-help groups (women), rural youths, small scale food processing industries etc.

C. Cashewnut Processing Machineries

ICAR-Directorate of Cashew Research has developed several cashewnut processing machinery technologies suitable for small scale processing. Two of these technologies are patent protected. In these machineries emphasis is given on improving efficiency and quality of cashewnut and cashew apple processing.

Tenure of License: Five years from the day of signing licensing agreement

Potential licensees: Machine manufacturing units

7. Dual mode dryer for raw cashewnuts

Raw cashewnuts are normally dried under the sun light after harvest to reduce the moisture content to 8% which is safe for storage. Early onset of monsoon in Southern states and coincidence of rains and cashewnut harvest in North-Eastern hills of India will affect the quality of the raw cashewnuts, thus fetching a low price in the market,

Therefore it was envisaged to develop a dual mode dryer for raw cashewnuts which can be operated by either electricity or biomass such as cashew shell cake (CSC), wood etc. Time required to reduce its moisture level from initial moisture content of about 20 % to safer level of 8 % is about of 3-5 h. This dryer can also be used for drying of any farm commodities such as Spices, Arecanut etc.

Tenure of License: Five years from the day of signing licensing agreement

Potential licensees: Machine manufacturing units

8. Rotating drum roasting machine for raw cashewnuts

(Patent no.3483/CHE/2013)

Kernels obtained by drum roasting mode of processing gives a unique taste and flavour which is preferred over the steam boiled processed kernels. Traditional drum roasting of raw cashewnuts is being followed in certain parts of Andhra Pradesh, Tamil Nadu, Kerala and North Eastern states. However, these traditional methods are labour oriented where continuous attention of labour is needed for feeding the nuts, rotating the drum, regulating the fire below the drum and to remove the roasted cashewnuts from drum. These activities are performed automatically by rotating drum roasting machine, which reduces cost of processing.

Another important feature of this machine is that the chimney is designed to reduce the release of smoke generated during roasting process. Thus it can reduces environmental pollution. This technology is suitable for hygienic and scientific drum roasting of raw cashewnuts.

Tenure of License: Five years from the day of signing licensing agreement

Potential licensees: Machine manufacturing units

9. Concentric drum type rotary sieve grader for raw cashewnuts

In the raw cashewnut processing, the cashewnuts are graded based on size before processing because it increases the efficiency of shelling, peeling and grading processes. It can overcome problem of labour scarcity. Four different sizes of nuts can be segregated using this ICAR-DCR developed machine. This technology is suitable for medium to large scale cashewnut processing units.

Tenure of License: Five years from the day of signing licensing agreement

Potential licensees: Machine manufacturing units

10. Hydraulic type cashew apple juice extractor

Extraction of juice is essential in the cashew apple based beverage preparation such as RTS and Cider. Therefore to extract clear juice from cashew apple, a hydraulic juice extractor was developed with this juice extractor about 80-85% of juice can be extracted in the first pass and about 60-65 % of the residual juice in the second pass can be extracted. This technology is suitable for cashew apple processing units.

Tenure of License: Five years from the day of signing licensing agreement.

Potential licensees: Machine manufacturing units

11. Updraft gasifier for cashew shell cake

Cashew shell cake (CSC) is a byproduct of cashewnut processing industry. Currently, large quantity of Cashew shell cake is utilized for energy generation by burning which cause extensive pollution due to inefficient combustion. The gasification of biomass such as cashew shell cake into fuel can enhances its potential as a energy resource. A cashew shell cake based updraft gasifier was developed which produces 10-12kW thermal energy. This is a bioenergy technology which can be used in all thermal applications *viz.* cooking purpose in home and hotels, cashew processing and other industrial applications.

Tenure of License: Five years from the day of signing licensing agreement

Potential licensees: Machine manufacturing units

Radial Arm type Cashew Kernel Extracting Machine (Patent no.272371)

In this kernel extractor, single operation enables splitting of steam boiled cashewnuts. This machine is operated in sitting posture, which reduces strain faced by laborer during shelling of raw cashewnut. This increases work efficiency and also production rate is improved with this shelling unit. This technology is suitable for small scale cashewnut processing units.

Tenure of License: Five years from the day of signing licensing agreement.

Potential licensees: Machine manufacturing units

Reference:

Balasubramanian D., Post Harvest Technologies Commercialization, Leaflet

IP&TM, ICAR: https://icar.org.in/node/131

Preethi, P., Rajkumar, A.D., Shamsudheen, M. and Nayak, M.G., 2019. Prospects of Cashew Apple - A Compilation Report, Technical Bulletin No. 2/2019. ICAR-Directorate of Cashew Research, Puttur, Karnataka, India, pp. 28.

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