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PREFACE

The Annual Report for 1998-99 summarises the progress made in different research projects pursued at this Centre. Unfortunately, this is the second consecutive year during which the crop failed due to vagaries of weather. Low temperatures during flowering season in the morning hours and sudden shoot up of temperature in day time followed by very low humidity in most of the States, caused the severe crop loss. However, on the research front, we have made some progress in the Crop Improvement, Crop Management as well as in the Crop Protection.

In continuation of the efforts to characterise the germplasm, 97 accessions planted during 1987-88 were catalogued as per the IPGRI Descriptors and Volume-II of the Descriptor was brought out. An ad-hoc scheme which was in implementation for the last three years for the survey of forest plantations in Karnataka was concluded during the year. In this programme, we identified the accessions, which were performing very well even under neglected conditions in the coastal areas, maidan parts and higher elevations. These collections will certainly help in regionalising the varieties in future for specific areas. To evaluate the performance of hybrids prior to the release, efforts have been initiated to test them in the farmers' plots under the management conditions being followed by them. This will help in refining the recommendations both in terms of varieties as well as its management.

Hitherto, we have been using only seeds for raising root stocks. During the last year, 29 plants raised from nodal culture were planted in the field and their growth was vigorous. Further, in vitro propagated nodal cultured plants were also used for grafting and it was found to be quite successful. This should bring in a break-through in the coming years in changing over from seedling root stocks to vegetatively propagated root stocks.

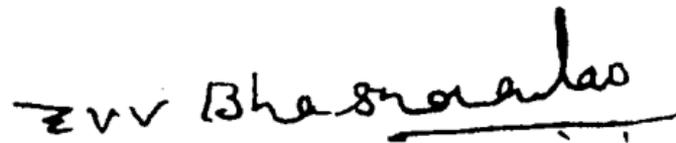
In studies on planting systems and spacing, results reported during the year indicated that planting density of 500 plants per ha was quite profitable. This will be of significance in replanting programmes contemplated especially in the forest plantations of different States. High density planting with 500 plants per ha should certainly lead us towards the goal of achieving 10 lakh MTs of raw nuts by 2002.

One of the main problems which is yet to be resolved is the menace of pests such as stem and root borers and the foliage pests, especially the tea mosquito bug (TMB) which causes considerable crop loss in adverse weather conditions. The observations low intensity of TMB infestation in the plants in which weaver ant (*Oecophylla*) colonies were noticed is of significance.

For the first time, the farmers participation in the technology refinement was attempted during the year. A Kisan Ghosti was organised in which the progressive farmers shared their experience in the management practices adopted by them. During the discussion in Kisan Ghosti, it was evident that many farmers preferred to adopt conventional practices while at the same time there was a perceptible change in the knowledge of the farmers with reference to the planting material. This should give an impetus for the researchers to popularise the varieties released for different regions and also for the

development departments to make available vegetatively propagated (soft wood grafts) planting material of cashew in the future development programmes.

I would like to place on record my sincere appreciation to all my colleagues at NRCC who spared no effort in pursuing the research projects to generate the data which are presented in this Annual Report. I am also grateful to the Editorial Committee for concisely presenting the achievements of the Centre during the year.

A handwritten signature in black ink, reading "EVV Bhaskara Rao". The signature is written in a cursive style with a horizontal line underneath the name.

(EVV. Bhaskara Rao)

Director

Place : NRCC, Puttur

Date : 01 July 1999

EXECUTIVE SUMMARY

There were 19 on going research projects to fulfill the mandate of the research centre. Out of these, five were in crop improvement, eight in crop management, three in crop-protection, two in post-harvest technology and one is transfer of technology. During the year, one project each under crop improvement and crop management, three research projects under crop protection and one project under post harvest technology were concluded. Besides, two research projects each under crop management and crop protection and one research project on post-harvest technology were started.

A total of 24 diverse types of cashew were collected after surveying plots of farmers and forest development corporations in Karnataka, Kerala and Tamilnadu. Twenty nine clonal accessions were also planted and with this, the total number of collections maintained was 392 in National Cashew Gene Bank (NCGB). Ninety seven accessions were characterised on completion of six harvests as per IPGRI cashew description and a catalogue was brought out. Eighteen groups (core collections) were identified from 153 accessions. Data on morphological characters and yield attributes recorded in 56 accessions were subjected to principle component analysis. Under varietal improvement programme 56 lines/varieties, 8 selfs and 43 hybrid combinations were evaluated in six trials. Among the 14 elite germplasm lines, VTH 539/2 gave highest cumulative yield which was 36% more than the control (VRI-2). Among the recommended varieties, VRI-I exhibited highest fruiting intensity per sq metre (6.89%). Highest

yield per sq. metre was in BLA 39-4 (40.16g). BLA 39-1 and VRI-2 had predominantly mixed flowering phase. Out of 27 varieties screened for adherence of testa to kernel, seven had loose adherence, nine had medium and eleven had tight adherence. NRCC sel-1 had loose medium adherence of testa while NRCC sel-2 had medium adherence. Twenty cashew varieties were characterised in respect of oil content, proteins and sugars. In the preliminary evaluation, hybrids H 46, H 1346 and H 1354 showed promise with 84 to 88 per cent increase in nut weight over their female parents. Nodal cultures were established from mature tree source of NRCC sel-1 and Ullal-2. Among the different antibrowning substances tried in media, polyvinylpyrrolidone (PVP - 360) and PVPP were found to be useful. In NRCC sel-1, MS medium containing 2 mg/l BAP, 0.5mg/l GA₃ and 0.1mg/l of IBA induced axillary shoot-bud proliferation while in Ullal-2 MS medium containing 0.1mg/l each of TDZ and BAP induced multiple shoot-buds. Pulse treatment of microshoots in 10mM NAA induced 60% rooting. Four VAM species were isolated from cashew soils of which *Scutellospora nigra* was predominant. Tissue culture plants planted in field showed better growth and higher root density than control plants. Tissue culture plants were also used as root-stock plants and obtained 60-100% grafting success.

In situ grafting made with air layers of tall and semitall types as root-stocks and NRCC sel - 1 as scion revealed no significant effect on scion variety. Studies on root-stock-scion interaction was also initiated with eight root

stocks and one scion variety and one-interstock variety. Cost of establishment of top worked plot and replanted plot for the last nine years was worked out and was found to be on par. Top-worked plot recorded highest cumulative yield. Effect of soil and foliar application of paclobutrazol (cultural) on cashew was also studied and found that the effect was not pronounced during first year. Canopy management trial initiated in four varieties with four pruning treatments revealed significant difference among pruning treatments for yield in the initial years of planting. Among the various planting systems and spacings tried, maximum yield was recorded in hedge planting (5m x 4m spacing) followed by 5x5m spacing. In the experiment on drip irrigation coupled with graded doses of N, P and K significant increase in canopy area was observed in plots applied with fertilizers and irrigation. Interaction effect of irrigation and fertilizer was significant. Higher levels of irrigation (60-80 l/tree) and middle and highest level of fertilizers resulted in significant increase in photosynthetic rate, transpiration and carboxylation efficiency. Irrigation alone without fertilizer lead to significant increase in yield by 38 to 72% over control. Irrigating cashew once in four days with 80 l/tree even without fertilizer application resulted in higher cumulative yield over control. Irrigating 60 to 80 l/tree once in four days with highest dose of fertilizers increased yield by 132.8 to 157.7 kg over check. Cropping system tried with different combinations of acacia casuarina, subabul, ailanthus and bamboo indicated adverse effect of casuarina and acacia on cashewnut yield. Maximum profit was realised by growing two rows of acacia and one row of casuarina as intercrops between two rows of cashew.

Field survival of fungal pathogen (*Metarhizium anisopliae*) of cashew stem and root borer (CSRB) was recorded upto 120 days. However, infectivity of the spores to induce micosis on CSRB grubs was limited to 60 days.

In studies on physical parameters of CSRB infested trees, it was noticed that trees were infested randomly. Trees aged 10 years were more prone to incidence of CSRB.

Under studies on parasitoids of tea mosquito bug (TMB), a technique to detect endoparasites due to hymenopteran nymphal adult parastoid/mermithid nematode in the field population of TMB was standardised. Egg endo parasitoids of *Telenomus* and *Chaetostricha* sp were found to survive in plots sprayed with monocrotophos/carbaryl. TMB eggs exposed to natural parasitisation were parasitised in all months.

TMB incidence was found to be less wherever weaver ant (*Oecophylla smargdina*) edonics were noticed.

In studies on functional properties of cashew kernel flour it was found that cashew flour obtained from whole cashew kernels was better than almond flour and soybean flour with respect to water and oil absorption, least gelation concentration, foaming and emulsification capacity.

In the transfer of technology front, a campaign on soil and water conservation in cashew gardens and "Kisan goshti" during annual cashew day were the highlights. Four training courses were conducted for officials of development departments.

INTRODUCTION

Research on cashew was first initiated in the early 1950's by Indian Council of Agricultural Research by sanctioning ad-hoc schemes for Research Centres located at Kottarakkara (Kerala), Ullal (Karnataka), Bapatla (Andhra Pradesh), Daregaon (Assam) and Vengurla (Maharashtra). Cashew research received further impetus by the establishment of Central Plantation Crops Research Institute (CPCRI) at Kasaragod, Kerala. Cashew was included as one of the mandate crops of CPCRI. Simultaneously, ICAR also sanctioned All India Coordinated Spices and Cashew Improvement Project (AICS & CIP) for CPCRI, Kasaragod. The CPCRI Regional Station, Vittal (Karnataka) was given the mandate to work on cashew while four University Centres (Baptala, Vridhachalam, Anakkayam and Vengurla) were assigned the research component on cashew under AICS&CIP. During the V and VI Plans three more centres (Bhubaneswar, Jhargram and Chintamani) came under the fold of AICS & CIP.

Efforts on cashew research were further strengthened by the implementation of World Bank aided Multi State Cashew Project (MSCP) with a research component in Kerala, Karnataka, Andhra Pradesh and Orissa from 1982 to 1986. The Quinquennial Review Team (QRT) constituted by ICAR in 1982, after reviewing the entire research work on cashew recommended delinking of cashew and spices research from CPCRI and establishing two independent National Research Centres one each on cashew and spices in Puttur, Karnataka and Calicut, Kerala respectively. 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 made similar recommendations at the same time. This laid the foundation for establishment of National Research Centre for Cashew at Puttur on 18th June 1986. Subsequent to bifurcation of AICS&CIP, the headquarters of All India Coordinated Research Project on Cashew was shifted to NRC for Cashew, Puttur. A Cashew Seed Farm at Shantigodu which was started by CPCRI in 1972 was transferred to NRC for Cashew which now forms the Experimental Station of NRCC.

MANDATE

National Research Centre for Cashew is conceived to undertake mission oriented research projects with the mandate of evolving high yielding varieties of cashew with resistance / tolerance to pests such as tea mosquito, high protein, lysine and other desirable parameters; standardisation of agrotechniques for achieving higher production and productivity with sustainability in view, and transfer of technology to farmers and extension agencies on improved production techniques through training, demonstrations and extension literature.

The Director of National Research Centre for Cashew also monitors AICRP on Cashew, mandate for cashew research as a whole under National Research Centre for Cashew and All India Coordinated Research Project on Cashew was reoriented as under:

- * To conduct mission-oriented research on all aspects of cashew for improving productivity and quality with special reference to export.
- * To serve as a national repository for

cashew germplasm and a clearing house for research information on cashew.

- * To act as centre for training in research methodologies and technology updating of cashew and to coordinate national research projects.
- * To provide consultancy regarding cashew production technology.
- * To generate quality planting material.
- * To collaborate with national and international agencies for achieving the mandate.

ORGANIZATIONAL SET UP AND INFRASTRUCTURE

3.1 Headquarters

National Research Centre for Cashew is located with its headquarters at Puttur, Dakshina Kannada, Karnataka. The main campus is situated 5 KM away from Puttur town (45° N latitude, 75.4° E longitude and 90 m MSL). It is contemplated to acquire 69.02 ha of land for laying out field experiments at Kemminje of which 68 ha have already been acquired. Besides the main campus which houses Laboratory-cum-Administrative Block, and Experimental Station (spread over 80 ha of area) at Shantigodu which is 13 KM away from the main campus also forms part of the Research Centre.

The research programmes are pursued in the areas of Crop Improvement, Crop Management, Crop Protection, Post harvest Technology and Transfer of Technology. Besides, a well equipped Biotechnology Laboratory, the research centre has sophisticated instruments/facilities for conducting research.

A well established Library at the Centre has got 815 reference volumes, 380 book volumes

of journals and 725 reprints. Indian (38 Nos) and international (10) journals are also subscribed for the library. Photocopying, lamination and spiral binding facilities have been established at the library.

The headquarters of AICRP on Cashew is located at NRC Cashew, Puttur. It has eight Coordinating Centres and a Sub-Centre located in Karnataka, Kerala and Maharashtra in the West Coast, Andhra Pradesh, Orissa, Tamil Nadu and West Bengal in the East Coast and in Madhya Pradesh which is a non traditional cashew growing area.

LAN facility - ARIS Cell became operational with the establishment of LAN facility.

Significant achievements of the centre:

- (a) It has largest germplasm collection in the country (NCGB) of cashew with 392 accessions.
- (b) It has released two selections namely NRCC Sel-1 and NRCC Sel-2 which are high yielding and medium nut types for cultivation in Karnataka.
- (c) It also demonstrated the advantage of growing intercrops like pineapple profitably in cashew gardens.
- (d) High density planting (625 plant density/ha) was shown to be better than normal space planting (8m x 8m) with an yield increase of 2.5 times that of control.
- (e) Irrigating cashew at 60-80 litre of water per tree once in four days after initiation of lowering till fruit set and development with the application of 750 : 187.5 : 187.5 of NPK per tree led to significantly higher yields.
- (f) Leader shoot pruning combined with removal of dead wood was found to have beneficial effect in cashew.

- (h) Soft-wood grafting method was standardised for the commercial multiplication of cashew high yielding varieties.
- (i) Biochemical quality of cashew varieties, biochemical changes during tea mosquito infestation, nut storage and causes for kernel rejects have been investigated.
- (j) Integrated Pest Management practices for the control of tea mosquito bug and cashewnut stem and root borer are being worked out. The rearing technique for cashew stem and root borer (CSR B) utilising host bark has been standardised to obtain sufficient numbers of test insects for further trials.
- (k) In micropropagation, regeneration of cashew from the seedling explants (nodal cultures) was standardised. Field planted tissue culture plants had higher root density and better morphological attributes when compared to control. Four species of VAM viz., *Scutellospora nigra*, *Glomus*

multicaule, *G. macrocarpum* and *G. australe* were isolated from native cashew soils.

- (l) The centre has established very good linkage with farmers and officials. It is monitoring 69 demonstration plots. It conducts training on cashew production technology, vegetative propagation of cashew and holds plant protection campaign and field days for the benefit of farmers.
- (m) It is serving as information centre on all aspects of cashew research and development.

Budget

The institute had an annual budget of Rs. 90 lakhs under plan and Rs.80 lakhs under non plan heads for the year 1998-99. Besides, ICAR Revolving Fund Scheme had an outlay of Rs. 4.5 lakh and DCD Revolving Fund had Rs. 8.85 lakhs. Ad-hoc scheme had an allocation of Rs. 2.99 lakhs.

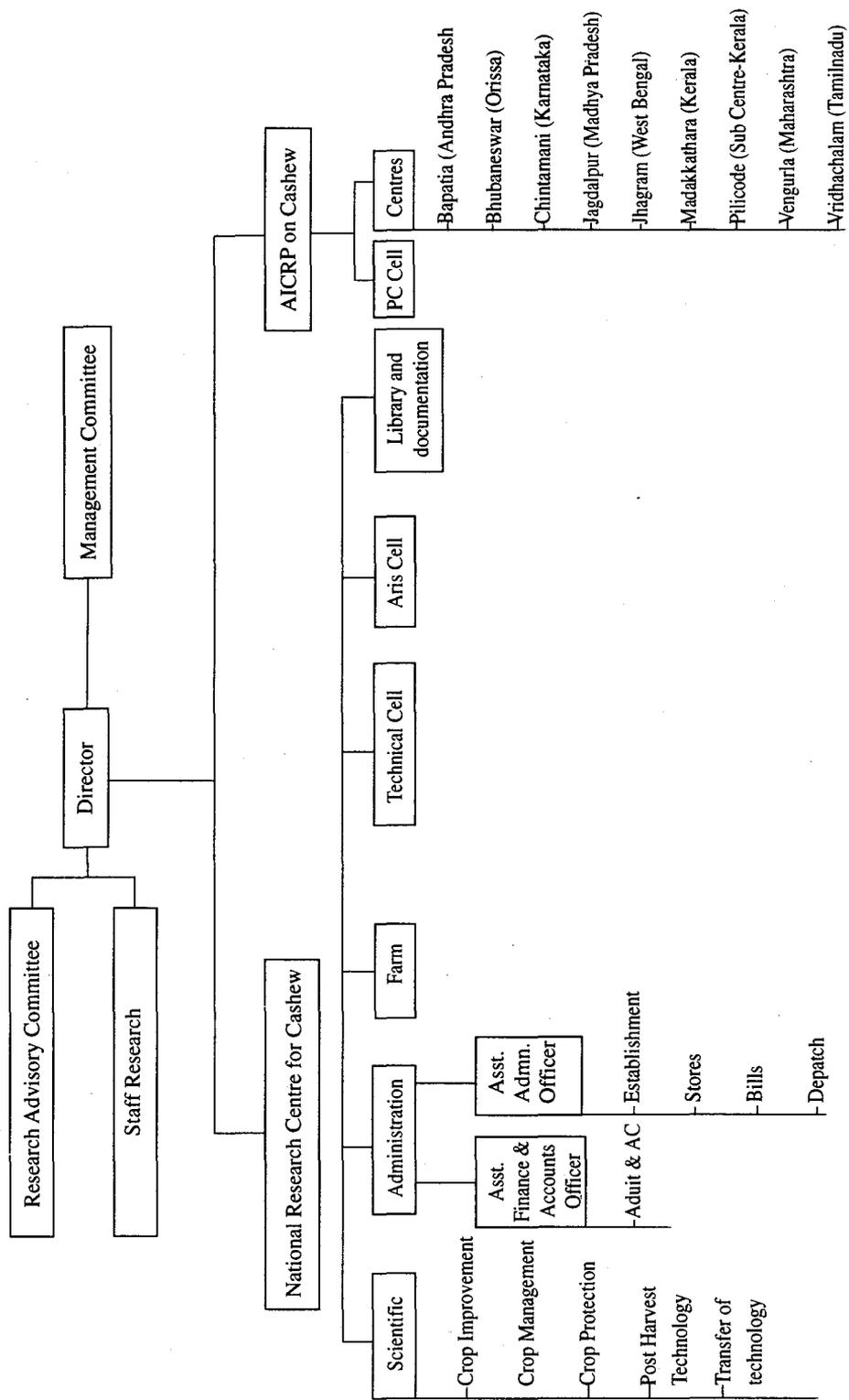
Staff Position as on 31.3.99

Category	NON PLAN			PLAN			TOTAL		
	Sanctioned	Filled	Vacant	Sanctioned	Filled	Vacant	No. of Posts	No. filled No.	Vacant
Scientific	16	12	4	1	1	-	17	13	4
Technical	17	17	-	5	5	-	22	22	-
Administrative	7	6	1	8	8	-	15	14	1
Supporting	36	35	1	9	8	1	45	43	2
Total	76	70	6	23	22	1	99	92	7

Total Manpower

	Sanctioned	Filled	Vacant
Non Plan	76	70	6
Plan	23	22	1
Total	99	92	7

ORGANISATIONAL SETUP OF NRC-CASHEW



1. CROP IMPROVEMENT

1.1 Genetic resources of cashew

Collection of cashew germplasm - both indigenous and exotic, conservation of germplasm in the National Cashew Gene Bank (NCGB), and evaluation and cataloguing of germplasm are being carried out at this research centre for breeding better varieties.

1.1.1 Germplasm collection and conservation

During the year, cashew plantations in Karnataka, Tamil Nadu (southern districts) and Kerala (northern districts) were surveyed for collection of germplasm. The cashew plantations of Forest Department / Karnataka Cashew Development Corporation (KCDC) in four districts of Karnataka namely, Shimoga, Mysore, Kodagu and Dakshina Kannada were surveyed and seven trees (Thagginathala-1, Talakad-1, 2, 3, 4, 5 and Kodyala-2) were marked for collection. These collections had high yielding and cluster bearing characters with small to medium

nuts. Thagginathala-1 had a short duration of nut collection (30 days) and Kodyala-2 was a semitall type. Three bold nut types (Kattadabari-1, Pundikai-1 and Ubaradka Mittur-1) were also collected from farmers' plots in Dakshina Kannada district. A total of 14 elite and diverse types (5 from Tamil Nadu and 9 from Kerala) were collected in collaboration with AICRPC centres. Two cluster bearing types (SN-20, SN-38) from Bhubaneswar (Orissa) and one long flowering duration type (Spice-1) from Old Goa, were also added to the collection.

A total of 29 clonal accessions collected from Pondicherry (3 no.), Maharashtra (1 no., Vengurla-7) and Karnataka (11 no. from Forest / KCDC plantations in Uttara Kannada, 1 tea mosquito bug escape - Goa 11/6, and 13 clones from seedlings of Brazilian origin) were planted in NCGB during the year leading to a total of 392 clonal accessions in NCGB (Table 1.1).

Table 1.1: Clonal accessions planted in NCGB during 1998

Source of collection	Number of collections		
	Existing	Planted during 1998	Total
Karnataka	228	25*	253
Andhra Pradesh	27	-	27
Tamil Nadu	10	-	10
Pondicherry	-	3	3
Goa	40	-	21
Maharashtra	20	1	21
Orissa	15	-	15
Kerala	9	-	9
West Bengal	14	-	14
Total	363	29	392

* Including 13 clones prepared from seedlings of Brazilian origin.

1.1.2 Germplasm evaluation

Ninety seven accessions (1987 and 1988 planted) in which six annual harvests were made were evaluated and characterized as per IPGRI cashew descriptors. Variability observed for some of the qualitative descriptors (Table 1.2) revealed that majority of the accessions had upright and open tree habit, obovate leaf shape, extensive branching, yellow red colour of young leaves, mid-season flowering, yellow coloured apples, conical-obovate shape of apple, intermediate attachment of apple to nut, non-uniform shell thickness, loose attachment of peel to kernel and

rounded flanks of nut.

From the 153 clonal accessions (1986, 1987 and 1988 planted) so far characterized and catalogued were grouped into 18 clusters / groups were identified based on three criteria, namely, category of material / level of domestication, agro-ecological region and characterization and evaluation data (season of flowering, duration of flowering and colour of mature cashew apple). Of the 18 groups, the largest group had 39 accessions and five groups consisted of single

Table 1.2: Variability for the qualitative descriptions in 97 accessions.

Descriptor	Descriptor State	Number of Accessions
Tree habit	3. Upright & Compact	12
	5. Upright & Open	64
	7. Spreading	21
Leaf shape	1. Oblong	3
	2. Obovate (Club-Shaped)	88
	3. Oval	6
Branching pattern	1. Extensive	90
	2. Intensive	7
Colour of young leaves	1. Red	5
	2. Yellow Red	84
	3. Green Yellow	7
	4. Purple	1
Season of flowering	3. Early (Nov-Dec)	29
	5. Mid (Dec-Jan)	59
	7. Late (Jan-Feb)	9
Colour of mature apple	1. Yellow	59
	2. Red	38
	3. Yellow Red	-
	4. Red Purple	-
Shape of cashew apple	1. Cylindrical	35
	2. Conical-Obovate	43
	3. Round	15
	4. Pyriform	4
Attachment of apple to nut	3. Loose	28
	5. Intermediate	51
	7. Tight	18
Uniformity of shell thickness	0. Not uniform	93
	+. Uniform	4
Attachment of peel to kernel	1. Loose	90
	2. Tight	7
Flank of nuts	3. Flattened	22
	5. Round	64
	7. Bulging	11

Table 1.3: Accessions with high shelling percentage and high kernel weight identified from the core collections.

Accessions Number	Shelling percentage	Kernel weight (g)	Yield/plant (6 annual harvests) (kg)
NRC 1 (VTH 10/25, M 6/1)	31.7	1.8	12.8
NRC 19 (VTH 170/16, K 28-1)	29.1	1.9	9.1
NRC 63 (Goa T.No. 1)	30.1	2.1	9.1
NRC 99 (M 26/2, VRI-3)	29.3	2.1	10.0
NRC 137 (VIH 105/2 1)	31.4	2.1	10.5
NRC 140 (VTH 155L, T.No. 44 VTL.)	27.2	2.3	12.4

accession. From each group a 10 per cent sample size was randomly selected as core entries and six accessions (NRC 1, 19, 63, 99, 137 and 140) having high shelling percentage (27.2 - 31.7%), high kernel weight (1.8 -2.3g) and medium yield (9.1 - 12.8 kg/plant from 6 annual harvests) were further identified from core collections (Table 1.3).

A ready reckoner of characteristics of core collections representing the 18 core groups was prepared (Table 1.4) for using as a reference in the germplasm collection survey.

Sixteen seedling accessions of Brazilian origin and *A. microcarpum* were evaluated for their growth. The mean plant height recorded after

27 months of planting showed minimum plant height in *A. microcarpum* (1.82 m) and maximum plant height in C.P.1001-6.2 (3.35 m). The Brazilian accessions did not reveal dwarf features.

Principal component analysis was carried out to determine the group constellations for the data on morphological and yield attributes of 56 accessions. It was observed that the first two eigen roots (variables) could absorb only about 30 per cent of the total variation. The graph drawn taking the first two canonical variates as coordinate axis gave some idea of the configuration of groups (Fig.1.1 and Table 1.5). The accessions 1, 2, 7 and 18 remained independent.

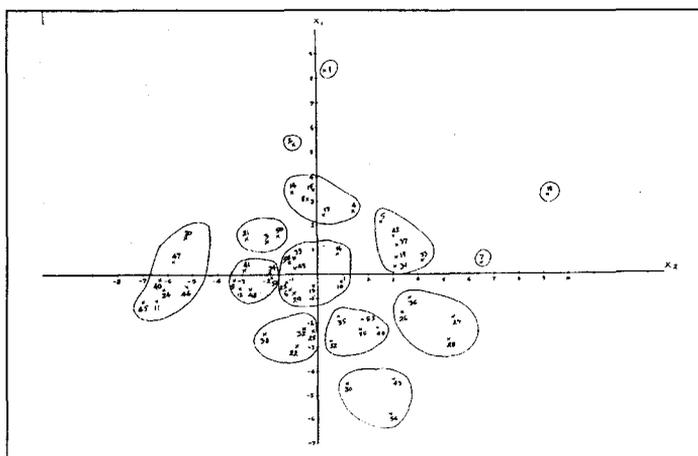


Fig.1.1 Grouping pattern of 56 accessions in the ($x_1 - x_2$) chart

Table 1.4: Ready reckoner of characteristics of cashew core collections in NCGB

Group No.	Accession No.	Tree habit	Tree ht. (m)	Tree spr. (m)	Branching type	Season of flowering	Apple colour	Wt./Nut (g)	Wt./Apple (g)	Attachment of nut to apple
1	2	3	4	5	6	7	8	9	10	11
1	NRC1	U & O	3.7	5.1	Extn.	Early	Yellow	5.6	56.7	Loose
2	NRC3	U & O	3.5	4.4	Extn.	Early	Yellow	4.8	20.0	Loose
	NRC140	Spr.	3.1	4.4	Extn.	Early	Yellow	8.3	142.8	Intermediate
3	NRC38	U & O	4.9	5.9	Extn.	Early	Red	3.8	56.6	Tight
4	NRC7	U & O	3.9	5.6	Extn.	Mid	Yellow	7.5	71.6	Tight
	NRC80	U & O	5.5	4.2	Extn.	Mid	Yellow	7.1	60.0	Tight
5	NRC27	U & O	6.9	6.2	Extn.	Mid	Red	6.2	86.6	Loose
	NRC79	U & O	6.5	6.4	Extn.	Mid	Red	3.9	26.0	Intermediate
	NRC141	U & C	4.0	4.6	Extn.	Mid	Red	5.6	72.0	Intermediate
6	NRC4	U & O	4.2	5.6	Extn.	Mid	Yellow	5.8	56.6	Tight
	NRC-63	U & O	6.1	6.5	Extn.	Mid	Yellow	6.8	50.0	Intermediate
	NRC110	Spr.	4.3	5.9	Extn.	Mid	Yellow	6.1	57.5	Intermediate
	NRC114	Spr.	3.4	5.1	Extn.	Mid	Yellow	5.4	67.5	Tight
7	NRC8	U & O	3.7	5.6	Extn.	Mid	Red	5.9	51.6	Loose
	NRC108	Spr.	3.6	5.2	Extn.	Mid	Red	5.9	33.0	Intermediate
8	NRC26	U & O	3.7	5.6	Extn.	Late	Yellow	6.4	58.3	Intermediate
9	NRC124	U & O	5.0	4.2	Extn.	Late	Red	7.7	37.6	Intermediate
10	NRC24	U & O	8.0	7.2	Extn.	Mid	Yellow	4.5	40.0	Intermediate
11	NRC19	U & O	4.5	5.7	Extn.	Late	Red	6.5	65.0	Intermediate
12	NRC93	Spr.	5.1	5.1	Extn.	Early	Yellow	5.6	49.1	Intermediate
13	NRC101	U & C	3.1	4.2	Intn.	Early	Yellow	5.1	50.0	Intermediate
14	NRC131	Spr.	2.4	2.7	Extn.	Early	Red	7.2	63.4	Intermediate
15	NRC99	U & C	2.9	4.2	Intn.	Mid	Red	7.0	50.0	Intermediate
16	NRC137	U & O	4.8	4.9	Extn.	Late	Yellow	6.9	39.1	Intermediate
17	NRC153	Spr.	1.5	1.5	Extn.	Mid	Red	2.0	10.0	Loose
18	NRC142	U & O	4.6	5.4	Extn.	Late	Red	7.4	70.6	Loose

Group No.	Accession No.	Tree habit	Tree ht. (m)	Tree spr. (m)	Branching type	Season of flowering	Apple colour	Wt./Nut (g)	Wt./Apple (g)	Attachment of nut to apple
1	2	12	13	13	15	16	17	18	19	20
1	NRC1	Rounded	Infront	3.0	87	57.0	10.1	31.7	1.8	12.8
2	NRC3	Rounded	Infront	2.2	121	50.0	4.1	32.9	1.6	16.7
	NRC140	Rounded	Inline	3.0	120	90.0	17.2	27.2	2.3	12.4
3	NRC38	Rounded	Inline	2.8	98	72.7	14.8	25.0	0.9	14.1
4	NRC7	Bulged	Infront	4.0	90	44.4	9.5	26.3	1.9	14.1
	NRC80	Bulged	Infront	4.0	88	50.0	8.4	23.4	1.8	3.5
5	NRC27	Flattened	Inline	3.1	90	77.7	13.9	28.8	1.8	10.5
	NRC79	Rounded	Infront	2.0	80	58.3	6.6	31.6	1.3	10.8
	NRC141	Flattened	Inline	3.1	88	95.2	12.8	26.0	1.5	13.8
6	NRC4	Rounded	Infront	2.6	95	42.8	9.7	32.2	1.9	11.5
	NRC63	Flattened	Behind	4.0	114	53.8	7.3	30.1	2.1	9.1
	NRC110	Rounded	Inline	3.0	105	83.3	9.4	29.0	1.8	7.6
	NRC114	Bulged	Infront	3.0	95	73.6	12.5	25.4	1.4	4.3
7	NRC8	Rounded	Inline	3.3	112	33.3	8.7	27.1	1.1	7.3
	NRC108	Flattened	Inline	2.9	100	83.3	5.5	24.2	1.4	6.8
8	NRC26	Flattened	Inline	3.5	90	63.6	9.1	26.3	1.7	9.0
9	NRC124	Rounded	Behind	3.5	68	81.2	4.8	25.7	1.8	6.0
10	NRC24	Rounded	Infront	3.0	130	55.5	9.8	28.9	1.3	8.7
11	NRC19	Rounded	Infront	2.8	91	50.0	10.0	29.1	1.9	9.1
12	NRC93	Rounded	Inline	3.8	92	72.7	8.7	25.0	1.3	9.6
13	NRC101	Rounded	Infront	3.9	98	72.4	9.8	26.1	1.4	12.4
14	NRC131	Bulged	Infront	3.1	95	81.8	8.8	24.1	1.6	11.6
15	NRC99	Rounded	Infront	2.9	94	73.9	7.1	29.3	2.1	10.0
16	NRC137	Rounded	Infront	2.8	68	83.3	5.6	31.4	2.1	10.5
17	NRC153	Flattened	Infront	1.5	100	33.3	5.0	20.0	0.4	0.4
18	NRC142	Rounded	Infront	3.4	72	81.8	9.5	28.6	2.0	8.3

U & O = Upright and Compact ; Spr - Spreading, Extn - Extensive, Intn - Intensive, U & O - Upright and Open

Table 1.5: Grouping of 56 clonal accessions of cashew

Group	No. of accessions	Accession number (NRC)	Original source
I	1	1	Vridhachalam
II	1	2	Vridhachalam
III	1	7	Vittal
IV	1	18	Anakkayam
V	6	5	Bapatla
		19, 31, 33	Anakkayam
		37	Vengurla
		42	Vridhachalam
VI	5	4	Vridhachalam
		8	Vittal
		14, 15, 17	Anakkayam
VII	3	3	Vridhachalam
		21	Anakkayam
		50	Bapatla
VIII	9	6	Bapatla
		10, 13, 16, 23, 29	Anakkayam
		39	Vengurla
		49, 54	Bapatla
IX	6	9, 12, 34	Anakkayam
		41	Vengurla
		48, 51	Bapatla
X	4	26, 27, 28	Anakkayam
		36	Vengurla
XI	4	22, 25, 32	Anakkayam
		38	Vengurla
XII	5	35	Vengurla
		44	Vittal
		52, 53, 55	Bapatla
		11, 20, 24	Anakkayam
XIII	7	40	Vengurla
		45, 46	Vittal
		47	Bapatla
XIV	3	30	Anakkayam
		43	Vittal
		56	Bapatla

1.1.3 Cataloguing of germplasm

A catalogue for the 97 cashew accessions (planted during 1987 and 1988) which were characterized after six annual harvests was published. The catalogue entitled Catalogue of Minimum Descriptors of Cashew (*Anacardium occidentale* L.) Germplasm Accession-II" was released in 1998.

1.2 Varietal improvement

Genetic improvement of cashew for yield and other important characters such as nut weight (>7g), kernel weight (>2g), shelling percentage (>28%), resistance to tea mosquito bug and quality of kernels (high protein and lysine), were attempted. A total of 58 elite lines/varieties, 8 selfs and 43 hybrid combinations were evaluated in seven trials. Thirty two hybrid combinations are in the initial stage of evaluation.

1.2.1 Evaluation of elite germplasm accessions

Fourteen elite germplasm accessions were evaluated along with VRI-2 as control. Highest cumulative yield for 8 years was recorded in VTH 539/2 (M 76/2) (10.97kg/tree) followed by VTH 59/2 (13/5 Kodur) (10.93 kg/tree) as compared to 8.04kg/tree in VRI-2 and population mean of 7.60 kg/tree. The increase in cumulative yield of VTH 539/2 and VTH 59/2 over VRI-2 was 36.5 per cent and 36.0 per cent respectively.

1.2.2 Evaluation of recommended varieties

Nineteen recommended varieties were evaluated in two trials along with VRI-2 as common check. The highest cumulative yield of 12.18 kg/tree for 10 annual harvests was recorded in VRI-2 variety. NDR-2-1 performed better for cumulative yield for five annual harvests (3.78 kg/tree) as compared to other eight varieties. Proportion of hermaphrodite flowers ranged from 1.76 per cent (in H 3-13) to 27.98 per cent (in VRI-2). The duration of male phase (0-5% hermaphrodite flowers) and mixed phase (>5% hermaphrodite flowers) of flowering were determined in 20 varieties. In all the varieties studied, mixed phase was present. However, in varieties H 3-13 and NDR-2-1 the mixed phase period was shorter than the male phase. In varieties BLA 139-1, BPP-1, VRI-2 (Trial-2), the duration of mixed phase was quite extended and male phase was of very short duration. In spite of longer duration of mixed phase in these varieties, cumulative yield was only medium and hence definite relationship between flowering phase and yield could not be established (Table 1.6).

1.2.3 Status of adherence of testa to kernels

Varieties differed for the extent of

adherence of testa to kernels. Based on the strokes required for removal of testa/peel from the kernels, the 27 released varieties and 5 promising varieties were classified into 3 categories of which, seven had loose adherence, nine had medium and eleven had tight adherence of testa to the kernel. NRCC Sel-1 had loose adherence of testa while NRCC Sel-2 had medium adherence (Table 1.7).

1.2.4 Evaluation of hybrids/selfs

Hybrid Tree No.46 (T.No.56 x A 18/4) showed superior performance for cumulative yield (20.11 kg/tree) for nine harvests with a nut weight of 7.2g and kernel weight of 2.0 g, and shelling percentage of 28.3. The increase in cumulative yield over check VRI-2 was 163 per cent.

1.2.5 Improvement of nut size in released varieties

Over 850 hybrids involving 21 parents (between released varieties and bold nut types) were planted since 1991. Hybrid nos. 1346 and 1354 (V-5 x VTH 711/4) showed an increase in nut weight over female parent from 84 to 88 per cent. The cumulative yield from four harvests was 6.20 kg/tree in both the hybrids.

1.2.6 Evaluation of high yielding and high shelling types

Seven genotypes having a shelling percentage of over 30 were evaluated along with a check (VRI-2). The cumulative yield of 3.3 kg/tree was recorded in VTH 79/1 followed by VTH 57/1 (2.7 kg/tree) in 5th harvest. Eight genotypes along with a check (VRI-2) were evaluated for big apple and medium nut size. VTH 146/1 had the highest apple weight of 78 g and its cumulative yield was 3.2 kg/tree in 5th harvest.

Table 1.6: Performance of recommended varieties for yield and flowering phases

Variety	Cum. yield (Kg/tree)	Hermaphrodite flower		Flowering phase (in days)	
		Absolute	% of total	Male phase	Mixed phase
Trial-1	For 10 harvests				
BPP-1	6.87	26	14.72	3	67
BPP-2	9.17	30	10.24	32	38
BPP-4	11.00	31	9.36	20	62
BPP-5	10.66	61	16.19	9	73
BPP-6	8.61	36	9.94	27	55
BLA 139-1	7.95	84	22.60	4	78
BLA 39-4	11.70	50	11.48	17	65
Ullal-1	7.47	64	12.43	28	97
H 3-13	2.16	7	1.76	55	18
H3-17	5.28	73	17.15	17	65
VRI-1	9.51	52	11.52	24	65
VRI-2	12.18	37	13.92	21	51
Population Mean	8.55				
CD 5%	4.09				
Trial-2	For 5 harvests				
BPP-3	1.92	25	5.41	38	55
K 22-1	2.44	50	5.48	46	54
NDR-2-1	3.78	8	3.04	43	19
Vengurla-1	3.02	27	4.55	30	58
Vengurla-4	2.95	8	7.19	34	54
Ullal-2	3.18	59	12.06	19	50
NRCC Sel-1	2.00	39	7.65	35	5
NRCC Sel-2	2.06	45	6.96	27	51
VRI-2	2.61	88	27.98	5	79
Population Mean	2.66				
CD 5%	NS				

1.2.7 Primegenic dominance studies

Twenty varieties of cashew and a few promising hybrids were studied for primegenic dominance in fruit set and retention and it was found that this phenomenon is operating in most of the varieties. However, in some varieties such as BPP-2, BPP-4, K 22-1, NDR-2-1, V-1, VRI-1

and H 3-13, the effect of primegenic dominance is less.

1.2.8 Pollen germination studies

The extent of germination of pollen grains obtained from male as well as hermaphrodite flowers in different varieties was studied. The

Table 1.7: Status of adherence of testa to kernels in different varieties

Status of adherence	Mean no. of strokes required	No. of varieties	Name of varieties
LOOSE			
Release varieties	< 5.0 strokes	7	VRI-1, VRI-3, V-1, V-2, Ullal-4, K 22-1, NRCC Sel-1
Promising Varieties		1	M 15/4
MEDIUM			
Released varieties	5.0-7.5 strokes	9	BPP-2, BPP-6, V-5, V-6, UN-50, Bhubaneswar-1, Jhargram-1, BLA 39-4, NRCC Sel-2
Promising Varieties		1	HY 367
TIGHT			
Released varieties	> 7.5 strokes	11	Chintamani-1, BPP-5, VRI-2, V-3, V-4, V-7, Ullal-3, BLA-139-1, Dhana, Kanaka, Priyanka
Promising varieties		3	M 33/3, Hy. 303, HY. 320
Total		32	

following media were tried for the purpose of pollen germination by hanging drop method.

- a) Pollen medium (liquid) containing 100 mg/l each of boric acid, sucrose, potassium nitrate and 300 mg/l of calcium nitrate and 200 mg/l of magnesium sulphate.
- b) Sucrose liquid medium at concentrations of 0, 2, 5, 20, 22.5, 25.0, 27.5, 30.0, 40.0 and 50.0 per cent.
- c) PEG based medium having sucrose 25% liquid medium with polyethylene glycol 8000 (PEG 8000) (30 gms/100 ml) or polyethylene glycol 4000 (PEG 4000) (30 gms/100 ml) and boric acid (20 ppm) and calcium nitrate (20 ppm).

Pollen grains were incubated in the liquid medium at $28^{\circ}\text{C} \pm 2^{\circ}\text{C}$ for 2, 4 and 20 hours. The best medium for cashew pollen germination was found to be sucrose liquid medium (25%). Using the standardised medium, germination of pollen from male flowers and hermaphrodite flowers of nine cashew varieties was studied.

Pollen grains from male flower had higher germination than those from hermaphrodite flowers. Pollen from hermaphrodite flowers of six varieties (BLA 139-1, BLA 39-4, NRCC Sel-1, NRCC Sel-2, Ullal-1 and BPP-4) did not germinate while, those from the hermaphrodite flowers of three varieties (H 3-13, VRI-1 and VRI-2) showed moderate germination (Table 1.8). The germination of pollen from male flowers was highest (55.4%) in Ullal-1 variety followed by

Table 1.8: Percentage of pollen germination in two types of pollen source and cumulative yield in different cashew varieties

Variety	Pollen germination (%) at 20h		Cumulative yield (kg/tree)	
	Male flower as pollen source	Hermaphrodite flower as pollen source	10th harvest	5th harvest
BLA 139-1	32.3	Nil	8.0	-
BLA 39-4	46.2	Nil	11.7	-
NRCC Sel-1	30.6	Nil	-	2.0
NRCC Sel-2	35.4	Nil	2.1	
Ullal-1	55.4	Nil	7.5	-
H 3-13	17.3	14.2	2.1	-
BPP-4	34.9	Nil	11.0	-
VRI-1	24.7	11.1	9.5	-
VRI-2	33.4	16.3	12.2	-

BLA 39-4 (46.1%) while it was lowest in H 3-13 (17.3%) at 20 hours of incubation. The highest cumulative yield (12.2 kg/tree) was observed in VRI-2 which also had good pollen germination of 33.4 and 16.3 per cent in male and hermaphrodite flower respectively. The pollen germination was 46.2 per cent in BLA 39-4 which had a yield of 11.7 kg/tree (Table 1.8).

1.2.9 Biochemical analysis

Cashew kernels of 20 released varieties

were analysed for oil, protein, sugar and starch content. Oil content among different recommended varieties varied from 31.6 per cent (BLA 39/4) to 41.9 per cent (BPP-3). Protein content among the varieties varied from 35.59 per cent (NDR 2-1) and 59.15 per cent (H 2/12). Sugar content among different varieties exhibited variation from 6.52% (BLA 39/4) to 9.56 per cent (BLA 139-1). Starch content showed variation between 16.50% (EPM 9/8) and 28.33 per cent (NDR 2-1) (Table 1.9).

Table 1.9: Kernel composition of released varieties

Variety	Oil %	Protein %	Sugar %	Starch %
Trial-1				
BPP-1 (H 2/11)	36.5	47.09	8.88	19.32
BPP-2 (H 2/12)	37.7	59.15	7.81	19.05
BPP-4 (EPM 9/8)	34.4	49.94	7.97	16.50
BPP-5 (T.No. 1)	35.4	48.13	8.54	23.18
BPP-6 (T.No. 56)	38.1	54.52	8.57	19.60
BLA 139-1	35.3	52.32	9.56	18.87
BLA 39-4	31.6	40.76	6.52	20.03
Ullal-1	38.5	47.63	7.77	21.38
H 3-13	38.2	49.24	7.76	19.09
H 3-17	38.5	42.36	8.04	23.25
VRI-1	39.7	53.47	6.98	19.73
VRI-2	33.7	43.50	9.23	27.36
CD 1%	-	NS	NS	3.50
Trial-2				
BPP-3	41.9	56.16	8.27	20.96
K 22-1	35.4	49.82	7.27	18.15
NDR-2-1	34.7	35.59	8.08	28.33
Vengurla-1	37.9	46.03	7.30	25.73
Vengurla-4	38.2	52.79	7.31	19.82
Ullal-2	37.9	44.94	8.14	20.79
NRCC Sel-1	37.2	48.37	8.30	20.07
NRCC Sel-2	37.3	51.33	7.73	21.96
VRI-2	36.8	51.31	8.15	21.48
CD 1%	-	6.23	NS	NS

Note: Protein, sugar and starch on defatted kernel flour basis.

1.2.10 Sensory evaluation of processed kernels

Kernels obtained after processing the cashew nuts from a total of eleven varieties were evaluated for both physical and sensory characters such as colour, size, texture, taste and overall acceptability by a panel of 17 judges consisting of eight vegetarians and nine non-vegetarians. Hedonic scorings for these characters are

presented in Table 1.10. Among the 11 varieties, Selection-1 has been scored as the best with scoring of 1.56, 1.62, 1.94, 1.94 and 1.75 for colour, size, texture, taste and overall acceptability respectively. This is followed by Ullal-1 and Selection-2. Kernels of BPP-6 were least preferred with an overall acceptability score of 4.47.

Table 1.10: Sensory evaluation scores for eleven varieties

Variety	Colour	Size	Texture	Taste	Overall acceptability
H/2/12	3.06	4.35	3.47	3.47	3.33
BLA 139-1	3.18	3.58	4.41	3.65	3.83
Vengurla-1	3.41	3.82	2.82	2.70	2.80
Vengurla-4	2.52	2.70	2.52	2.47	2.60
VRI-1	2.76	2.76	2.82	2.71	2.71
VRI-2	3.73	2.31	2.87	2.68	3.86
NDR 2-1	2.94	3.58	2.76	3.88	3.06
BPP-6	3.76	4.70	3.35	4.12	4.47
Ufal-1	2.17	1.94	2.35	2.59	2.47
Section-1	1.56	1.62	1.94	1.94	1.75
Section-2	2.31	2.56	2.87	2.75	3.81

1.3 Micropropagation

Standardisation of a suitable micropropagation technique for cashew was attempted through nodal cultures from mature and juvenile explants and by induction of somatic embryogenesis.

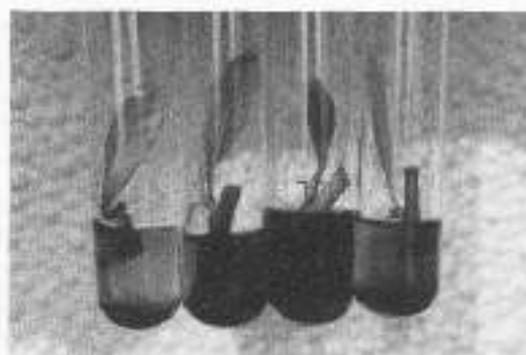
1.3.1 Regeneration from mature tree explants

a) Nodal cultures

Nodal cultures were established from 1 to 1 1/2 year old young cashew grafts of Ufal-2 and NRCC Sel-1 on half-MS medium. The establishment and budding of explants varied with month and season. Contamination was high (50-60%) during rainy season with reduced percentage of budding (20%). With the cessation of rains, the contamination of explants reduced (20-30%) and budding increased to a maximum of 75 per cent in February. In nodal culture NRCC Sel-1 responded better than Ufal-2. *Fusicoccum* was the predominant fungal contaminant.

Among the three basal media (semi-solid) tried viz., half-MS, full MS and woody plant medium (WPM) containing 0.2% activated charcoal and gelled with 2 g/l of phytoigel, half-MS medium with half the level of major nutrients proved superior with highest budding (82%).

Similarly, among four different antibrowning substances tried in media viz., activated charcoal (2g/l), 0.1% each of PVP-360 and PVPP (sigma) and 100mg/l of filter sterilized ascorbic acid. The media with PVP-360 and ascorbic acid showed maximum budding (70%).



Budding of nodal explants from mature tree

Eleven combinations of hormones (TDZ, BA alone and together at 3 levels each) were supplemented in MS basal medium for multiple shoot induction in Ufal-2. Media containing both TDZ (0.1mg/l) and BAP (0.1mg/l) induced maximum number of multiple shoots (2-3/ explant) in Ufal-2. In NRCC Sel-1, 12 media containing three levels each of BAP, kinetin, 2iP and TDZ, all with a common level of IBA (0.1

mg/l) and GA3 (0.5 mg/l) were tried. Here the medium containing 2mg/l BA along with IBA and GA3 induced maximum number of shoots (5-7 explant).

b) Induction on somatic embryogenesis

Ovules (nucellus) excised from three week old nuts of BLA 39-4 and H 4-7 were bisected and inoculated after removing embryos onto 6 sets of media (MS) containing 0.5 to 2 mg/l of 2,4-D with 0.5mg/l BAP or 0.1mg/l TDZ. Callus was induced after a fortnight in dark, which varied from 13.3 to 26.7 per cent and 71.4 to 100 per cent in BLA 39-4 and H 4-7 respectively. Callus induced in the early stage was white and compact and showed dark discoloration upon transfer to hormone free media and light condition.



Callus induction in bisected ovule (nucellus)

1.3.2 Regeneration from seedling explants

Shoot-tip cultures of H 4-7 (In vitro raised seedlings) were subjected to three cycles of multiple shoot-induction alternating the multiplication and elongation phase. The rate of multiplication recorded was 1:5, 1:3 and 1:6 respectively for first, second and third cycle. The cultures in third cycle of multiplication, were sub cultured for elongation of shoots.

When microshoots of VRI-2 (cotyledonary nodal cultures) were pulsed with 10m M NAA and IBA alone for 2 min and recultured on semisolid basal medium and soilrite medium, maximum rooting of shoots (60%) could be

observed in 10 mM NAA treatment when combined with semi-solid basal medium as an expression medium. Rooted plantlets (88 nos.) in five varieties (VRI-1, VRI-2, H 4-7, BLA 39-4 and dwarf type) were hardened in laboratory and the survival was 60-70 per cent. The hardened plants were repotted and maintained in green house for field planting.

1.3.3 VAM isolation

Four VAM species namely *Scutellospora nigra*, *Gigaspora multicincta*, *G. macrocarpa* and *G. austade* were isolated from native cashew soil. Pure cultures of most common VAM species (*S. nigra*) were used during hardening process by inoculating potting mixture with 50 g soil culture containing about 60-80 spores. There was no significant difference between the inoculated and uninoculated plants resulting in an uniform survival of 84.2 per cent.

1.3.4 Evaluation of tissue culture plants

One third of tissue cultured plants (29 nos.) planted during 1997 showed flowering during the year. Tissue cultured plants had greater trunk girth, height and lateral spread than control plants (grafted plants). Further they had greater root mass than control plants. Tissue culture plants showed predominantly extensive lateral system with extensive feeder roots (Table 1.11).

Table 1.11: Root studies in tissue cultured plants (1 year after planting)

Plant type	Root density (g/M ³ soil)		
	Thick roots	Thin roots	Total
Tissue cultured	53.42	38.26	91.68
Grafted plant	10.50	7.82	18.32

Biochemical analysis of microshoots for total phenolic content and ortho-hydroxy phenols showed no significant difference with rooting ability of genotypes. When tissue culture plants (20 nos.) from seedling explants of H 4-7 were grafted with scion of NRCC, Set 1, the grafting success was 100 per cent.

2. CROP MANAGEMENT

2.1 Propagation and rejuvenation

The objectives of the project are (i) to identify a root stock which can impart its dwarf/ semi-tall growth habit to the scion variety, (ii) to work out the economics of top working in cashew, and (iii) to study the effect of Paclobutrazol on canopy growth.

2.1.1 Root stock studies

Air layers of semi-tall types (VTH 762/2, VTH 762/4, S 11/1 and S 11/2) and tall type (Selection-1) planted during September 1996 were grafted *in situ* with the scions of tall type (Selection-1) during July 1997, to study the

influence of semi-tall root stocks on the growth of scion variety (Selection-1). Of the 40 air layers grafted *in situ* (@ 8 plants/root stock type), 22 were successful. Growth observations were recorded on semi-tall and tall root stocks (air layers - 2 years after planting) and *in situ* grafts of the above root stocks with scions of Selection-1 (15 months after grafting). Selection-1 root stocks were found to be vigorous as compared to other root stocks as revealed by the plant height and stem girth. Irrespective of the root stocks, the growth of the scion variety (Selection-1) was vigorous (Table 2.1).

Table 2.1 Mean plant height and stem girth of 15 month old *in situ* grafts involving tall and semi-tall root stocks (air layers) and tall growing scion variety (Selection-1)

Root Stock	Scion variety	Mean plant height (cm)			Mean stem girth (cm)	
		Below graft joint	Above graft joint	Total	Below graft joint	Above graft joint
Selection-1 (T)	Sel-1	69.4	149.2	218.6	11.5	11.6
VTH 762/4 (ST)	Sel-1	34.0	146.6	180.6	10.6	10.8
VTH 762/2 (ST)	Sel-1	26.0	184.0	210.0	14.0	13.0
S 11/1 (ST)	Sel-1	38.2	187.5	225.0	11.7	10.3
S 11/2 (ST)	Sel-1	37.0	151.6	188.6	10.8	10.0

Studies on root stock-scion interaction have been initiated with eight root stocks (Selection-1, Selection-2, VRI-1, VRI-2, VTH-174, Ullal-2, Kodyala-2 and NDR-2-1) and a vigorous/tall growing scion variety (Selection-1) and a less vigorous / semitall interstock variety (VRI-2). The seeds of eight root stock types namely, Selection-1, Selection-2, VRI-1, VRI-2, VTH-174, Ullal-2, Kodyala-2 and NDR-2-1 were sown in polythene bags for raising root stock

seedlings. Two month old seedlings of Selection-1 were taller (40.0 cm) as compared to the other root stock types (<32.2cm). Grafts/root stock type with scions of Selection-1 (vigorous type) and scion of VRI-2 (inter stock) (less vigorous type) were prepared and the successful grafts were utilized for producing double grafts with scions of Selection-1. The single grafts of VRI-2 (inter stock) with all the 8 root stocks were grafted (on new growth) with scions of vigorous growing

variety (Selection-1). The graft success in double grafting was found to be low.

2.1.2 Studies on top working

This trial was initiated during 1990 with the objective of comparing the economics of top working with that of replanting. Of the 30 top worked trees, 14 trees succumbed to CSRB

infestation during the initial years. The cost of establishment and maintenance of 0.2 ha plot each of top worked plot and replanted plot for the last nine years was Rs. 7060/- and Rs. 7014/- respectively (Table 2.2) and the cumulative yield obtained from top worked plot was 320.7 kg (7 annual harvests) and from replanted plot was 244.7 (6 annual harvests) (Table 2.3).

Table 2.2: Cost of establishment and maintenance of 0.2ha each of top worked plot and replanted plot during the last 9 years.

Year	Top worked plot (Rs.)	Replanted plot (Rs.)
1990-91	1241	620
91-92	845	530
92-93	955	808
93-94	829	1000
94-95	582	595
95-96	598	663
96-97	832	1023
97-98	456	855
98-99	622	920
Total	7060	7014

Table 2.3: Yield from 0.2 ha plot each of top worked plot and replanted plot

Year	Top worked plot (Kg.)	Replanted plot (Kg.)
1992-93	35.6	—
93-94	34.4	10.0
94-95	27.9	20.4
95-96	27.9	17.3
96-97	42.5	34.0
97-98	77.7	86.0
98-99	54.8	77.0
Total	320.7	244.7

Seven year old plants of V-2 were top worked with scions of V-4) during 1996. Of the 94 trees top worked six trees have died due to stem and root borer infestation despite regular prophylactic and curative treatments. Wherever CSRB infestation was observed the eggs and grubs were removed and treated with carbaryl (0.2%). The cost of establishment and maintenance of 0.25 ha of top worked plot in the scion bank for the last three years was Rs. 8542/- and the cumulative yield obtained during the second and third year of top working was 222 kg from 88 trees (Table 2.4).

Table 2.4: Cost of establishment and maintenance of 0.25 ha top worked plot in the scion bank during the last 3 years.

Year	Expenditure (Rs.)	Yield (Kg.)
1996-97	3098	-
97-98	2688	37.8
98-99	2756	184.3
Total	8542	222.1

2.1.3 Canopy Management Studies

The objectives of the project are to study the effect of pruning on canopy containment, flushing, flowering and yield of cashew.

A trial on canopy management was laid out with 4 x 4 factorial design wherein the first factor included four cashew varieties (VRI-1, Ullal-1, VTH 30/4 and Selection-1) and the second factor included four levels of pruning namely, no pruning (control), yearly pruning (general pruning + leader shoot pruning), alternate year pruning (general pruning + leader shoot pruning) and shape pruning (only general pruning). The pruning treatments were imposed during August 1995 (first cycle of pruning). The third cycle of pruning was imposed during the first week of September 1997. Yield did not vary significantly among varieties, it was however significant for pruning levels. The plants receiving no pruning (check) produced significantly more nut yield (4.5 kg cum.yield/plant), followed by shape pruning, alternate year pruning and yearly pruning. The fourth cycle of pruning treatments were imposed during first week of August 1998. (Table 2.5).

Table 2.5: Cumulative yield/plant (kg) (3 annual harvests)

Factor-A	Factor-B				Mean of Varieties
	No pruning	Yearly pruning	Alternate year pruning	Shape pruning	
VRI-1	5.5	4.0	4.8	4.7	4.7
Ullal-1	5.0	4.0	3.7	4.6	4.3
VTH 30/4	3.9	4.2	3.9	4.3	4.1
Selection-1	3.9	2.9	3.9	4.1	3.7
Mean of pruning levels	4.6	3.8	4.0	4.4	-

CD for variety : NS; CD for pruning : 0.57; CD for variety x pruning : NS

2.1.4 Evaluation of paclobutrazol

To study the effect of paclobutrazol (Cultar 25 EC), an antigibberellin biosynthate, on growth and fruiting in cashew, two experiments (RBD with split plots), namely, soil application and foliar application, were initiated on 10 year old V-3 and VTH 30/4 plants with 5m x 5m spacing.

The plant canopies were made uniform by pruning during first week of August 1998. Paclobutrazol was applied as both soil application (2.0, 4.0, 6.0 and 8.0 g.a.i./plant) and foliar spray (100 ppm, 200 ppm, 300 ppm and 400 ppm a.i./plant) separately. The soil application was done in months of September near the collar region and in circular ring mid way between trunk and drip line. Each dosage of paclobutrazol was dissolved in two litres of water and applied in 15 cm deep trench and covered with soil. Foliar application was given in pre and post flushing periods viz., September and November respectively. Each dosage of paclobutrazol was sprayed at two litres per plant.

2.2 Planting systems and spacing

The study was initiated to understand the effect of systems of planting and spacing on growth and yield of cashew under pruned and

unpruned conditions. The experiment was laid out following split plot design with three replications.

The main plot treatments included square systems (5.0 x 5.0m, 6.5 x 6.5m and 8.0 x 8.0m) and hedge system (5.0 x 4.0m, 6.5 x 4.0m and 8.0 x 4.0m) and with sub plot treatments being pruning and no pruning.

During summer, soil moisture at deeper levels was low in plot with high tree density (5 x 4m and 5 x 5m) when compared with that of low tree density (Table 2.6). Soil temperature in low tree density plot was observed to be higher as compared to high tree density plot (Table 2.7). Weed biomass collected in low tree density plots was three times more than that in high tree density plots (Table 2.8). Light interception of 85 per cent was observed five months after pruning in high tree density plots (pruning done in August to intercept light upto 80 per cent). In unpruned plot of the same treatment light interception was 92 per cent. Minimum light interception of 40 per cent was observed under low tree density eight years after planting. This indicates that there is a need for thinning during next season in high tree density plots (Table 2.9).

Table 2.6: Effect of plant density on soil moisture at three depths.

Treatment	Density (no./ha)	Pruned				Unpruned			
		0-30 depth (cm)	30-60 depth (cm)	60-90 depth (cm)	90-120 depth (cm)	0-30 depth (cm)	30-60 depth (cm)	60-90 depth (cm)	90-120 depth (cm)
1	400	18.4	22.6	22.7	20.3	17.5	23.0	22.5	19.4
2	236	18.2	23.6	23.5	25.3	18.4	24.6	24.5	26.4
3	156	16.2	18.2	24.5	26.3	17.2	19.2	22.5	25.2
4	500	19.6	22.4	20.8	18.5	18.5	23.4	19.5	17.2
5	384	18.0	23.4	22.5	19.5	18.2	22.8	23.5	19.8
6	312	18.5	23.5	21.6	19.8	18.2	24.5	20.6	19.5

NB: Field capacity : 37.8% (by volume)
Available moisture range : 16-37%

Table 2.7: Effect of plant density on soil temperature at three depths

Treat	Density (no./ha)	Pruned			Unpruned			Mean		
		5cm	10cm	15cm	5cm	10cm	15cm	10cm	15cm	
1	400	32.8	32.3	31.2	33.0	31.5	31.2	32.9	31.9	31.2
2	236	39.0	38.0	37.2	40.2	41.2	38.2	39.6	39.6	37.8
3	156	39.2	38.4	37.2	42.2	41.5	40.5	40.7	39.9	28.8
4	500	31.6	28.8	28.2	30.8	30.0	27.0	31.2	29.4	27.6
5	384	34.0	32.0	31.5	33.0	31.2	31.0	33.5	31.6	31.3
6	312	34.3	34.3	32.3	33.3	33.0	31.8	33.8	33.62	32.0

Table 2.8: Effect of spacing and system of planting on weed biomass collected and cashew leaf deposit

Treat	Density (no./ha)	Weed biomass (tonne/plot)		Cashew leaf deposit (tonne/plot)	
		Pruned	Unpruned	Pruned	Unpruned
1	500	0.10	0.11	0.32	0.29
2	236	0.34	0.35	0.24	0.26
3	156	0.36	0.38	0.18	0.19
4	400	0.10	0.13	0.36	0.34
5	384	0.25	0.25	0.31	0.28
6	312	0.27	0.26	0.25	0.24
CD for spacing		0.054		0.051	
CD for pruning		NS		NS	

Table 2.9: Effect of spacing and system of planting on girth, height, ground coverage and light interception

Treat.	Density (no./ha)	Girth (cm)		Height (cm)		Ground coverage (%)		Light interception (%)	
		Pruned	Un- Pruned	Pruned	Un- Pruned	Pruned	Un- Pruned	Pruned	Un- Pruned
1	500	44.8	43.5	384.0	349.3	75.5	96.3	57.7	90.3
2	236	44.9	43.4	337.3	324.3	52.8	54.5	49.0	49.7
3	156	45.9	45.0	348.0	333.3	44.6	51.0	39.7	43.0
4	400	44.4	44.0	376.6	364.3	91.0	100.0	85.0	92.7
5	384	44.7	44.9	355.3	340.3	69.0	71.7	58.0	60.0
6	312	45.9	45.4	361.0	340.0	58.5	53.5	52.7	55.3
CD for spacing		NS		25.68		3.364		4.61	
CD for pruning		NS		10.84		1.872		2.65	

Maximum yield of 500.6 Kg/ha was recorded with a spacing of 5 x 4m and minimum yield of 202.8 Kg/ha was recorded with a spacing of 8 x 8m in the sixth harvest. Cumulative yield

from six harvests was maximum (2372 kg/ha) in 5 x 4m spacing followed by 5 x 5m spacing (1930 Kg/ha) (Table 2.10). Cumulative yield was minimum (689 Kg/ha) in 8 x 8m spacing.

Table 2.10: Effect of spacing and system of planting under pruned and unpruned conditions on yield (8 years after planting)

Spacing (m x m)	Plant Population	Yield/plant (kg)		Yield/ha (kg) 6th harvest		Cumulative yield (kg/ha)	
		Pruned	Unpruned	Pruned	Unpruned	Pruned	Unpruned
Square							
5.0x5	400	1.0	1.1	391	433	1930	1877
6.5x6.5	236	1.3	1.2	315	269	1125	1004
8x8	156	1.3	1.1	200	177	689	515
Hedge							
5x4	500	1.1	1.0	561	510	2372	2236
6.5x4	384	1.3	1.2	454	447	1544	1461
8x4	312	1.3	1.2	404	384	1417	1239

2.3 : Cropping systems

In plots where casuarina and acacia trees were grown as intercrops for the first 6 years in cashew plantations and subsequently removed, the yield did not increase even after three years after removal of tree species. The income realised from intercrops acacia and casuarina were Rs.40505/ha. Income realised from subabul and ailanthus were minimum (Rs.11500 and Rs.9900/ha) (Table 2.11).

Economics worked out for the entire plot including main crop (cashew) indicated that maximum profit of Rs.15902/ha was realised from plot where two rows of acacia and a row of casuarina were grown as intercrops between 2 rows of cashew for the first six years. Next to this, maximum profit of Rs.15378/ha was realised from plot where high density planting of cashew was adopted. The profit realised when cashew alone was grown was Rs.4624/ha (Table 2.12).

Table 2.11: Poles and fuel wood yield from intercrops.

Cropping systems	Poles (Nos/ha)	Fuel wood (tonnes/ha)	Revenuc/ha (Rs.)
Cashew + casuarina (2 rows) + acacia (1 row)	390+770	0.57+1.14	33375
Cashew + acacia (2 rows) + casuarina (1 row)	820 + 540	2.12 + 0.65	40505
Cashew + bamboo	12400	--	12400
Cashew + ailanthus	--	16.5	9900
Cashew + subabul	--	23.0	11500

Table 2.12: Cost benefit analysis for the first 9 years in cashew based cropping system (Rs./ha)

Cropping systems	Cost of cultivation of main crop	Cost of cultivation of intercrop	Returns from Main crop	Returns from Intercrop	Total profit
Cashew + casuarina (2 rows) + acacia (1 row)	26862	14300	12798	33375	5011
Cashew + acacia (2 rows) casuarina (1 row)	26862	13900	16159	40505	15902
Cashew + bamboo	26862	11578	28891	12400	2851
Cashew + ailanthus	26862	6578	34066	9900	10526
Cashew + high density	53724	--	69102	--	15378
Cashew + subadul	26862	10500	28476	11500	2614
Cashew alone	26862	--	31486	--	4624

2.4 Integrated Nutrient Management

The possibility of composting and vermicomposting cashew wastes and to develop suitable organic manure for cashew was evaluated in this trial. Separate experiments are laid out for the standardisation of vermi-composting and composting of cashew waste which include leaves and apples.

All the organic manures were analysed for the nutrient contents and accordingly the quantity of different manures were applied as per the treatment requirements.

Out of the initial 1.5 ton of partly decomposed cashew waste, 0.3 ton of vermi compost was produced from cashew wastes within six months of introduction of earthworms (*Eudrilus* spp.). The nutrient content of vermicompost produced from the first batch was as follows:

N(%)	-	1.2	Cu (ppm)	-	12.36
P ₂ O ₅ (%)	-	0.92	Fe (ppm)	-	161.5
K ₂ O (%)	-	0.60	Zn (ppm)	-	29.7
Ca (%)	-	2.76	Mn (ppm)	-	24.5
Mg (%)	-	0.83			

3. CROP PROTECTION

Various approaches were evaluated for management of two important pests of cashew viz., cashew stem and root borers (CSRB) and tea mosquito bug (TMB). Physical parameters of trees infested by CSRB were recorded to identify the pre-disposing factors for pest incidence. Besides post treatment prophylaxis using synthetic insecticides, entomopathogenic fungi and physical barriers to avoid oviposition were evaluated.

Plant products and new insecticides were evaluated for the management of TMB. The presence of natural enemies was studied by

adopting host enrichment technique (HET).

3.1 Cashew stem and root borer (CSRB)

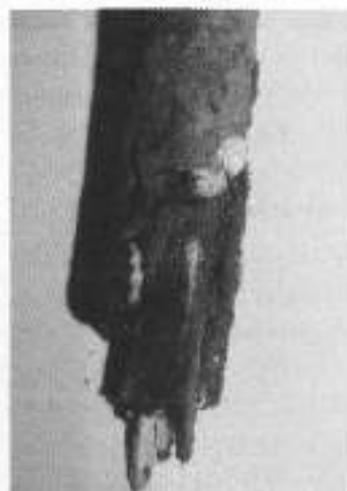
3.1.1 Enumeration of physical parameters

The observations on stem circumference, percentage circumference of bark damaged, age of the tree, zone of incidence, nature of bark and distance from severely infested tree were recorded to understand the relationship between the physical characters of the tree and pest incidence. The frequencies of infested trees and trees without reinfestation were assigned to each group and are mentioned in Table 3.1.

Table 3.1: Physical parameters of infested and recovered trees in various locations.

Parameters	Kemminje		Shantigodu		Aladka	
	Infested trees (no.)	Trees with no reinfestation (%)	Infested trees (no)	Trees with no reinfestation (%)	Infested trees (no)	Trees with no reinfestation (%)
1. Tree girth (cm)						
60	49	91.8	8	62.5	--	--
60-80	69	69.6	21	66.6	3	66.6
80	37	37.5	5	80.0	13	84.6
2. % Circumference of bark damaged						
25	52	84.6	12	100.0	9	66.6
26-50	50	74.0	9	88.8	5	100.0
51-75	10	90.0	3	66.7	2	50.0
75	43	48.8	10	10.0	--	--
3. Age of tree						
5-10 yrs	35	94.3	12	83.3	--	--
> 10 yrs	120	65.0	22	59	16	81.2
4. Zone						
Stem/Fork	8	87.5	2	100.0	--	--
Collar + Stem	53	69.8	1	100.0	2	50.0
Collar + Root	94	71.3	31	64.5	14	85.7
5. Distance from severely infested tree						
8m	9	22.2	1	100.0	--	--
8-16m	1	100.0	--	--	--	--
> 16m	145	74.5	33	66.7	16	81.2
6. Nature of bark						
Smooth	--	--	5	100	--	--
Rough	155	71.6	29	62.6	16	81.2
Flaky	--	--	--	--	--	--

Percentage circumference of bark damaged had a strong relevance to the recovery of trees. The recovery of infested trees was better when less than 75 per cent of bark was damaged. Number of infested trees in different categories had no specific trend, and recovery was higher (>50%) when less than 75 per cent of bark was damaged. The infestation was more in trees of over 10 years age and recovery of trees was higher (beyond 80.0%) in trees aged less than 10 years.



CSRB grubs feeding in root zone

Infestation occurred in the collar + root zone in majority of trees (61.0%) while least infestation (5.2%) was noticed in stem / fork zone. With the exception of Goa 11/6 which had smooth bark, all other infested trees had rough bark texture. A vast majority of infested trees (93.5%) were more than 16 away from a severely infested tree or did not have a severely infested tree nearby indicating the random incidence by the pest.

3.1.2 Post treatment prophylaxis trials

(a) Evaluation of pesticidal treatments

After mechanical extraction of CSRB grubs, trees were swabbed / drenched with different insecticides. Trees were free from reinfestation to the tune of 55.0 per cent in chlorpyrifos (0.2%), 65.0 per cent in carbaryl

(1.0%), 70.0 per cent in monocrotophos (0.2%) and 75.0 per cent in lindane (0.2%) treatments. No fresh infestation was observed during monsoon (June-September). However, infestation persisted in 22 treated trees which had grubs in the root zone without having come into pesticidal contact. Statistical analysis of data indicated no significant difference among various insecticidal treatments (Table 3.2).

Table 3.2: Efficacy of post treatment prophylaxis on checking reinfestation.

Insecticidal suspension evaluated	Mean % trees without re-infestation	Cost/tree/round (Rs.)	
		Swabbing	Drenching
Chlorpyrifos 0.2%	55	3.60	7.20
Monocrotophos 0.2%	70	2.28	4.56
Carbaryl 1.0%	65	6.40	12.80
Lindane 0.2%	75	1.50	3.00
CD at 5%	N.S	--	--

In order to understand the oviposition period, grubs collected from infested trees were categorised into different age groups based on prothoracic shield width and their ages were backdated for estimating the month of oviposition. This indicated peak oviposition during Feb-May, which is the critical time for checking oviposition and removing the grubs. Trees which were treated during this period recovered without being reinfested by the pest and showed fresh bark growth.



Fresh bark growth in tree recovering from CSRB attack

b) Evaluation of fungal entomopathogen (*Metarhizium anisopliae*)

Eighty per cent of the treated trees had no reinfestation by the pest when treated with spore suspension of *M. anisopliae* (250 g spore + 500 g neem cake/tree). Fungal mycelial growth was also noticed in seven trees during July-Aug.

c) Evaluation of physical barriers

Trees in initial stages of infestation did not have fresh egg laying or pest incidence when the physical barriers viz., polythene sheet wrapping, stem swabbing with Snowcem and application of mud slurry with carbaryl was adopted. However, application of coal tar + kerosene was not effective as egg laying and pest incidence were observed in the treated trees. Some trees had residual infestation in the physical barrier treatments under moderate level of attack.

3.1.3 Field survival of *M. anisopliae*

Spore of *M. anisopliae* was applied (250 g/tree) along with 500 g of neem cake. A sample of 100 g soil (apprx.) from around the plant was suspended in 250ml water and diluted to 10⁻⁵. The dilution was then used for inoculation on PDA medium. The number of colonies of *M. anisopliae* developing on PDA medium was duly recorded.

Fungal survival was noticed upto 150 days, while infectivity ceased after 60 days after application (Table 3.3).

Table 3.3: Survival of *M. anisopliae* under field conditions and infectivity on CSRI grubs.

Days after soil treatment	No. of colonies/ petri dish	% Mortality of CSRI grubs at 30 DAT
0	42.51	100.00 (90.00)
15	34.06	71.21 (76.72)
30	28.50	70.00 (57.10)
60	25.615	50.00 (45.00)
90	21.742	0.00 (0.00)
170	18.100	0.00 (0.00)
150	16.10	0.00 (0.00)

DAT = Days after treatment

Note: Values in parentheses are arc transformed values

3.1.4 Studies on volatiles

a) Bioassay of plant parts

Various portions of infested cashew tree viz., fresh frass, exuded gum and infested bark were evaluated for their ability to evoke response in adult CSRI beetles using a glass wind tunnel olfactometer. There was a significantly higher response of female beetles (both virgin and mated) to fresh frass. Response of male beetles to the test material was on par with check (blowing air without placing any plant part) (Fig. 3.1).

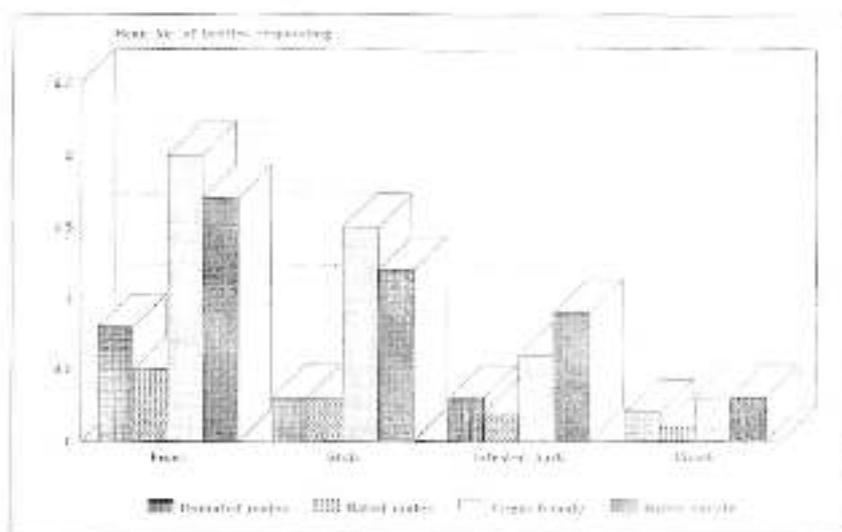


Fig. 3.1 Response of CSRI grubs to different plant parts under olfactometer studies

3.2 Tea Mosquito Bug

3.2.1 Plant products

The Dillapiole formulation received from M/s Plant Lipids Ltd., Cochin was tested under laboratory condition for knockdown mortality of TMB at three concentrations viz., 0.25, 0.5 and 1.0 per cent. Complete mortality was observed within 24 and 48hr at 1.0 and 0.5 per cent respectively. However, all the three concentrations induced phytotoxicity. At the same time, when

Dillapiole (1.0%) was tested under field condition for residual toxicity to TMB, the phytotoxicity was observed within one hour of spraying and was not effective against TMB. Similarly when a neem based formulation (Achook) was tested under field condition @ 10ml/litre of water, it induced least control of TMB (Table 3.4).

Table 3.4: Residual effect of insecticides on survival and damage of TMB recorded on panicles.

Treatment	No. surviving after 24 h				Damage grade after 48 h			
	0 day	3rd day	7th day after spray	Mean	0 day	3rd day	7th day after spray	Mean
Dillapiole 1.0%	3.3 bA	4.0 dA	4.0 cA	3.8 c	2.0 cA	3.0 cA	3.7 cB	3.2 d
Endosulfan 0.05%	0.0 aA	3.7 cC	2.7 bB	2.1 b	1.0 cA	3.0 dB	3.7 cC	2.7 cd
Monocrotophos 0.05%	0.0aA	2.3 bB	2.7 bB	1.7 b	1.0 cA	1.7 cB	2.3 bC	1.7 c
Carbaryl 0.1%	0.0 aA	0.7 aB	0.0 aA	0.2 a	0.7 bA	0.7 bA	1.0 aB	0.8 b
Profenphos 0.05%	0.0 aA	3.3 cB	4.0 cC	2.4 b	1.0 cA	2.7 dB	3.7 cC	2.5 cd
Profenphos 0.05% + Cipermethrin	0.0 aA	1.0 aB	1.0 aB	0.7 a	0.0 aA	0.3 aB	1.3 aC	0.5 a
Quinalphos A.F. 0.05%	0.0a A	2.3 bB	3.3 cC	1.9 b	1.7 dA	2.7 dB	4.0 dC	2.8 d
Control	4.0 bA	4.0 dA	4.0 cA	4.0 c	3.3 cA	3.3 cA	3.3 cA	3.3 d

Means followed by common small letter in each column & capital letter in each row is not statistically different at 5% LSD.

3.2.2 Synthetic insecticides

Three synthetic formulations viz., profenphos (0.05%), profenphos (0.05%) + cypermethrin and quinalphos A.F. (0.05%) were evaluated along with standard recommended insecticides (endosulfan 0.05%, monocrotophos 0.05% and carbaryl 0.1%) under field condition for residual toxicity and oviposition deterreny. Carbaryl (0.1%) had shown highest residual action against adults of TMB. The damage by first instar nymphs and oviposition were least in this treatment. However, none of the insecticides exhibited ovicidal action (Table 3.4 & 3.5).

3.2.3 Studies on natural enemies

Telenomus sp. laricis group was recorded as a dominant egg parasitoid species of TMB throughout the year when the eggs of TMB were subjected to natural parasitism through host enrichment technique (HET) and in simultaneous field collected egg samples of TMB collected from the insecticide treated plot (Fig.3.2). Parasitoid emergence on thirtieth day of parasitism under HET was highest during August-September (22.2-25.9%) whereas in the field collected egg samples of TMB, highest emergence could be seen during March-April (12.7-16.2%) and August-September (11.7-12.2%).

Table 3.5: Residual effect of insecticides on oviposition, hatching of eggs and damage of 1st instar nymphs of TMB

Treatment	No. surviving after 24 h				Hatching of eggs (%)	Damage grade by 1st instar nymphs
	0 day	3rd day	7th day after spray	Mean		
Dillapiole 1.0%	24.3	19.0	27.0	23.4 c	100.0	4.0 b
Endosulfan 0.05%	11.0	15.0	15.3	13.8 b	100.0	4.0 b
Monocrotophos 0.05%	3.0	0.7	6.0	3.2 a	100.0	0.3 b
Carbaryl 0.1%	1.3	0.0	0.7	0.7 a	100.0	0.0 a
Profenphos 0.05%	2.3	15.7	19.7	12.7b	100.0	0.0 a
Profenphos 0.05% + Cipermethrin	0.7	1.3	20.3	7.4 ab	100.0	0.0 a
Quinalphos A.F. 0.05%	13.7	22.3	30.3	22.1 c	100.0	4.0 b
Control	9.0	13.7	21.0	14.6 bc	100.0	4.0 b
CD					N.S.	
CD for interactions				N.S.		

Mean followed by common small letter in each column is not significant at 5% LSD.

The nymphal and adult population of TMB were periodically sampled for detection of nymphal adult parasitoid (NAP) and mermithid nematode (MN). Out of 1954 nymphs and adults examined, the occurrence of NAP was observed

only in certain months in a range of 0.5 to 6.6 per cent whereas, the occurrence of MN was observed at a low level (1.8-5.1%) which was confined only to rainy season.

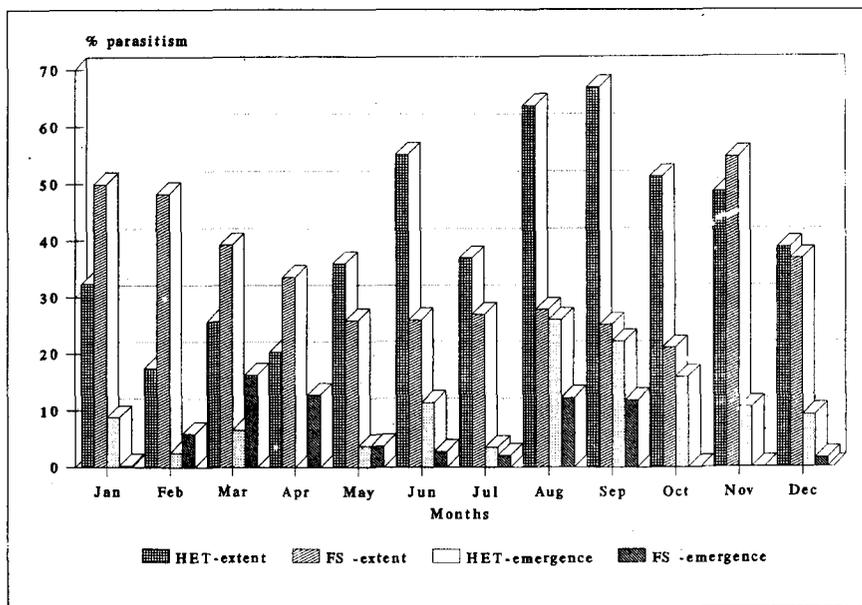


Fig. 3.2: Egg parasitism of TMB by *Telenomus* sp (1988)

4. POST-HARVEST TECHNOLOGY

4.1 Functional properties of defatted cashew kernel flour

Processing of cashew results in kernels of different grades among which baby bits are of the lowest grade. In order to develop value added products from such low grade kernels, understanding of the functional properties of the defatted cashew kernel flour is essential.

Defatted flour from different grades of cashew kernels, almond kernels (commercial sample and widely cultivated variety procured from CITH, Srinagar) and soybean (JS 335 variety from NRCS, Indore) was prepared by extraction with n-hexane at ambient temperature (27-30°C)

and defatted kernel flour was used for the study of functional properties such as water and oil absorption capacities, least gelation concentration, foaming capacity, emulsification capacity and protein solubility (Table 4.1). Defatted cashew kernel flour from whole kernels was better than almond with respect to water and oil absorption capacities, foaming capacities and emulsification capacity. This indicates that cashew kernel flour would be better in developing products compared to almond. Similarly, least gelation concentration with respect to cashew was quite less which is an added advantage in developing products whenever

Table 4.1: Functional properties of different defatted meal.

Defatted meal	Water absorption capacity (%)	Oil absorption capacity (%)	Least gelation conc. (%)	Foaming capacity (% volume increase)	Emulsification capacity		<i>In vitro</i> digestibility
					ml oil/g flour	ml oil/g protein	
Whole cashew kernel	56.3	128.8	6.0	53.0	30.2	49.6	37.0
Cashew kernel- Baby bits	59.8	100.4	9.0	10.0	32.5	58.6	38.7
<i>Cashew kernel- Dessert</i>	<i>48.8</i>	<i>84.0</i>	<i>7.5</i>	<i>8.0</i>	<i>30.8</i>	<i>55.8</i>	<i>41.3</i>
Almond kernel- Commercial	36.7	84.4	10.0	20.0	27.0	48.9	47.2
Almond kernel- Sample	46.8	115.5	6.0	42.0	32.8	63.0	47.0
Soybean JS335	100.2	96.8	15.0	50.0	22.7	34.7	56.8

foaming is desirable. Defatted soybean flour had higher water absorption capacity compared to cashew which is a desirable factor for developing products. *In vitro* digestibility of defatted flour of different grades of cashew did not show variation (37 to 41%). Similarly variation *in vitro* digestibility was not observed in different almond samples. Protein solubility of different defatted flours at pH from 3.0 to 8.0 were similar.

Solubility did not increase with pH from 3.0 to 8.0. Beyond pH 8.0, the solubility of protein from all the defatted flour increased. Solubility of protein at pH 2.0 was higher compared to pH 3.0 with defatted flour from whole cashew kernel.

soybean and commercial sample of almond (Fig.4.1).

Solubility behaviour of protein from different defatted flour was similar at sodium chloride concentration ranging from 0 to 0.6 M indicating that addition of salts is not necessary for enhanced extraction (Fig.4.2). Decrease in foaming capacity of the defatted kernel flour from whole cashew kernels over a period of 180 min was less between pH 3.0 and 9.0 whereas, the foam was less stable at pH 2.0 and 10.0 (Fig.4.3). This indicates that foam stability needs to be increased with the help of stabilising agents at neutral pH.

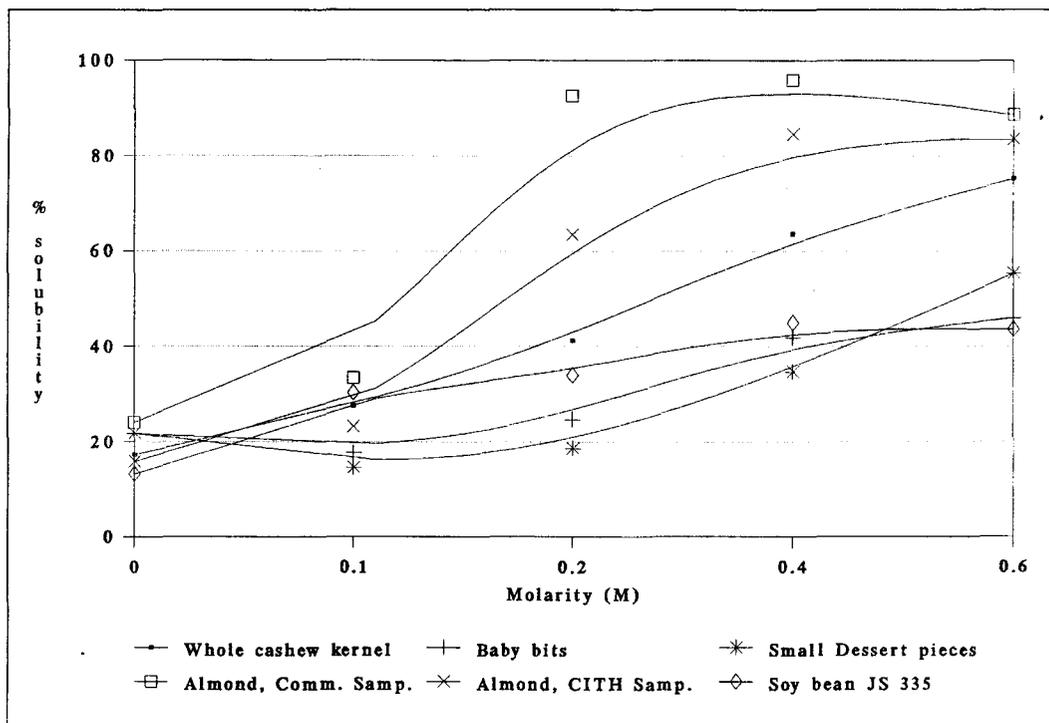


Fig. 4.1: Protein solubility at different NaCl concentration (%)

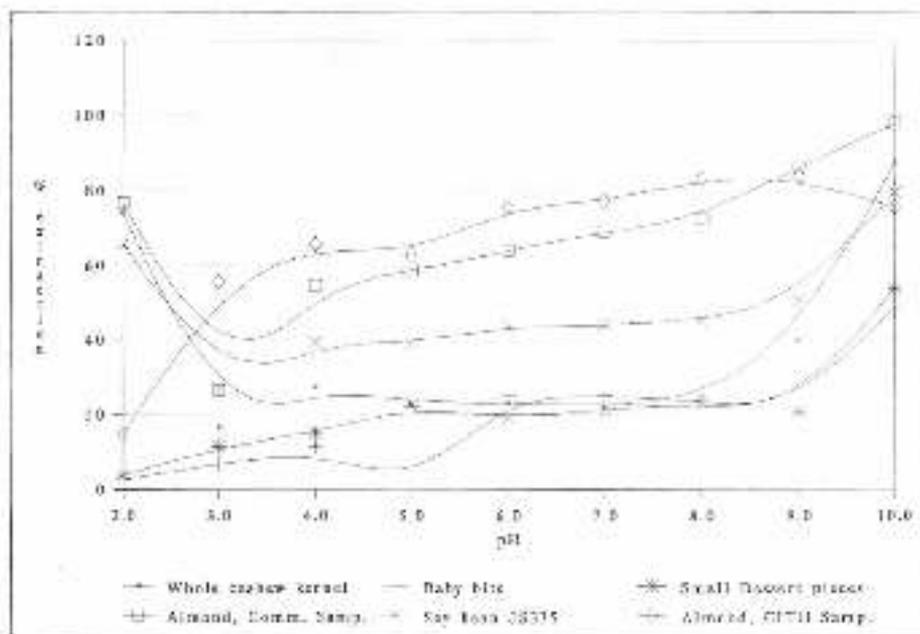


Fig. 4.2: Protein extractability at different pH

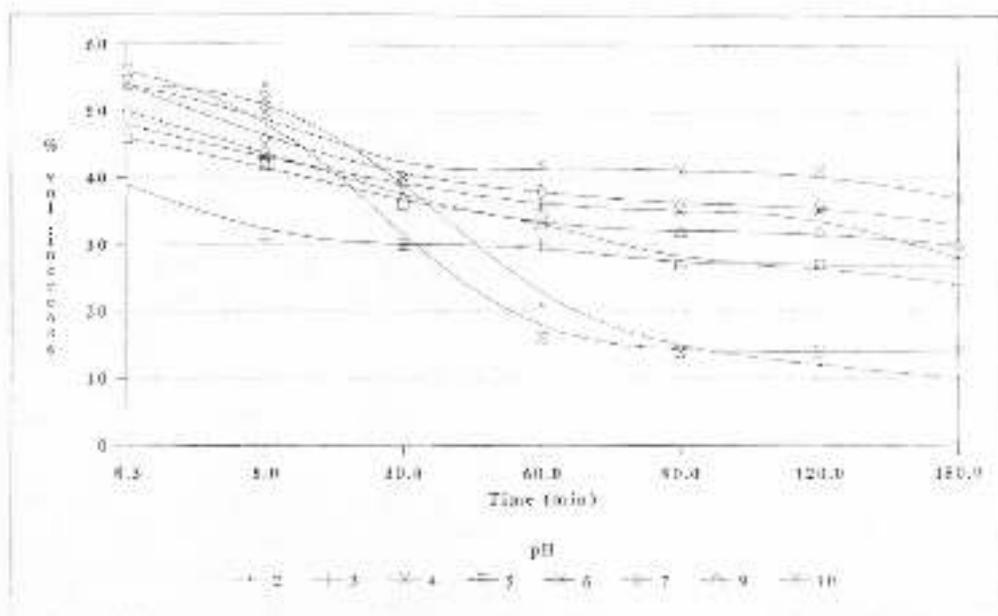


Fig. 4.3: Effect of pH on foaming stability of defatted kernel flour of whole cashew kernels

5. TRANSFER OF TECHNOLOGY

5.1 Research cum demonstration plots

Twenty sites were visited in Bantwal, Belthangadi, Karkala, Puttur and Sullia taluks for selecting plots for laying out demonstrations under the Central Sector Scheme of DCCD. Of these, 15 farmers were short listed and called for a meeting to finalise the selection process. Nine farmers attended the meeting held on July 16, 1998. Of these farmers, eight complied with planting as per recommendations within the planting season. All the eight plots were visited on 18th and 19th August 1998 to see whether planting was done as per recommendations.

5.2 Soil and water conservation campaign

A series of campaigns on soil and water conservation in cashew garden was conducted in two villages of Puttur and Sullia taluks during September-October, 1998.

Planning

Since adoption of soil and water conservation practices involves understanding of the concept and committed interest, it was decided to involve only selected farmers. A press note was issued in all local newspapers and All India Radio to give wide publicity to the programme and farmers were informed to register themselves for the programme. Detailed programme chart was intimated to registered participants.

Execution

On the specified day, the farmers assembled at either Panchayat office or on the farm of demonstration farmer and were briefed about the need for the programme. The techniques of soil and water conservation were explained to



Farmers discussing during soil & water conservation campaign

them with the help of charts/posters prepared specially for the purpose. After the initialisation, the farmers were taken to the nearby demonstration farmer's plot and the actual technique of terracing, opening catch pits/slaggered trenches etc. were demonstrated. Later, the farmers re-assembled to clear their doubts. Leaflets and hand outs were distributed to them before they dispersed.

Follow Up

A press release was issued about the campaign held. A questionnaire was sent to all the farmers who had participated in the programme to obtain their suggestions/comments for further improvement. Feedback was received from 40 per cent of the farmers to whom questionnaire was sent. Majority of the respondents felt that the timing of the event was appropriate, information provided was adequate, visuals used were effective, literature provided was supplementary and the adoptability of the soil and water conservation practices was high. However, 21 of the respondents expressed that they would adopt the practices fully while 18 responded that they would adopt partially.

Specialities of the event

There was no formal function in order to avoid waste of time and promote focused attention on the topic. The entire programme was carried out in the village setting availing the existing facilities only. This facilitated better discussion as there was no barrier between the scientists and farmers. The demonstration farmer in the village hosted the event.

5.3 Annual Cashew Day

Annual Cashew Day was conducted on 26th March 1999 in which over 170 farmers participated. The farmers registered for the event responding to the press note / AIR announcements issued about the event. Farmers organisations, NGO's were also contacted to sponsor farmers for participation in the event. A 'Kisan Goshthi'

was organised for farmers in which selected progressive farmers presented their experience in different aspects of cashew cultivation. A booklet was brought out in which answers to the questions asked by farmers on cashew cultivation were compiled. This was one step ahead in ensuring farmers participation in technology refinement and transfer.



Kisan Goshthi

2.1 Propagation and rejuvenation studies in cashew - studies on top working

Leader	:	KRM Swamy (1990-1999)
Associates	:	N Baktavatsalam (1990-1992) PS Bhat (1993-1994) T.N. Raviprasad (1995-1999) MG Nayak (1994-1995)

INTRODUCTION

One of the reasons for low yields in cashew is that most of the cashew plantations have been established from seedling progenies of low genetic potential. The research work carried out at Agricultural Research Station, Ullal, has indicated that it is possible to double the yields of existing poor yielding cashew seedling progenies in a short span of time, if these plantations are rejuvenated by top working with the scions of high yielding variety. Top working involves substituting the crown of the poor yielding tree with scions of high yielding varieties, taking advantage of the well developed root system, to improve their productivity. Earlier studies conducted at NRCC have indicated that heading back of trees during April-September and grafting the juvenile shoots during June-November gave good graft success (53-78%). Heading back of the trees to a height of 0.75-1.00 m from ground level was found to be ideal. However, mortality of the top worked trees was high due to cashew stem and root borer (CSR) infestation (61.1-94.5%). Hence, the studies on top working were initiated at National Research Centre for Cashew, Puttur with the following objectives.

OBJECTIVES

- i) To compare the economics of top working with replanting of cashew.
- ii) To conduct on-farm trials on top working.

- iii) To replace a variety in the scion bank by adopting top working technology.

MATERIALS AND METHODS

1. Technique of top working

The selected cashew trees were headed back to a height of about 0.75-1.00 m from ground level by cutting the branches and then the trunk with a saw to avoid splitting of main stump. Bordeaux paste (10%) was applied to the cut surface to protect the stems from die-back or fungal diseases and later the entire trunk portion was swabbed with carbaryl (0.2%). The stumps were shaded during May using paddy straw / dry grass to avoid bark splitting.

Sprouts developing were thinned after 15-20 days after sprouting retaining 15-20 shoots per tree for grafting. Precured scions of a desired variety were utilized for grafting the 30-40 cm juvenile shoots (10-12 shoots/tree) by adopting softwood grafting technique.

The grafts sprouted within 3-4 weeks and the graft joint got healed within two months' time and 4-5 successful grafted shoots were retained per tree after 5-6 months of grafting. All the new shoots on the stump and on the root stock below the graft joint were removed frequently and successful grafts were staked to avoid wind damage. The polythene strips from the graft joint were removed after 2 months of grafting, to avoid girdling at the graft joint.

Prophylactic swabbing with carbaryl (0.2%) to check stem and root borer infestation was done at regular intervals. As the beheaded trees attracted the stem and root borer beetles for egg laying, the top worked trees were checked at regular intervals, and the eggs and grubs present were removed by chiselling out the bark and the affected portion was swabbed with carbaryl (0.2%).

The recommended package of practices were adopted for maintaining the top worked trees.

2. Experiments on top working

(i) Top working vs. Replanting

With the objective of comparing the economics of top working with replanting of cashew, this experiment was started during June 1990 at Shantigodu. Thirty cashew trees (0.2 ha) of 14 year old which were headed back during June 1990, were top worked with scions of VTH 30/4 by adopting soft wood grafting technique during September-October 1990 adopting suitable plant protection measures. Adjacent to this plot, 30 cashew trees (0.2 ha) were removed and replanted with one year old grafts of VTH 30/4 during August 1990.

(ii) "On Farm trial"

An "On Farm Trial" of top working was laid out in the Karnataka Cashew Development Corporation (KCDC) Plantations, Kunthur during May 1992. Sixty cashew trees (11 year old) were top worked and prophylactic treatment with coal tar and kerosene (1:2) upto a height of 30 cm from ground level was adopted. The remaining portion was swabbed with carbaryl (0.2%). During July-

August precured scions of VTH 174 were grafted on these beheaded trees. Another "On Farm trial" on top working was initiated during August 1994 at CPCRI, Regional Station, Vittal. Thirty five healthy trees (12 years old) were topworked using scions of NRCC Sel-1 adopting softwood grafting technique and suitable plant protection measures were followed.

The top worked trees were inspected for presence of stem and root borer egg/grubs which were mechanically removed by chiselling the bark followed by swabbing of carbaryl (0.2%) to the infested area.

(iii) Top working in the scion bank

Ninety four cashew trees of Vengurla-2 variety, aged seven years, were top worked with scions of Vengurla-4 variety during 1996 (beheading in May and grafting in July) by adopting softwood grafting technique. Prophylactic treatments were given at regular intervals with carbaryl (0.2%), after removing the eggs and grubs from the CSRB infested trees.

The recommended package of practices were adopted for maintaining these experimental plots.

RESULTS AND DISCUSSION

(i) Top working vs Replanting

The mean graft success was 72.5% in the top worked trees. Of the 30 top worked trees, 14 trees (46.6%) have died due to stem and root borer infestation during the first (11 no.) and second (3 no.) year of establishment, despite of swabbing the trunk portion with carbaryl (0.2%) after removing the eggs and grubs at regular intervals

(Table 1). The cost of establishment and maintenance of 0.2 ha each of top worked and replanted plot for the last nine years was Rs. 7060 and Rs. 7014, respectively. The cumulative yield obtained from top worked plot (320.73 kg/7 annual harvests) was more than that from replanted plot (244.60 kg/6 annual harvests) (Table 2). The cumulative income obtained from top worked plot was more (Rs. 10,344/-) than that from replanted plot (Rs. 9370/-).

(ii) "On Farm trial"

The graft success was 83.0 per cent (Table 1). Of the 60 top worked trees, 48 died (80%) during the first year and 5 died (8.3%) during the second year due to CSRIB infestation, inspite of regular prophylactic treatment with carbaryl (0.2%). This plot was surrounded by the other KCDC plantations with many CSRIB infested trees. However, this area has been converted into scion bank by planting cashew grafts of Selection-1 and Selection-2 during the

second year, as the mortality of the top worked trees was high. The expenditure incurred for establishing and maintaining 0.4 ha top worked plot (60 trees) during the first year was Rs. 2455.

In this trial, conducted at Vittal, a mean graft success of 57.7 per cent was observed (Table 1). Of the 35 be-headed trees, 11 trees (31.4%) died due to stem and root borer infestation and the remaining 24 trees were top worked, of which 14 trees died due to CSRIB infestation (58.3%), inspite of regular prophylactic treatments given with carbaryl (0.2%) (Table 1). The number of eggs and grubs extracted from each infested tree ranged from 0-93 and 1-22, respectively. The peak activity of the adults was noticed in the months of March and April and about 90 per cent of eggs were collected during this period.

This plot was also surrounded by plantations with several CSRIB infested trees. The cost of establishment and maintenance of 0.2

Table 1: Results of top working trials conducted during 1990-1999 at different locations.

Location	Year	Age of Plants (yrs)	Month of heading back	Month of grafting	No. of plants top worked	Graft success (%)	Surviving plants (No.)	Mortality (No.)	Mortality (%)
Shantigodu	1990	14	June	Sept/Oct.	30	72.5	16	14	46.6
Kunthur	1992	11	May	July/Aug	60	83.0	7	53	88.3
Vittal	1994	12	August	Nov/Dec	24	57.7	10	14	58.3
Shantigodu (Scion bank)	1996	7	May	July	94	82.5	88	6	6.4

Table 2: Comparison of economics of top working with replanting

Year	Top working plot (0.20 ha)			Replanted plot (0.20 ha)		
	Establishment / maintenance cost	Yield (Kg)	Income (Rs.)	Establishment / maintenance cost	Yield (Kg)	Income (Rs.)
1990-91	1241	--	--	620	--	--
1991-92	845	--	--	530	--	--
1992-93	955	35.63	891	808	--	--
1993-94	829	34.35	859	1000	10.00	250
1994-95	582	27.90	697	595	20.40	510
1995-96	598	27.86	836	663	17.30	519
1996-97	832	42.54	1489	1023	34.00	1190
1997-98	456	77.65	3106	855	85.90	3436
1998-99	722	54.80	2466	920	77.00	3465
Total	7060	320.73	10344	7014	244.60	9370

ha top worked plot during the first year was Rs. 3784.

(iii) Top working in scion bank

Scions of Vengurla-4 were utilised with a mean graft success of 82.5 per cent (Table 1). Of the 94 top worked plants, 6 plants succumbed to CSRB infestation (6.4%) inspite of regular prophylactic treatment (Table 1). The top worked trees were checked for CSRB infestation periodically and wherever infestation was observed, the eggs and grubs of CSRB were removed by chiselling out the bark and treated with carbaryl (0.2%). The percentage of bark removed at the time of extraction of eggs and grubs from such trees ranged from 5-60 per cent and 78 such treated trees survived. This is due to the fact that there was no girdling effect on the tree.

The cost of establishment and maintenance of 0.25 ha top worked plot in the scion bank for

the last 3 years was Rs. 8542/-. The cumulative yield obtained from top worked plot (0.25 ha) was 222 kg from two annual harvests with an income of Rs. 9801/- (Table 3), this plot is being utilized for scion collection.

CONCLUSIONS

- Top working is economical as compared to replanting, if CSRB is managed effectively.
- The technology of rejuvenation being simple, can be adopted by small and marginal farmers with training and proper technical know-how.
- Top working technology is suitable for homestead gardens/small holdings where the farmer would be able to take intensive care of the top worked trees.
- Mortality of the successfully top worked trees was encountered due to cashew stem

Table 3: Cost of establishment and maintenance of 0.25 ha top worked plot in the scion bank

Year	Establishment/ maintenance cost (Rs.)	Yield (Kg)	Income (Rs.)
1996-97	3098	--	--
1997-98	2688	37.8	1512
1998-99	2756	184.2	8289
Total	8542	222.0	9801

and root borer infestation inspite of giving *regular prophylactic treatments*. The mortality was more in those plots which were surrounded by the CSRFB infested plantations and in the older trees.

Cashew trees of less than 10 year old are desirable for top working as there will be minimum mortality due to CSRFB infestation.

This technology is not suitable for areas where prevalence of cashew stem and root borer population is high, particularly for cashew development corporation plantations. In such areas the mortality of successfully top worked trees would be

high (upto 80%) due to stem and root borer *infestation, inspite of taking up regular prophylactic control measures* against stem and root borer.

- Before venturing into top working of cashew plants, one should have trained persons for grafting the juvenile shoots and after care of the plants.
- An unwanted variety in the scion bank can be successfully top worked with a desired variety. Since the spacing adopted is generally 4m x 4m, (closer spacing, compact area) in scion bank, it is easy to manage the top worked plants. The dead plants need to be uprooted and replanted with grafts.

Ad-hoc Scheme : Collection of Cashew (*Anacardium occidentale* L.) germplasm from forest plantations in Karnataka

Leader : KRM Swamy (1996-1999)
Associates : Thoyajaksha (1996-1997)
NS Shankararaja (1998)

INTRODUCTION

Collection and conservation of cashew germplasm is an important activity in the crop improvement programme. By this, the elite and diverse types present in the crop species could be identified, collected and conserved before they are lost. In view of the fast replacement of the presently available local varieties / land races / elite types with the released high yielding varieties that would be taking place, the collection and conservation of cashew germplasm should receive priority. In Karnataka, most of the cashew plantations established by Forest Department / Karnataka Cashew Development Corporations (KCDC) have been raised from seedlings of non-descript origin and some of these plantations are as old as 30-40 years. Therefore, there is a possibility of locating high yielding types (natural hybrids) with desirable characteristics, particularly the types suitable for growing in waste lands / degraded soils / forest lands, from these plantations. If these elite and diverse types are not identified, collected and conserved, they may be lost for ever. Hence, this ad-hoc research project on "Collection of cashew (*Anacardium occidentale* L.) germplasm from forest plantations in Karnataka" was approved by the Indian Council of Agricultural Research, New Delhi, for a period of three years (January 1996 to January 1999).

OBJECTIVES

1. To survey the Forest / Karnataka Cashew Development Corporation (KCDC) Plantations in Karnataka for identifying the

elite and diverse germplasm.

2. To collect the scions from the identified cashew trees and produce their clones.
3. To conserve the clonal accessions in the National Cashew Gene Bank (NCGB).

MATERIALS AND METHODS

1. Germplasm collection survey

As a part of the three year research scheme, the cashew plantations belonging to Forest Department / Karnataka Cashew Development Corporation (KCDC) were surveyed for cashew germplasm collection in five districts of Karnataka, namely, Dakshina Kannada, Uttara Kannada, Shimoga, Mysore and Kodagu, during the fruiting season of 1996, 1997 and 1998. During 1996, the cashew plantations in Dakshina Kannada district (Puttur, Kundapura and Moodabidri divisions of KCDC), during 1997, the cashew plantation in Uttara Kannada district (Kumta division of KCDC), and during 1998, the cashew plantation in Shimoga, Mysore and Kodagu districts were surveyed.

During the grafting season of 1996, 1997 and 1998, scions were collected (25 no./tree) from the identified trees and were grafted in the nursery and clones were produced.

2. Germplasm conservation

The clonal accessions collected from different districts were planted in NCGB during the succeeding planting season (6 grafts/ accession; spacing 6 x 6m).

RESULTS AND DISCUSSION

1. Germplasm collection survey

A total number of 42 elite and diverse types of cashew were identified from Forest Plantations / KCDC Plantations in Dakshina Kannada, Uttara Kannada, Mysore and Shimoga districts of Karnataka during the fruiting season of 1996, 1997 and 1998 and marked for collection. The 42 trees identified from different plantations have been classified into three groups based on site description of the plantations as follows (Table 1).

Group-1 : Coastal plains - Low lands

The plantations are nearer to sea (less than 30 km from sea) and the elevation from mean sea level is less than 50 M. These plantations have been raised on laterite soils/laterite soils with small stones and open boulders/laterite soils with hard pan down below. In some of the plantations the soil depth was shallow. The topography of the land ranged from level to slopy. In some of these plantations general yellowing of plants/stunted growth of plants was observed due to moisture

stress/poor soil fertility. These plantations are not receiving any cultural operations since their establishment. In some of the plantations the plant density is very low (50-60/ha). The cashew plantations at Sablady, Shirur Paduware, Mavalli, Gunavanthe Malkode, Uluware, Gokarna and Aghanashini fall under this group and a total of 13 accessions were collected from these plantations (Table 1).

Group-2 : Coastal plains - Mid lands

The plantations are away from sea (more than 30 km from sea) and the elevation from mean sea level is between 50-100 M. These plantations have been raised on laterite soils/laterite soils with hard pan down below. In some of the plantations the soil depth was shallow. The topography of the land ranged from level to slopy. The plant density in some of the plantations is very low (50-60/ha). Most of these plantations have not received any cultural operations since establishment. Stem borer infestation was observed and in some of the plantations the infestation was as high as 30-40%. The cashew plantations at Koila, Halaneranki, Kidu, Suvarmale, Aranthakallu, Belal, Alike,

Table 1: Grouping of cashew collections based on site description

Group-1 (Coastal plains-Low lands)	Group-2 (Coastal plains-Mid lands)	Group-3 (Uplands/upghats)
Sablady-1	Kodiyala-1, Kodiyala-2, Paranki-1,	Thagginathala-1
Shirur Paduware-1	Paranki-2 Konaje Marpady-1, Konaje	Talakad-1
Mavalli-1	Marpady-2, Daregudde Valpady-1,	Talakad-2
Mavalli-2	Daregudde Valpady-2, Koila-1,	Talakad-3
Mavalli-3	Halaneranki-1, Halaneranki-2, Kidu-1,	Talakad-4
Mavalli-4	Suvarmale-1, Aranthakallu-1, Belal-1,	Talakad-5
Mavalli-5	Belal-2, Belal-3, Belal-4, Alike-1, Alike-2,	
Mavalli-6	Kodippady-1, Kodimbady-1, Kodimbady-2	
Gunavanthe Malkode-1		
Gunavanthe Malkode-2		
Uluware-1		
Gokarna-1		
Aghanashini-1		

Kodippady, Kodimbady, Kodiyala, Paranki, Konaje Marpady and Daregudde Valpady fall under this group. A total of 23 accessions were collected from these plantations (Table 1).

Group 3 : Uplands/upghat region

The plantations are far away from sea (100-250 km away from sea) and the elevation from mean sea level is 600-650 M. The plantations at Thirthahally have been raised on laterite soils and the topography of the land is undulating. The plantations at Talakad have been raised on sand dunes. These plantations are not receiving any cultural operations since establishment. Six accessions were collected from these plantations (Table 1).

Fourteen collections, namely, Kodiyala-2, Gunavanthe Malkode-1, Belal-2, Mavalli-2, Mavalli-6, Gokarna-1, Kodiyala-1, Koila-1, Halaneranki-1, Kidu-1, Aranthakallu-1, Belal-1, Belal-4, Thagginathala-1 and Talakad-2, had 4-5 desirable characters. These accessions can be used in breeding programme to develop hybrids with all the desirable characters as well as high yield. Five of the 42 collections had distinct characters such as big sized flowers (Kodippady-1, Sablady-1), long apple shape (Suvarmale-1), round shaped nuts (Kodimbady-1) and rare leaf shape (Kodimbady-2) (Table 2).

2. Scion collection and production of clones

During the grafting season of 1996, the precured scions (25 no/tree) were collected from the 24 marked trees from Dakshina Kannada district and they were grafted on root stock plants in the nursery at Shantigodu by adopting softwood grafting technique. During the grafting season of 1997, the scions (25 No./tree) were collected from 11 marked trees from Uttara Kannada district and the clones were produced. During the grafting season of 1998, the scions (25 No./tree) were

collected from seven marked trees from Mysore, Shimoga and Dakshina Kannada districts and the clones were produced.

3. Germplasm conservation

Softwood grafts of 24 accessions which were collected from Dakshina Kannada district were planted in NCGB at Shantigodu during the planting season of 1997. During the planting season of 1998, collected from Uttara Kannada district were planted in NCGB. During the planting season of 1999, grafts of 7 accessions collected from Mysore, Shimoga and Dakshina Kannada would be planted in NCGB at Shantigodu.

CONCLUSION

1. A total of 42 accessions were collected from forest / KCDC plantations in Karnataka during 1996-1999.
2. Of the 42 accessions, 14 accessions had 4-5 desirable characters.
3. Some of these accessions can be utilized as parents in the hybridization programme.
4. Some of these accessions can be tested in waste lands as they were collected from forest plantations under neglected conditions, so that selections suitable for low input condition / waste lands can be identified.
5. Some of these collections can be tested for their efficiency as root stocks in utilizing native fertility, as forest plantations seldom receive manures / fertilizers.
6. Five accessions had distinct characters such as big sized flowers (Kodippady-1, Sablady-1), long apple shape (Suvarmale-1), round shaped nuts (Kodimbady-1), and rare leaf shape (Kodimbady-2).

Table 2: Grouping of accessions based on desirable characters/distinct characters

Group-1 (Coastal Plains - low lands)

Collection number	Upright & compact tree habit	Semittall Growth (< 4m)	Cluster bearing (>6fruits/bunch)	Bold nuts (>8g)	Big sized apple (>70g)	Low apple to nut ratio (<5.0)	High shelling percentage (>30%)	Short duration of flowering (<60 days) & nut collection (<30 days)	High yield potential (>500g/m ²)	Remarks
Sablady-1	-	-	✓	-	-	-	-	-	✓	Big sized flowers, no downward curling of petals
Shirur Paduware-1	-	-	✓	-	-	-	-	-	✓	
Mavalli-1	-	-	✓	-	-	-	✓	-	✓	
Mavalli-2	✓	✓	✓	-	-	-	-	-	✓	
Mavalli-3	-	-	✓	-	✓	-	-	-	✓	
Mavalli-4	-	-	✓	-	✓	-	-	-	✓	
Mavalli-5	-	-	✓	✓	✓	-	-	-	✓	
Mav: Ilt-6	-	-	✓	-	✓	-	-	-	✓	
Gunavanthe Malkode-1	✓	✓	✓	-	✓	-	-	-	✓	
Gunavanthe Malkode-2	-	✓	✓	-	-	-	-	-	✓	
Uluware-1	-	-	✓	-	-	✓	-	-	✓	
Gokarna-1	-	✓	✓	-	-	✓	-	-	✓	
Aghanashini-1	✓	✓	-	-	-	-	✓	-	-	

Group-2 (Coastal Plains - mid lands)

Collection number	Upright & compact tree habit	Semital Growth (< 4m)	Cluster bearing (>6fruits/bunch)	Bold nuts (>8g)	Big sized apple (>70g)	Low apple to nut ratio (<5.0)	High shelling percentage (>30%)	Short duration of flowering (<60 days) & nut collection (<30 days)	High yield potential (>500g/m ²)	Remarks
Kodiyala-1	-	-	-	✓	✓	-	-	✓	✓	
Kodiyala-2	✓	✓	✓	-	-	-	-	✓	✓	
Paranki-1	-	-	✓	-	-	-	-	-	✓	
Paranki-2	-	-	✓	-	✓	-	-	-	✓	
K.Marpady-1	-	-	✓	-	-	-	-	✓	✓	
K.Marpady-2	-	-	✓	-	-	-	-	-	✓	
D.Valpady-1	-	-	✓	-	-	-	-	-	✓	
D.Valpady-2	-	-	✓	-	-	-	-	✓	✓	
Koila-1	-	-	✓	-	-	-	✓	✓	✓	
Halanranki-1	-	-	-	✓	✓	-	-	✓	✓	
Halanranki-2	-	-	-	-	-	-	-	✓	✓	
Kidu-1	-	-	✓	-	-	✓	✓	-	✓	
Suvarmale-1	-	-	-	-	✓	-	✓	-	-	Long apple shape
Aranthakallu-1	-	-	✓	-	-	✓	-	✓	✓	
Belal-1	-	-	✓	✓	✓	-	✓	-	✓	
Belal-2	-	-	✓	✓	✓	-	✓	-	✓	
Belal-3	-	-	✓	-	-	-	-	-	✓	
Belal-4	-	-	✓	-	-	✓	-	✓	✓	
Alike-1	-	-	✓	✓	-	-	-	-	✓	
Alike-2	-	-	-	✓	✓	-	-	-	✓	
Kodipady-1	-	-	✓	-	-	-	-	-	-	Big sized flowers
Kodimabady-1	-	-	✓	-	-	-	-	-	✓	Round shaped nuts
Kodimabady-2	-	-	-	-	-	-	-	-	-	Rare leaf shape

Group-3 (Uplands/upghats)

Collection number	Upright & compact tree habit	Semitall Growth (< 4m)	Cluster bearing (>6fruits/bunch)	Bold nuts (>8g)	Big sized apple (>70g)	Low apple to nut ratio (<5.0)	High shelling percentage (>30%)	Short duration of flowering (<60 days) & nut collection (<30 days)	High yield potential (>500g/m ²)	Remarks
Thangginathala-1	-	-	✓	-	-	✓	-	✓	✓	
Talakad-1	-	-	✓	-	✓	-	✓	-	✓	
Talakad-2	-	-	✓	-	✓	-	✓	-	✓	
Talakad-3	-	-	✓	-	-	-	-	-	✓	
Talakad-4	-	-	✓	-	-	-	-	-	✓	
Talakad-5	-	-	✓	-	-	-	-	-	✓	

2.5 Economic feasibility of drip irrigation and graded doses of NPK on the productivity of cashew.

Leader : N. Yadukumar (1987-97)

INTRODUCTION

Several nutritional trials on cashew, especially on the major nutrients have been attempted in India as well as in the tropical countries and response to applied nutrients have been highly favourable. Cashew has been predominantly a rainfed crop grown in degraded soils with little or no management. Several studies have shown that cashew responds favourably to nutrient application. Further it has also been shown that irrigation enhances the yield by 10 to 70 per cent. However, efforts to study the nutritional and irrigation requirement of the crop were meagre.

Therefore a study was taken up to ascertain the effects of drip irrigation with graded doses of NPK on the growth, yield and quality aspects of cashew. This study also aims to ascertain the economics of drip irrigation alongwith fertilizer application.

MATERIALS AND METHODS

The experiment was conducted at experimental station, National Research Centre for Cashew, Shantigodu between 1987 and 1997.

Layout and design

The experiment was laid out by adopting split plot design including five main plots and four sub plots with four replications. Cashew grafts of VRI-1 variety was planted in 1989 with a spacing of 7m x 7m. Details of the treatments are as follows.

Main plot treatments

- I₁ No irrigation
- I₂ Irrigation through drip @ 20 l/tree once in 4 days
- I₃ Irrigation through drip @ 40 l/tree once in 4 days
- I₄ Irrigation through drip @ 60 l/tree once in 4 days
- I₅ Irrigation through drip @ 80 l/tree once in 4 days

Sub-plot treatments

- M₁ No fertilizers
- M₂ 250 g N, 62.5 g P₂O₅, 62.5 g K₂O/tree/year
- M₃ 500 g N, 125 g P₂O₅, 125 g K₂O/tree/year
- M₄ 750 g N, 187.5 g P₂O₅, 187.5 g K₂O/tree/year

Details of irrigation treatment are as follows:

Irrigation treatments	No. of drippers/tree	Total quantity of water discharged l/h/dripper	Duration of irrigation (h)	Total quantity of water discharged per irrigation l/ tree
I ₁	--	--	--	--
I ₂	2	2½	4	20
I ₃	2	5	4	40
I ₄	3	5	4	60
I ₅	4	5	4	80

Irrigation was given every year from the year of planting upto third year during December to April. Later, the crop was irrigated from 2nd fortnight of December after 75 per cent flowering to March.

In the sub-plot treatments fertilizers were applied in the form of urea, rock phosphate and potassium chloride (Muriate of potash) in split doses. Two-thirds of the treatment dose was applied in August at 1.5 m away from stem in circular trenches. Remaining one-third was applied during February in pits dug out in drip point. Temperature, rainfall and potential evaporation were monitored using B class weather station through out the period of study.

Fertilizer treatments were imposed with one third dose in the first year of planting, two-thirds in the second year and full dose from third year onwards.

In the case of irrigation treatments, pressure compensating drippers were used, which were connected to sphagette pipes (4 mm) which in turn were connected to lateral pipes (8 to 12 mm OD). Length of sphagette pipe was 1 m so that the drippers were spaced 1 m away from tree base in one points in I₂ treatment, two points in I₃

treatment and three points in I₄ treatment and four points in the case of I₅ treatment.

Growth measurements

Tree girth, height and spread was measured during peak flowering season in February every year from fourth year onwards. Girth of the stem was measured at 25 cm height from ground. Height of the plant and height of the canopy were measured from ground level. Height of the canopy was computed along with canopy area. Spread of the tree was measured east-west and north-south directions. While calculating mean values of EW and NS spread were taken into consideration. Radius of the canopy was calculated from the canopy direction

$\left(\frac{EW + NS}{4} \right)$. From these observations, canopy area was calculated using the following formula (Balasimha and Nair, 1989).

Canopy area = $\pi r l$, where

$$l = \sqrt{h^2 + r^2}$$

h = height

r = radius of the canopy spread

Leaf water potential

Leaf water potential was measured during March (peak summer) and December (winter) in

two consecutive years during eighth and ninth year. The method adopted was pressure pump using leaf water potentiometer (Environment and Earth Sciences, Ltd., US make). Fourth and fifth opened leaves were used for the purpose during day time in the forenoon (11 to 12 h).

Soil moisture studies

Wetting front of discharge rate of 2.5 l/h and 5 l/h was done for one, two, three and four hours after irrigation. The wetting boundaries were identified in tracing paper after cutting across the soil profile at each hour upto four hours after irrigation. The same procedure was adopted after 24 h of irrigation also to see any further downward and horizontal movement of water.

Distribution of soil moisture content using neutron probe

At the experimental site, aluminium tubes with a diameter of 4.6 cm and 1.7 mm thickness were installed at a depth of 1.25 m by using soil auger. These access tubes were located 1 m from trunk of the tree. Three access tubes were installed for each irrigation treatment.

Fresh and dry weight of soil samples were determined gravimetrically and later weighed after drying the sample at 105°C to a steady weight (for approximately 70 h). The volumetric moisture content (VMC) of the sample was calculated as the difference between fresh and dry weight as related to the volume of the sample. The results were plotted against the corresponding neutron probe reading and analysed using regression analysis available from the control unit of the equipment.

Soil moisture level was monitored from the first to 30th irrigation using neutron moisture probe before each irrigation and three days after.

Soil moisture readings were recorded at three trees/treatment and at 25, 50, 75, 100 and 125 cm soil depth in 1997 and 1998. Additional probe readings were taken in the case of control plot also.

Leaf and soil analysis for N, P & K

Leaves of flushing, flowering and fruiting shoots were used for analysis. Leaf samples were dried at 70°C in an oven and ground with a sample grinder Nitrogen was determined using Kjeltak Analyser.

Phosphorus was estimated colorimetrically by Venado Molybdo Phosphate method. Flame photometer was used for K estimation. Soils at three depths (0-30, 30-60 and 60-90) were also analysed for N, P and K levels. Available N was determined by method of Subbaiah and Asija (1956) and P_2O_5 by Bray and Curtz P_1 method (Bray and Kurtz, 1945) and K_2O by Ammonium Acetate method (Jackson, 1958).

Yield components

Nut retention

Nut retained from mustard, peanut, marble and finally ready to harvest stage were counted per panicle and like wise per m² of canopy area from all the four sides of the tree. Till the harvest the immature nut drop at different stages were noted and total nut retention was calculated in terms of per cent of total nuts present from mustard stage.

Yield

The yield was recorded year wise from six trees in each treatment of irrigation and fertilizer. Nuts were collected manually from the ground under the tree and counted and weighed. Final weight was taken after sun drying for six days.

Shelling per cent and kernel yield

The nuts of each of the experimental trees were roasted, shelled and peeled according to Kuppelwischer (1989). Fresh and dry weight of the kernels were determined gravimetrically and the kernel yield was calculated on the basis of 3 per cent moisture. Shelling per cent was calculated as the kernel weight in percentage of the weight of raw nuts (Kuppelwischer, 1989).

Quality characters

Nuts were shelled and kernels were extracted after removal of testa with mixture of chloroform and methanol (2:1 v/v) and defatted cashew kernel flour was used for the estimation of total protein ($N \times 6.25$) (AOAC, 1980). Defatted cashew kernel flour was extracted with hot 80 per cent ethanol and ethanolic extract after concentration was fractionated into sugars. Sugars in the neutral fraction was estimated by phenol sulphuric acid method (Dubois *et al.*, 1952). Residue after ethanol extraction was extracted with 52 per cent perchloric acid and starch was estimated (Clegg, 1956).

Economics

Economics of treatment plots was worked out and computed per hectare basis.

RESULTS AND DISCUSSION

Physiological parameters

Exposed canopy area increased significantly with drip irrigation upto 7th year. Highest level of drip irrigation of 80 l/tree once in 4 days increased exposed canopy area significantly over rainfed trees receiving no fertilizers (Table 1). Similarly exposed canopy area increased significantly up to seventh year due to fertilizer application. Highest dose of fertilizer

application increased exposed surface area significantly over control (no fertilizers). Combination of highest dose of fertilizers and irrigation increased exposed canopy area significantly over rainfed trees receiving no fertilizer. Irrigation and fertilizer application had no significant effect on photosynthetic rate, transpiration, stomatal conductance, intercellular CO_2 concentration and other parameters in leaf when measured in December. During March significant variations were observed due to irrigation and fertilizers. Photosynthetic rate transpiration and stomatal conductance were significantly more in irrigated trees than in unirrigated trees. Similarly, these parameters were significantly more in trees receiving fertilizers than in trees, without fertilizer application. Interaction effect of irrigation and fertilizers was not significant. However, higher levels of irrigation (60-80 l/tree) and middle and higher levels (M_3 and M_4) of fertilizers resulted in more photosynthetic rate and transpiration in leaf of such trees than those trees receiving lower levels of irrigation and fertilizers and no irrigation and fertilizers. Water use efficiency and carboxylation efficiency did not vary significantly due to irrigation and fertilizer application. (Tables 2, 3 & 4).

The light interception was 60.27 per cent at the lower level of irrigation (I_2) and it was as high as 71.6 per cent at higher level of irrigation (80 l/tree). Similarly light interception by the canopy of trees receiving no irrigation was only 61.94 per cent. Light interception at middle and higher doses of fertilizers ranged from 68.78 to 68.95 per cent which was significantly more in comparison to trees receiving no fertilizer or having lowest fertilizer dose. Light interception was highest when trees received highest irrigation and fertilizer (76.95%) (Table 5).

Table 1: Effect of drip irrigation and graded doses of NPK on the exposed canopy area (m²/tree)

Irrigation Treatments	1996					1997					Mean of two years				
	M ₁	M ₂	M ₃	M ₄	Mean	M ₁	M ₂	M ₃	M ₄	Mean	M ₁	M ₂	M ₃	M ₄	Mean
I ₁	17.20	19.15	17.37	17.28	17.75	46.18	40.10	44.15	47.27	43.11	50.25	62.11	59.15	62.61	43.11
I ₂	19.77	21.82	25.17	22.89	22.40	43.84	51.44	48.06	48.57	47.65	57.94	60.66	67.13	64.37	47.65
I ₃	24.47	22.63	19.89	23.94	22.74	51.09	48.50	50.83	49.73	50.04	59.10	61.70	60.84	67.74	50.04
I ₄	33.93	24.48	22.82	24.38	26.40	51.89	52.33	57.70	55.30	54.28	64.18	69.81	68.83	68.41	54.28
I ₅	24.69	26.01	27.02	28.98	26.68	58.34	53.90	56.20	54.02	55.62	65.20	68.03	69.93	72.66	55.62
Mean	24.01	22.82	22.46	23.49		50.26	48.23	51.25	50.97		59.33	64.66	65.17	67.16	

Parameters	SEm±			CD		
	7th year	8th year	8th year	7th year	7th year	8th year
Irrigation (I)	2.29	2.64	2.64	6.9	6.9	NS
Fertilizer (M)	1.67	1.92	1.92	NS	NS	5.4
Interaction (IxM)	3.74	4.28	4.28	NS	NS	NS

Table 2: Effect of drip irrigation and graded doses of NPK on net photosynthetic rate in leaf ($\mu\text{mol CO}_2/\text{M}^2/\text{sec}$) in March

Irrigation Treatments	1996					1997					Mean of two years				
	M ₁	M ₂	M ₃	M ₄	Mean	M ₁	M ₂	M ₃	M ₄	Mean	M ₁	M ₂	M ₃	M ₄	Mean
I ₁	9.45	11.90	11.18	10.95	10.87	11.67	11.60	13.87	14.00	12.79	10.56	11.75	12.53	12.48	11.83
I ₂	11.00	11.35	12.95	13.23	12.14	14.75	15.95	16.53	15.73	15.74	12.88	13.65	14.75	14.48	13.94
I ₃	10.88	10.98	10.95	13.93	11.68	16.65	14.30	14.68	16.73	15.59	13.76	12.64	12.82	15.33	13.63
I ₄	10.70	14.30	15.92	14.56	13.87	12.85	14.18	15.88	16.43	14.84	11.78	14.24	15.90	15.49	14.35
I ₅	12.15	15.55	16.28	18.35	15.33	16.60	17.33	16.73	16.85	16.88	14.38	16.44	16.50	17.10	16.10
Mean	10.84	12.82	13.46	14.00		14.51	14.67	15.54	15.95		12.67	13.74	14.50	14.97	

Parameters	SEm±	CD
Irrigation	0.3142	1.258
Fertilizer (M)	0.3192	1.107
Interaction (I×M)	0.6672	NS
Year	0.2018	0.795

Table 3: Effect of drip irrigation and graded doses of NPK on transpiration (mmol/m²/sec in March.)

Irrigation Treatments	1996					1997					Mean of two years				
	M ₁	M ₂	M ₃	M ₄	Mean	M ₁	M ₂	M ₃	M ₄	Mean	M ₁	M ₂	M ₃	M ₄	Mean
I ₁	7.75	7.70	9.30	7.55	8.08	7.75	7.70	8.90	8.62	9.58	7.75	7.70	9.10	8.09	8.15
I ₂	7.75	8.90	9.38	12.30	9.92	8.92	8.05	9.40	8.90	10.06	8.34	8.48	8.39	10.60	9.20
I ₃	9.78	9.18	10.40	10.32	11.74	8.23	8.15	8.98	12.90	8.24	9.00	8.66	9.69	11.61	9.74
I ₄	9.63	9.93	10.53	10.18	8.82	9.00	9.38	10.45	10.38	9.56	9.31	9.65	10.48	10.28	9.93
I ₅	9.38	12.30	13.50	11.80	9.79	9.65	9.23	10.03	11.85	10.18	9.51	10.76	11.76	11.83	10.96
Mean	8.85	9.60	10.62	10.43	9.87	8.70	8.50	9.55	10.53	9.32	8.78	9.05	10.08	10.48	

Parameters	SEM±	CD
Irrigation	0.1437	0.567
Fertilizer (M)	0.1409	0.523
Interaction (I×M)	0.3150	1.168
Year	0.0909	0.358

Table 4: Effect of drip irrigation and graded doses of NPK on stomatal conductance (mol/m²/sec) in leaf

Irrigation Treatments	1996					1997					Mean of two years				
	M ₁	M ₂	M ₃	M ₄	Mean	M ₁	M ₂	M ₃	M ₄	Mean	M ₁	M ₂	M ₃	M ₄	Mean
I ₁	0.238	0.303	0.375	0.378	0.323	0.340	0.275	0.318	0.290	0.306	0.289	0.346	0.334	0.314	
I ₂	0.230	0.270	0.295	0.485	0.320	0.373	0.370	0.333	0.523	0.399	0.301	0.320	0.314	0.504	0.360
I ₃	0.238	0.303	0.375	0.378	0.323	0.387	0.353	0.377	0.353	0.368	0.312	0.328	0.376	0.365	0.345
I ₄	0.597	0.795	0.920	1.528	0.961	0.358	0.325	0.325	0.523	0.382	0.477	0.560	0.623	1.025	0.671
I ₅	0.313	0.367	0.670	1.790	0.785	0.397	0.400	0.440	0.407	0.411	0.355	0.348	0.555	1.099	0.598
Mean	0.323	0.408	0.527	0.912		0.371	0.345	0.359	0.419		0.347	0.376	0.443	0.665	

Parameters	SEM±	CD
Irrigation	0.0192	0.075
Fertilizer (M)	0.0204	0.075
Interaction (I×M)	0.0456	0.169
Year	0.0122	0.048

Table 5: Effect of drip irrigation and graded doses of NPK on light interception (%) over years

Irrigation Treatments	4th Year				7th Year				8th Year						
	M ₁	M ₂	M ₃	M ₄	Mean	M ₁	M ₂	M ₃	M ₄	Mean	M ₁	M ₂	M ₃	M ₄	Mean
I ₁	15.59	16.72	14.63	16.47	15.85	40.15	42.96	37.75	43.49	41.09	50.10	68.11	62.69	66.85	61.94
I ₂	17.69	19.10	23.44	20.34	20.14	46.11	45.02	54.23	47.02	48.05	55.78	52.99	68.28	64.25	60.27
I ₃	22.32	19.94	17.68	22.58	20.62	52.31	51.94	54.04	50.66	52.24	59.88	63.46	65.65	66.02	63.72
I ₄	22.04	21.40	25.64	26.61	23.50	54.63	53.12	56.18	51.35	53.82	66.90	66.93	75.61	76.95	71.60
I ₅	21.04	21.40	25.64	26.61	23.50	54.63	53.12	56.18	51.35	53.82	66.90	75.61	76.95	71.60	
Mean	21.98	21.40	19.13	18.90		49.92	49.00	52.46	50.16		59.48	64.82	68.78	68.95	

Parameters	SEM±			CD		
	4th year	7th year	8th year	4th year	7th year	8th year
Irrigation (I)	1.107	3.21	3.54	3.4	9.8	NS
Fertilizer (M)	0.77	2.16	1.75	NS	NS	4.83
Interaction (I×M)	1.725	4.83	3.92	NS	NS	NS

Soil wetting pattern

Total wetted ground area and soil volume in the available moisture range (17.0 to 38.0%) around drip points was maximum (7.75% and 4.09% of the given area and soil volume) when highest irrigation was provided as against 2.36 per cent and 1.49 per cent of the given area and soil volume in trees having lowest irrigation.

Nutrient contents in soil and leaf

Owing to fertilizer application, N content in soil increased. It was also found that N content increase in soil led to increase of N content in the leaves of all types of shoot (flushing, flowering and fruiting) in irrigated and rainfed trees. With irrigation the available N level reduced at lower depth and when replenished with fertilizer application it increased at 0-60cm depth. (Table 6 & 7)

Original available P in soil was minimum which increased with application of P fertilizers in the surface layer (0-30 cm). Under irrigated condition P content reduced considerably in non-fertilised soils but increased in fertilised soils. Increase in P content was observed only in leaf of shoots during fruiting stage along with increased P content in soil. (Table 8 & 9)

In general available K_2O content was more in the top soil layer of 0-30 cm depth (66.70 ppm) and reduced when depth increased. Minimum available K_2O content of 27.84 ppm was observed at 60-90 cm depth of the soil. Under unirrigated conditions without fertilizer application the available K_2O content in soil was minimum in all the three depths. Whereas it increased progressively in plot applied with lower to higher doses of fertilizers. Under irrigated conditions also the K content increased with increased

application of fertilizer from lower to higher doses (M_2 to M_4), (Table 10).

Irrigation had no influence on K content in leaf of the flushing shoot, whereas fertilizer application increased K content in leaf of flushing shoot significantly, when compared with the tree receiving no fertilizer. Interaction effect of both irrigation and fertilizer application was also found not significant. (Table 11).

Effect of irrigation and fertilizer application was found significant in the K content of leaf of flowering and fruiting shoots. Potassium content in leaf of flowering and fruiting shoots of tree receiving lowest irrigation of 20 l/tree was significantly inferior to all other irrigation treatments (40, 60 and 80 l/tree) which remained at par with tree of the unirrigated treatment (Table-11).

The leaf K content of leaf of flowering and fruiting shoots of the fertilized trees was significantly higher than that in leaf of flowering shoots of unfertilized trees. However, among the trees receiving lower to higher fertilizer doses leaf K content in flowering and fruiting shoots was significantly lower in tree receiving lower fertilizer doses than in those receiving medium to higher doses of fertilizers.

Significantly high K content in leaf was observed in flowering and fruiting shoots in highest fertilizers applied trees compared to medium and lower fertilizer applied trees (Table-11).

Yield

Irrigation resulted in significant increase in nut weight, shelling percent, kernel weight and nut retention. Fertilizer application also resulted

Table 6: Effect of drip irrigation and graded NPK on the available nitrogen content in soil (ppm) at three different depths

Irrigation treatments	M ₁			M ₂			M ₃			M ₄			Mean		
	Depth (cm)			Depth (cm)			Depth (cm)			Depth (cm)			Depth (cm)		
	0-30	30-60	60-90	0-30	30-60	60-90	0-30	30-60	60-90	0-30	30-60	60-90	0-30	30-60	60-90
I ₁	175	154	120	245	148	125	289	168	128	345	182	122	263.5	163.0	123.75
I ₂	183	148	132	283	132	125	312	183	128	314	182	155	273	161.25	135
I ₃	184	157	112	254	177	126	298	185	132	386	199	157	280.5	179.5	131.75
I ₄	232	185	182	259	187	163	282	191	149	308	196	146	270.25	189.75	160.00
I ₅	209	196	173	211	198	178	261	172	145	310	198	157	243.25	163.25	163.25
Mean	177	168	124	250.4	168.4	143.4	288.4	179.8	116.4	332.6	191.4	147.4			

Table 7: Effect of drip irrigation and graded NPK on N content (%) in leaf of flushing, flowering and fruiting, shoots after application of fertilizers.

Irrigation Treatments	Flushing				Flowering				Fruiting						
	M ₁	M ₂	M ₃	M ₄	Mean	M ₁	M ₂	M ₃	M ₄	Mean	M ₁	M ₂	M ₃	M ₄	Mean
I ₁	2.047	2.071	2.094	2.106	2.079	2.234	2.271	2.288	2.350	2.286	1.700	1.720	1.852	1.958	1.808
I ₂	2.060	2.306	2.386	2.435	2.298	2.347	2.356	2.371	2.327	2.350	1.683	1.770	1.824	1.813	1.772
I ₃	2.172	2.185	2.193	2.214	2.191	2.261	2.285	2.30	2.355	2.301	1.659	1.763	1.843	1.921	1.797
I ₄	2.127	2.280	2.403	2.382	2.298	2.267	2.283	2.351	2.332	2.308	1.708	1.773	1.797	1.799	1.760
I ₅	2.154	2.258	2.301	2.312	2.256	2.267	2.291	2.313	2.288	2.290	1.718	1.868	1.835	1.848	1.817
Mean	2.112	2.220	2.275	2.290	2.224	2.275	2.297	2.325	2.331	2.307	1.693	1.779	1.830	1.838	

Parameters	SEm±			CD		
	Flushing	Flowering	Fruiting	Flushing	Flowering	Fruiting
Irrigation (I)	0.015	0.0119	0.0276	0.006	0.036	NS
Fertilizer (M)	0.0075	0.0088	0.0099	0.028	0.033	0.1646
Interaction (IxM)	0.016	0.0198	0.0222	0.064	0.053	0.0375

Table 8: Effect of drip irrigation and graded NPK on the available P_2O_5 content (ppm) at three depths

Irrigation treatments	M_1			M_2			M_3			M_4			Mean		
	Depth (cm)			Depth (cm)			Depth (cm)			Depth (cm)			Depth (cm)		
	0-30	30-60	60-90	0-30	30-60	60-90	0-30	30-60	60-90	0-30	30-60	60-90	0-30	30-60	60-90
I_1	2.25	1.58	0.320	2.820	3.20	0.420	3.45	4.20	0.58	4.82	5.82	1.82	3.33	33.70	0.78
I_2	1.825	1.20	0.80	3.25	2.20	0.520	4.25	3.45	0.65	6.28	4.80	1.23	3.90	2.91	0.80
I_3	2.33	1.87	0.40	3.425	3.250	0.80	4.25	4.32	0.60	5.58	5.53	1.035	3.89	3.74	0.71
I_4	2.125	1.16	0.395	3.25	2.85	0.45	4.82	2.35	0.68	5.01	3.75	0.20	3.80	2.52	0.43
I_5	1.825	1.450	0.20	3.20	3.40	1.08	5.42	3.80	1.80	6.83	4.52	1.25	4.32	3.29	1.08
Mean	2.071	1.45	0.423	3.08	2.98	0.654	4.44	3.62	0.86	5.70	4.88	1.107	3.84	3.23	0.76

Table 9: Effect of drip irrigation and graded NPK on P content (%) in leaf of flushing, flowering and fruiting shoots after application of fertilizers

Irrigation Treatments	Flushing					Flowering					Fruting				
	M ₁	M ₂	M ₃	M ₄	Mean	M ₁	M ₂	M ₃	M ₄	Mean	M ₁	M ₂	M ₃	M ₄	Mean
I ₁	0.089	0.095	0.072	0.098	0.089	0.095	0.096	0.097	0.099	0.097	0.116	0.121	0.132	0.142	0.125
I ₂	0.096	0.098	0.097	0.105	0.099	0.070	0.086	0.096	0.100	0.088	0.114	0.127	0.177	0.133	0.188
I ₃	0.096	0.090	0.094	0.093	0.093	0.085	0.095	0.097	0.101	0.094	0.107	0.128	0.128	0.127	0.123
I ₄	0.094	0.097	0.095	0.099	0.096	0.082	0.088	0.094	0.103	0.092	0.109	0.122	0.125	0.132	0.122
I ₅	0.093	0.097	0.099	0.101	0.098	0.087	0.098	0.102	0.102	0.097	0.085	1.109	0.126	0.128	0.112
Mean	0.094	0.095	0.092	0.099	0.095	0.084	0.093	0.097	0.101	0.094	0.104	0.122	0.177	0.132	0.134

1

Parameters	SEm±			CD		
	Flushing	Flowering	Fruting	Flushing	Flowering	Fruting
Irrigation (I)	0.0031	0.025	0.0279	NS	0.064	NS
Fertilizer (M)	0.0125	0.0012	0.0251	NS	0.0045	NS
Interaction (IxM)	0.0056	0.0028	0.0562	NS	0.0106	NS

Table 10: Effect of drip irrigation and graded NPK on the available K₂O content (ppm) in soil at three depths

Irrigation treatments	M ₁			M ₂			M ₃			M ₄			Mean		
	Depth (cm)			Depth (cm)			Depth (cm)			Depth (cm)			Depth (cm)		
	0-30	30-60	60-90	0-30	30-60	60-90	0-30	30-60	60-90	0-30	30-60	60-90	0-30	30-60	60-90
I ₁	58.50	42.50	18.20	68.50	55.20	23.20	72.50	56.20	20.42	68.50	42.80	21.45	67.02	49.17	20.56
I ₂	68.00	48.20	22.80	72.80	48.20	24.80	68.90	50.80	22.80	69.80	41.20	16.80	70.01	47.10	21.80
I ₃	57.80	37.50	20.00	68.00	42.80	38.20	72.10	68.00	42.20	87.50	55.00	50.00	71.35	50.82	37.60
I ₄	45.00	45.00	27.50	68.20	50.20	29.20	72.80	58.20	40.10	52.00	35.00	25.00	59.50	47.10	32.95
I ₅	52.80	35.00	35.00	68.20	42.50	22.50	72.80	42.00	25.00	68.80	40.27	22.80	65.65	39.94	26.32
Mean	56.60	41.64	24.70	69.14	47.78	27.58	71.82	55.04	30.10	69.32	42.85	29.21	66.70	39.02	27.84

Table 11: Effect of drip irrigation and graded NPK on K (%) content of leaf of flushing, flowering and fruiting shoots after application of fertilizers

Irrigation Treatments	Flushing					Flowering					Fructing				
	M ₁	M ₂	M ₃	M ₄	Mean	M ₁	M ₂	M ₃	M ₄	Mean	M ₁	M ₂	M ₃	M ₄	Mean
I ₁	0.718	0.830	0.828	0.840	0.804	0.735	0.817	0.830	0.835	0.804	0.708	0.733	0.763	0.820	0.756
I ₂	0.675	0.760	0.830	0.855	0.780	0.730	0.718	0.755	0.750	0.738	0.760	0.750	0.770	0.767	0.762
I ₃	0.847	0.825	0.847	0.849	0.842	0.710	0.845	0.890	1.005	0.863	0.800	0.815	0.853	0.852	0.830
I ₄	0.727	0.825	0.832	0.825	0.802	0.670	0.778	0.910	0.930	0.822	0.775	0.830	0.820	0.860	0.821
I ₅	0.710	0.940	0.922	0.748	0.830	0.730	0.710	0.910	0.997	0.837	0.783	0.850	0.862	0.860	0.839
Mean	0.735	0.836	0.852	0.823	0.812	0.715	0.775	0.859	0.903	0.813	0.574	0.795	0.813	0.831	0.802

Parameters	SEM±			CD		
	Flushing	Flowering	Fructing	Flushing	Flowering	Fructing
Irrigation (I)	0.0258	0.0201	0.1068	NS	0.080	0.0293
Fertilizer (M)	0.0224	0.0110	0.0057	0.085	0.042	0.0216
Interaction (IxM)	0.572	0.0245	0.0128	NS	0.693	0.0485

in significant increase in nut retention, nut weight, shelling percent and kernel weight.

Nut Weight

Individual nut weight increased significantly due to irrigation. Trees receiving higher levels of irrigation (40, 60 and 180 l/tree) produced nuts having more weight than trees receiving lower levels and no irrigation. Trees receiving fertilizers (M_1M_2 & M_3) gave higher

weight of nuts (5.31 to 5.68 g) than tree receiving no fertilizer (5.16 g/nut) (Fig. 1).

Interaction effect of irrigation and fertilizer was also significant. Without irrigation and fertilizer application the nut weight was only 4.65 g. Fertilizer application without irrigation increased the weight significantly. Increase in nut weight by 0.45 g/nut over control was observed.

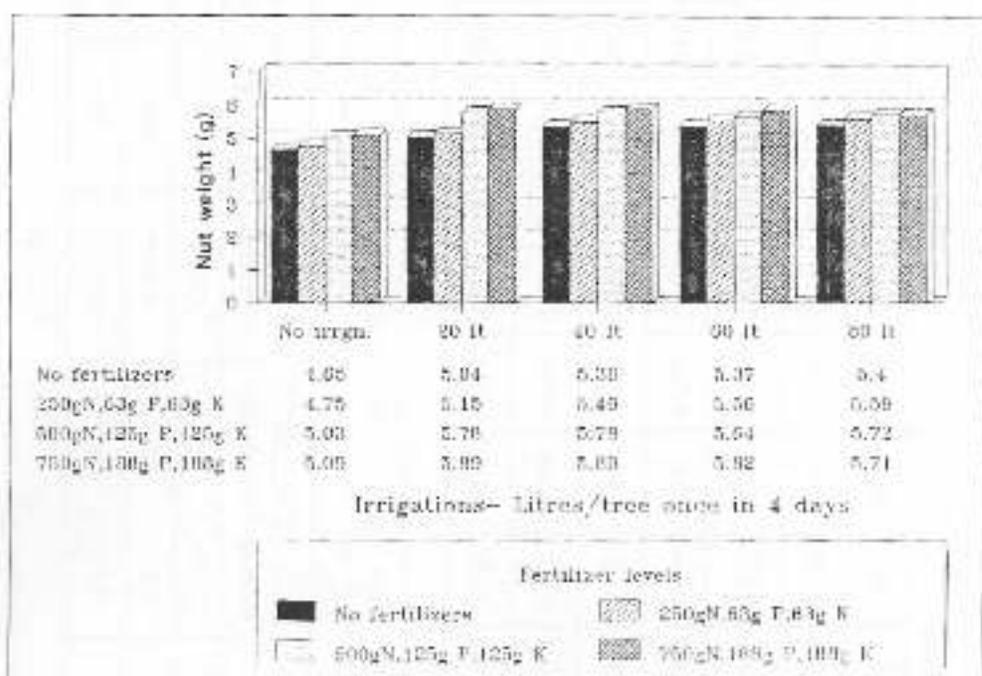


Fig. 1. Effect of drip irrigation and fertilizers on nut weight

With irrigation alone the increase in nut weight was significantly more than that from the tree receiving no irrigation. The increase was by 0.7g over control was observed. When lower to higher levels of irrigations and higher levels of fertilizers were given the nut weight increased significantly from 5.09 to 5.89 g/nut when

compared to that from the tree receiving irrigation alone or fertilizer alone or none of the two.

Shelling Percentage

Shelling percentage increased significantly due to irrigation as well as fertilizers. Trees receiving higher levels of irrigation (40 to 80 l/

tree) produced nuts having significantly higher mean shelling percentage than those from trees receiving no irrigation. Similarly trees receiving fertilizers (lower to higher levels of fertilizers) produced nuts having significantly higher mean shelling percentage than those from trees receiving no fertilizer.

Though the interaction effect of irrigation and fertilizers was not significant, increased shelling percentage with higher levels of irrigation and fertilizers was observed. Shelling per cent of the nuts of the tree receiving no irrigation and fertilizer was only 29.63 per cent whereas it was as high as 33.13 per cent in trees receiving highest levels of irrigation (80 litres/tree) and middle level of fertilizer application (500g N; 125g each of P₂O₅ and K₂O).

Kernel Weight

Kernel weight increased significantly due

to both irrigation and fertilizers. Trees receiving irrigation produced nuts having significantly higher mean kernel weight (1.67 to 1.82 g) than from trees receiving no irrigation (1.47 g). Similarly, trees receiving fertilizers also produced nuts having significantly higher mean kernel weight (1.66 to 1.84 g) than those from trees receiving no fertilizers (1.55 g). Though the interaction effect of irrigation and fertilizer was no significant, trend in increase in kernel weight with irrigation and fertilizer combination was observed. Kernel weight of the nut of the trees receiving no irrigation and fertilizer was only 1.37g/ kernel whereas it was as high as 1.88 to 1.90g/ kernel in nuts of trees receiving lowest to highest irrigation (20-80 litres) and highest fertilizers (750g N, 187.5g each of P₂O₅ and K₂O/ tree) (Fig. 2).

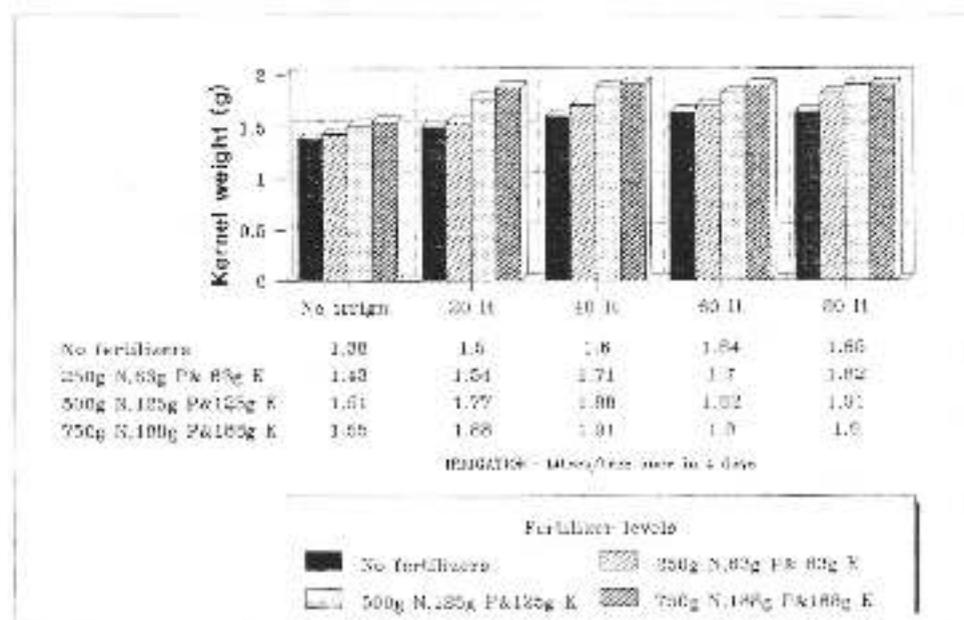


Fig. 2: Effect of drip irrigation and fertilizers on kernel weight.

Nut Retention

Irrigation and fertilizer influenced the nut retention significantly. Trees receiving higher level of irrigation (40 to 80 l/tree) retained significantly more nuts than in the low level of irrigation or no irrigation. Similarly trees receiving fertilizers retained significantly more nuts than in trees receiving no fertilizer. Though the interaction effect of irrigation and fertilizer was not significant increased retention of nuts was observed with increased level of irrigation and fertilizers. Tree receiving no irrigation and fertilizer retained minimum of 35.93 per cent nuts whereas tree receiving 80 litres of irrigation/tree and middle and higher doses of fertilizers (500 : 125 : 125 and 750 : 187.5 : 187.5 g of N, P₂O₅ and K₂O respectively) retained 79.58 to 80.40 per cent nuts which was 45 per cent more than control (I₁M₁) (Fig. 3).

Number of nuts

Irrigation and fertilizer application significantly increased yield in terms of number of nuts/tree in sixth and seventh year. Significant increase in yield (82 per cent) was observed in the case of trees receiving highest irrigation level of 80 l/tree compared to tree receiving no irrigation. Just with irrigation without fertilizer application significant increase in yield was observed upto 70 to 99 percent and 30 to 55.2 per cent in sixth and seventh years respectively.

The yield did not increase significantly in trees receiving lower to higher doses of fertilizers in seventh year under unirrigated condition where as in sixth year it increased significantly due to fertilizer application even at the highest dose of 750g N and 187.5g each of P₂O₅ and K₂O/tree / year (M-4) compared to tree receiving no fertilizer and lower dose of fertilizer under irrigated condition.

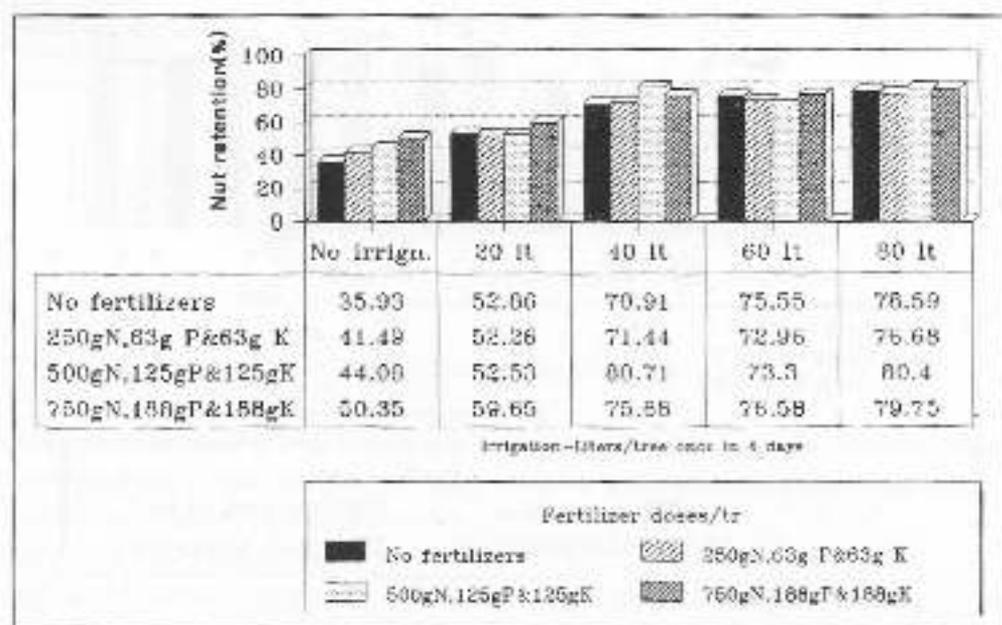


Fig. 3: Effect of Drip irrigation and fertilizers on nut retention

Under irrigated conditions significant increase in yield was observed in terms of number of nuts/tree when fertilizer doses increased from lower to higher level. Highest yield was achieved when the tree was irrigated at the rate of 80 l/tree with highest dose of fertilizer (M-4)

Pooled yield data for the five years from fourth to eighth year after planting indicated that with irrigation alone (without fertilizer application) significant increase in yield by 38 to 72 percent was observed as compared to trees receiving no irrigation and fertilizers. Irrigation at the rate of 80 l/tree once in four days without fertilizer application resulted in cumulative yield of 14.9 Kg/tree while without irrigation and fertilizer application the cumulative yield was 8.6 Kg/tree (Table 12).

Under unirrigated conditions highest cumulative yield of 12.72 and 12.61 Kg/tree was

recorded in trees receiving middle and highest doses of fertilizers while lowest cumulative yield of 8.7 Kg/ha was recorded in tree receiving no fertilizers and irrigation. Increase in yield by 47.4 and 46.1 per cent was observed when middle and higher dose of fertilizers were applied under unirrigated conditions over trees receiving no irrigation and fertilizers. However lower dose of fertilizers under unirrigated condition increased yield by 42.0 per cent over trees receiving no irrigation and fertilizer. Irrigating 60 to 80 l/tree once in 4 days with highest dose of fertilizers increased yield by 132.8 to 157.7 percent over trees receiving no irrigation and fertilizer.

Lowest net profit of Rs.17368/ha for the first eight years was realised in trees receiving no irrigation and fertilizers. Medium dose of fertilizers without irrigation increased profit by 39 per cent over control. Increase in the levels of

Table 12: Effect of drip irrigation and NPK doses on cumulative yield (Kg/tree) upto 8 years after planting.

Treatment	Fertilizer treatment				Mean
	M ₁	M ₂	M ₃	M ₄	
I ₁ (0/l tree*)	8.63	12.1 (42.00)	12.72 (47.39)	12.61 (42.12)	11.51
I ₂ (20 l/tree)	11.94 (38.40)	15.53	17.92	17.96	15.84
I ₃ (40 l/tree)	13.20	16.45	17.15	17.85	16.16
I ₄ (60 l/tree)	14.57	15.62	17.87	21.42	17.24
I ₅ (80 l/tree)	14.87 (72.30)	18.09	20.09 (132.79)	22.42 (157.71)	18.82
Mean	12.64	15.56	17.16	18.41	
CD for irrigation	: 0.918				
CD for fertilizer	: 0.501				
M ₁	= 0	: 0	: 0**		
M ₂	= 250	: 65.5	: 62.5		
M ₃	= 500	: 125	: 125		
M ₄	= 750	: 187.5	: 187.5		

* Once in four days through drippers ; ** N : P₂O₅ : K₂O

Figures in parenthesis is per cent increase over trees receiving no irrigation and fertilizers (I₁M₁)

Table 13: Summary of economics of different treatment plots

Input cost	Treatment			
	I_1M_1	I_3M_1	I_1M_3	I_5M_4
Labour	10855	15910	16300	20265
Materials	6650	23770	13224	33497
Total cost of production	17475	39560	27524	54060
Net income from produce	60356	103134	88186	157793
Discounted incremental benefit	17369	19305	24128	35085
Per cent increase in profit over control plot (I_1M_1)	--	39	11	102
Percent increase in profit over irrigation alone (I_5M_1)	--	--	--	82

Note:

I_1M_1 : No irrigation and fertilizer application.

I_3M_1 : Highest irrigation of 80 l/tree once in 4 days without fertilizer application.

I_1M_3 : Medium dose of fertilizer (500g N : 125g each of P_2O_5 and K_2O tree) without irrigation.

I_3M_4 : Highest level of irrigation (80 l/tree) and fertilizers (750g N, 187.5 g each of P_2O_5 and K_2O /tree).

irrigation under unfertilized condition led to increase in profit of 11 per cent over control. However, with highest level of irrigation (80 l/tree) and fertilizer application the increase in yield was 102 per cent over control and 82 per cent over irrigation alone (Table 13).

Quality of kernels

Rainfed tree and irrigated tree @20 to 60 l/tree produced nuts having significantly higher kernel starch than those trees irrigated @80 l/tree. Fertilizer application did not have any effect on starch content on kernels. Interaction effect of both irrigation and fertilizer was absent on starch content of kernels (Table 14).

Sugar content of kernels obtained from rainfed trees was significantly higher than that from trees irrigated @20 to 60 l/tree. Whereas sugar content in kernels of nuts obtained from tree irrigated at highest level (80 l/tree) was significantly lower than that of all the other

treatments (I_1 to I_4). Fertilizer application did not change sugar content in kernels. Though interaction effect of irrigation and fertilizer was seen on sugar content in kernels no definite trend was observed (Table 15).

Irrigating @ 20 to 60 l/tree (I_2 to I_3) increased protein contents of kernels significantly compared to kernels obtained from nuts of rainfed and that tree receiving highest level of irrigation (80 l/tree). Protein content of the kernel obtained from nuts of trees receiving no fertilizer was significantly higher than kernels of trees applied with fertilizers. Under unfertilised and unirrigated conditions the tree produced kernels having significantly lesser protein content than those trees receiving irrigation. Interaction effect of irrigation and fertilizer was also significant. Highest kernel protein was observed in kernels obtained from trees receiving 60 l irrigation and highest level of fertilizer (M_4) (Table 16).

Table 14: Effect of drip irrigation and graded NPK on starch content (mg/100mg of defatted flour) of kernels.

Irrigation Treatments	1996					1997					Mean of two years				
	M ₁	M ₂	M ₃	M ₄	Mean	M ₁	M ₂	M ₃	M ₄	Mean	M ₁	M ₂	M ₃	M ₄	Mean
I ₁	31.25	31.55	29.66	33.35	31.45	23.09	22.35	25.04	20.40	22.71	27.17	26.95	27.35	26.87	27.08
I ₂	35.54	35.79	32.60	33.49	34.36	22.82	22.46	22.76	22.46	22.62	29.18	29.13	27.68	27.97	28.48
I ₃	32.73	33.23	33.73	32.78	33.35	22.12	22.78	21.80	23.50	22.55	27.42	28.00	27.76	28.61	27.95
I ₄	31.23	36.80	35.72	26.68	34.13	22.43	20.34	21.30	18.17	20.56	27.61	25.79	29.05	26.95	27.35
I ₅	22.75	23.01	30.99	23.09	25.85	20.27	23.07	20.45	17.74	20.38	23.48	22.91	21.73	24.37	23.12
Mean	31.79	30.91	31.16	33.46	31.83	22.14	22.20	22.27	20.46	21.77	26.97	26.55	26.71	26.95	

Parameters	SEm±	CD
Irrigation	0.22	1.52
Fertilizer (M)	0.17	NS
Interaction (IxM)	0.37	NS
Year	0.14	0.96

Table 15: Effect of drip irrigation and graded doses of NPK on sugar content of kernels (mg/100 mg defatted flour)

Irrigation Treatments	1996					1997					Mean of two years				
	M ₁	M ₂	M ₃	M ₄	Mean	M ₁	M ₂	M ₃	M ₄	Mean	M ₁	M ₂	M ₃	M ₄	Mean
I ₁	8.11	11.33	7.74	10.70	9.47	5.35	6.12	7.53	6.65	6.41	6.73	8.72	7.64	8.67	7.94
I ₂	5.64	5.23	5.86	5.42	5.53	7.23	8.51	7.95	7.91	7.89	6.43	6.87	6.90	6.66	6.72
I ₃	7.22	5.75	5.95	5.43	6.09	8.31	7.85	7.39	7.10	7.66	7.76	6.80	6.67	6.27	6.88
I ₄	6.58	6.39	6.21	6.99	6.54	7.91	7.15	7.38	7.32	7.44	7.25	6.77	6.80	7.15	6.99
I ₅	5.54	5.12	5.82	5.73	5.56	4.86	2.24	3.32	2.29	3.18	5.20	3.68	4.56	4.00	4.36
Mean	6.62	6.77	6.32	6.85	6.63	6.73	6.37	6.71	6.25	6.52	6.67	6.57	6.51	6.55	6.54

Parameters	SEm±	CD
Irrigation	0.1634	0.5934
Fertilizer (M)	0.1461	NS
Interaction (IxM)	0.3267	1.18
Year	0.1033	NS

Table 16: Effect of drip irrigation and graded doses of NPK on protein content (mg/100 mg of defatted flour) in kernels

Irrigation Treatments	1996					1997					Mean of two years				
	M ₁	M ₂	M ₃	M ₄	Mean	M ₁	M ₂	M ₃	M ₄	Mean	M ₁	M ₂	M ₃	M ₄	Mean
I ₁	62.38	53.50	56.16	56.50	57.13	28.00	26.68	37.10	35.29	31.77	45.19	40.08	46.63	45.90	44.54
I ₂	68.12	55.21	54.91	54.05	57.07	44.32	45.19	47.22	48.45	46.29	56.22	50.20	51.07	51.24	52.18
I ₃	69.79	52.19	54.55	57.51	58.51	48.99	47.18	50.78	64.67	52.91	59.39	49.68	52.66	61.09	55.71
I ₄	66.69	51.18	53.51	54.56	56.48	52.29	44.13	44.53	43.83	46.21	59.49	47.65	49.02	49.22	51.35
I ₅	58.41	53.21	51.76	52.92	54.07	36.28	36.06	41.65	43.84	39.46	47.34	44.64	46.71	48.38	46.77
Mean	65.08	53.05	54.18	55.10	56.85	41.97	39.85	44.26	47.23	43.33	53.33	46.45	54.18	51.17	50.09

Parameters	SEm±	CD
Irrigation	1.044	3.79
Fertilizer (M)	0.0933	3.39
Interaction (I x M)	2.088	7.58
Year	0.6603	NS

SUMMARY

Irrigation significantly increased number and weight of nuts/tree. Highest yield was obtained when trees were irrigated at 80 l/tree once in four days from second fortnight of December to end of March compared to lowest level of irrigation (20 l/tree) and no irrigation. The crop responded significantly to the highest level of NPK fertilizers (750gN: 187.5g each of P_2O_5 and K_2O /tree) resulting higher yield than those receiving lower dose (250g N:62.5g each of P_2O_5 and K_2O /tree) and no fertilizers. Interaction effect of both irrigation and fertilizer was not observed. However, highest economic yield was obtained from trees receiving highest level of irrigation and fertilizer.

Increased yield due to irrigation and fertilizer application separately was as a result of increase in exposed canopy area, photosynthetic rate, light interception, nut retention, number and weight of nuts/tree and shelling percentage. Though the interaction effect of irrigation and fertilizer was not observed for the above yield

attributes, increasing trend was observed with the level of irrigation and fertilizers.

Irrigation at 20, 40 and 60 l/tree significantly increased kernel protein content compared to the nuts of tree receiving highest irrigation at 80 l/tree and no irrigation. Protein content of kernels in trees receiving middle and higher level of fertilizers was significantly more than the tree receiving no fertilizers and low level of fertilizers (250g N:62.5g each of P_2O_5 and K_2O_5 /tree/yr).

It was concluded that irrigating cashew tree at the rate of 80 l/tree once in 4 days from second fortnight soon after the flowering initiation is highly beneficial in increasing yield for the first eight years in the grafted plants. It is also beneficial if the tree is applied with 750g N: 187.5g P_2O_5 and K_2O /tree per year in two split doses two thirds in September and one third in February along with irrigation (80 l/tree once in four days from December to March).

2.6 Development of suitable cashew based cropping systems

1. Inter and mixed cropping with cashew

Leader : N.Yadukumar (1987-1996)

Associate : B.Nagaraja (1990-1996)

Associate : E.Mohan (1987-1990)

INTRODUCTION

Cashew is cultivated both in the west coast where the lands are fairly levelled and in the interior areas on undulating land and with slopes. The climate is warm and humid with temperature ranging from 22°C to 38°C, relative humidity 75 to 85% and mean annual rainfall of about 3500 mm. The soils are mainly lateritic or gravely in hilly tracts and porous with mostly acidic reaction. Because of undulating topography soil erosion is a major problem in exposed areas.

In coconut and arecanut plantations, intercropping and mixed cropping in the interspaces to reduce soil erosion and to augment additional income have been well documented (Nelliath 1974; 1983; Abraham 1974; Sadanandan, 1974). Selection of intercrops in high density cropping system is made with short and long term perspectives, annuals for immediate returns and perennials and fuel trees for sustained income on a long term basis. Compatibility studies were taken up by understanding root and canopy architecture energy input/output, PAR, micro and macro climate, competition for nutrients, moisture and light (Bavappa and Mandal, 1984) and the final choice is based on overall economics of the system.

In India cashew was mainly grown by

small holders in marginal lands despite the fact that it fetched valuable foreign exchange. Only in recent years, its economic importance has been realised and attempts were made to increase its productivity through improved management and better varieties.

Intercropping was not viable earlier as cashew itself was grown on soils with low water availability and fertility. With the establishment of large plantations and adoption of systematic package of practices, intercropping is practiced to obtain returns during the initial years of cultivation. Once cashew canopy becomes dense, intercropping (legumes and millets) is discontinued. Mixed cropping with other trees is not widely practised although there are some reports of casuarina being planted along with cashew in Andhra Pradesh and Orissa. For the first time, a trial was conducted at this research centre with cashew based cropping system models including annual crops, forest tree species and fruits crops (Mandal *et al.*, 1988). The present work describes the performance of cashew in such a cropping system with special reference to light profiles, photosynthetic characteristics, growth, yield and economics.

MATERIAL AND METHODS

The experiment was laid out in 1987 at National Research Centre for Cashew, in Randomised Block Design (RBD) with 10 treatments. Cashew grafts of variety M 10/4 were planted at 8 x 8m spacing and in the interspace the following inter/mixed crops were planted 1.5m away from main (cashew) crop at recommended spacings for the crops chosen as inter and mixed crops.

Pineapple was replanted in the original cashew + pineapple plot on 5th year and fruit yield was recorded subsequently upto 8th year. The tree species acacia, casuarina and subabul were removed five years after planting and in the same plots pineapple suckers were planted in trenches dugout across the slope between two rows of cashew trees. Fruit yield was recorded upto 8th year of the experiment.

Treatment	Variety	Spacing (m x m)	Population/ ha
Main Crop Cashew	M 10/4	8 x 8	156
Inter/mixed crop			
a) Annual crops			
Pigeonpea-first 2 years	ICPL-87	0.75x0.40	23500
Vaisaki			
Tapioca-first 2 years	M-4	1.00x0.75	7300
Sunflower Later 1 year	Morden	0.7x0.4	24000
Castor-1 year	Aruna	0.7x0.4	24000
Sweet potato & cucumber (later 1 year)	Local	0.7x0.4	24000
b) Fruit crops			
Pineapple	Kew	0.55x0.40x0.90	15625
Guava	L-49	8x8	156
c) Forest species			
Casuarina	Local	2.0x2.0	1430
Acacia	Local	2.0x2.0	1430
Subabul	Local	2.0x2.0	1430
d) Cover crop			
Mucuna bracteata	Local		
e) Control-Cashew alone	M 10/4	8 x 8	156

The recommended dose of fertilizers was applied to both main and intercrops. In addition, 2 kg of poultry manure/pit was applied to cashew, tree species and guava and one tonne/ha poultry manure was applied to pigeon pea, tapioca, castor and sunflower, cucumber and sweet potato and cover crops at the time of planting.

Morphological observations like height, girth and canopy of cashew, tree species and fruit crops were taken each year up to three years after planting and five years after planting. While yield of annual crops was recorded at the time of harvest and light interception by the main crop and all the intercrops (except cover crop and annual crops) was also measured. Net photosynthesis rate (P_N), transpiration, stomatal conductance, intercellular CO_2 concentration and microclimatic factors like humidity, leaf temperature and ambient temperature were determined continuously for three years from 3rd year onwards in plots where trees species were tried as intercrops. Moisture levels in soil at three depths during the peak summer season were

determined by oven dry method to find out any impact of intercropping especially in plots where pineapple, tree species and cover crops were grown. Yield of main and inter/mixed crops was also recorded. Economics of growing different inter/mixed crops was worked out.

RESULTS AND DISCUSSION

Observations on the main and inter/mixed crops were recorded one, to eight years after planting in the case of biennial and perennials and each year in the case of annuals at the time of peak vegetative growth and harvest.

Growth characters of cashew

Initially no difference was observed in the height of main crop (cashew) when inter/mixed cropped with annuals, fruit crop and tree species. Five years after planting height of cashew plant was significantly lesser when cashew was mixed with casuarina, subabul and acacia than the cashew grown without inter/mixed cropping. Girth was similarly less when interplanted with tree species, casuarina and acacia.

Table 1: Effect of inter and mixed cropping system on girth, height, canopy spread and ground coverage of main crop

Treatment (Cropping system)	Girth (cm)		Height (cm)		Canopy spread (cm)		Ground coverage (%)	
	3 YAP	5 YAP	3 YAP	5 YAP	3 YAP	5 YAP	3 YAP	5 YAP
Cashew alone	30	49.88	270	423	340	655	14.60	52.74
Cashew + Pineapple	28	54.30	320	439	360	744	18.20	68.10
Cashew + Guava	27	46.83	236	408	310	566	12.80	39.50
Cashew + Acacia	20	38.71	236	436	244	504	7.30	32.21
Cashew + Casuarina	23	46.66	256	417	287	535	10.02	35.78
Cashew + Subabul	26	42.20	249	440	261	592	8.40	35.17
Cashew + <i>Mucuna bruceata</i>	28	46.10	251	445	320	583	10.40	41.92

Table 2: Changes in P_N, gs and intercellular CO₂ in cashew grown with other forest tree species.

Treatment	P _N (μmol CO ₂ m ⁻² s ⁻¹)			gs (mol M ⁻² s ⁻¹)			Intercellular CO ₂ (ppm)		
	2/89	1/90	2/91	2/89	1/90	2/91	2/89	1/90	2/91
Cashew monocrop	10.01	11.35	13.07	0.41	0.85	0.82	252	265	280
Cashew + acacia	7.83	5.41	2.28	0.44	0.70	0.65	274	295	322
Cashew+ casuarina	10.69	9.11	7.72	0.50	1.12	0.81	259	283	294
Cashew + subabul	ND	10.97	8.09	ND	0.82	0.86	ND	271	296
SE	0.58	0.94	0.94	0.02	0.08	0.03	3.0	5.3	6.3

ND = Not determined

Maximum spread of canopy was observed in cashew grown with pineapple both three and five years after planting. The spread was minimum in plots where tree species were grown, particularly acacia. Ground coverage by the cashew canopy was highest in plot where cashew and pineapple were grown. Lower ground coverage by the main crop canopy was in cashew + acacia plot. (Table 1)

PAR and Photosynthetic characteristics in Cashew

The light received by the main crop was 27 per cent in acacia plot and 62 per cent in casuarina plot two years after planting indicating the need for removal (thinning) of acacia and casuarina trees situated on either side of cashew plant. In the same year, thinning of acacia and

cashew was done to reduce population to 78 per cent. Observations on PAR after thinning showed that the main crop received 68 per cent and 74 per cent light in acacia and casuarina plots respectively.

Observations on light (PAR) received by the main crop three years after planting (one year after thinning of acacia and casuarina plants) in the plots of tree species showed that there was considerable reduction in value in acacia (7.4%) and casuarina plots (21%). The light received under the canopy of subabul plants was to the tune of 43 per cent.

P_N and gs were maximum in cashew monocrop followed by cashew with subabul and casuarina (Table 2). There was a gradual decline in

Table 3: Changes in E_o and WUE in cashew grown with other forest species

Treatment	E (mmol H ₂ O m ⁻² s ⁻¹)			WUE (μmol CO ₂ /mmol H ₂ O)		
	2/89	1/90	2/91	2/89	1/90	2/91
Cashew monocrop	9.42	10.33	9.60	1.07	1.10	1.20
Cashew + acacia	6.95	9.03	7.38	1.12	0.60	0.37
Cashew + casuarina	9.46	15.03	7.34	1.13	0.61	1.01
Cashew + subabul	ND	13.15	8.64	ND	0.83	0.93
Mean	8.72	11.77	8.34	1.10	0.78	0.96
SE	0.48	0.89	0.32	0.03	0.08	0.10

ND = Not determined

the P_N over the years with the canopy of forest trees getting denser. Cashew was adversely affected when grown with acacia in respect to P_N and is reflected in its growth performance.

Transpiration rate and WUE in cashew are presented in Table 3. Evapotranspiration (E_o) showed responses almost parallel to the P_N values. Lowest WUE was observed in cashew grown with acacia and it further declined after three years. The regression analysis of P_N with E_o , WUE and PAR showed a significant positive linear relationship. Regression models for P_N ($n=46$) were $y_e = 2.188 + 7.014E$ ($r = 0.52$, $P = 0.01$) and $y = 1.781 + 7.465$ WUE ($r = 0.77$ $p = 0.01$). This explains the concomitant reductions of P_N , E_o and WUE.

Thus, there was a heavy competition for light when cashew grown as a mixed plantation especially with acacia. To avoid further competition for light all trees species were removed five years after planting. Observations were again taken on photosynthetic characteristics just before removal of tree species and after the removal of tree species.

Marked increase in photosynthetically active radiation (photon flux density) and net photosynthesis (PEP, 1408, 1412 and 1418 $\mu\text{mol CO}_2 \text{ m}^{-2}\text{s}^{-1}$) was observed two years after the removal of tree species (Table 5). The photon flux density (PFD) and net photosynthesis were as minimum as 97 $\mu\text{mol CO}_2 \text{ m}^{-2}\text{s}^{-1}$ and 2.7 $\mu\text{mol CO}_2 \text{ m}^{-2}\text{s}^{-1}$ respectively in the case of cashew when grown with acacia before the removal of this tree species (acacia). These values increased to 1312 $\mu\text{mol CO}_2 \text{ m}^{-2}\text{s}^{-1}$ and 8.8 $\mu\text{mol CO}_2 \text{ m}^{-2}\text{s}^{-1}$ two years after the removal of acacia (tree species) in the plot. Similar trend was observed in plots before and after the removal of subabul and casuarina.

This gives an indication that though the values for the above parameters were minimum when tree species were grown upto five years after planting, after the removal of these tree intercrops the main crop (cashew) picks up considerably resulting in higher values for the above parameters. This was also reflected in increased yield two years after the removal of tree intercrops.

Soil moisture status

Soil moisture level determined in March, in different plots revealed that it was more in pineapple and mucuna plots than in control plots. Further, the observation revealed that moisture content was minimum in plots with tree species. This was particularly evident in casuarina plot. Exhaustion of moisture by tree species during peak summer season adversely affected the main crop. Moisture content extracted by casuarina and acacia at deeper layers was evident with reduction in moisture levels at 50-75 cm depth (Table 5).

Microbial activity

In order to understand the effects of agroforestry tree species (acacia, casuarina and subabul) when grown as intercrops during the initial five years of cashew orchard (main crop), microbial counts were taken by serial dilution and plating in various media. The population of bacteria, fungi, actinomycetes, phosphate solubilizing bacteria, fungi and nitrogen fixing bacteria were enumerated. The results from the samples taken during December and January showed an increase in the population of actinomycetes and decrease in the total bacteria, fungi, phosphate solubilizing bacteria, fungi and nitrogen fixing bacteria (Table 6) in plots where tree species acacia, subabul and casuarina were grown as intercrops for the first five years of the

Table 4: Photosynthesis and other related parameters of cashew (main crop) under different cropping systems before and two year after the removal of tree species.

Cropping systems prevailing in 1992 (i.e., upto 5 years after planting)	PFD (mol m ⁻² s ⁻¹)		P _N (mol CO ₂ m ⁻² s ⁻¹)		g _s (mol m ⁻² s ⁻¹)		C _i (ppm)		E _o (M mol H ₂ O M ⁻² s ⁻¹)		WUE (mol CO ₂ m ⁻² s ⁻¹) (mmol H ₂ O m ⁻² s ⁻¹)	
	BRT	2yrs ART	BRT	2 yrs ART	BRT	2 yrs ART	BRT	2 yrs ART	BRT	2 yrs ART	BRT	2 yrs ART
Cashew monocrop	1229	1408	9.6	10.5	0.89	0.98	256	275	6.65	7.3	1.44	1.43
Cashew + acacia	97	1412	2.7	8.8	0.72	0.81	236	261	8.02	8.3	0.37	1.06
Cashew + casuarina	330	1418	4.6	8.9	0.80	0.89	204	274	7.24	8.4	0.63	1.05
Cashew + subabul	558	1424	6.1	9.8	0.79	0.92	214	285	8.8	0.86	1.11	
SEM				0.4207					0.089			
CD				NS					0.274			

PFD - Photon flux density P_N = Net photosynthesis g_s - Stomatal conductance C_i - Intercellular CO₂ Concern. E_o - Transpiration, WUE - Water use efficiency
 BRT - Before removal of tree species ART - After removal of tree species.

Table 5: Soil moisture content at three depths under different inter/mixed cropping systems.

Treatment	Moisture content (%)			Mean
	Depth (cm)			
	0-25	25-50	50-75	
Cashew + Pineapple	10.47	9.63	14.51	11.53
Cashew + Casuarina	5.55	7.66	6.86	6.59
Cashew + Subabul	8.56	10.56	10.23	6.78
Cashew + Acacia	8.35	9.16	8.17	8.56
Cashew + Mucuna	9.58	11.51	13.36	11.48
Cashew alone	7.51	7.94	9.82	8.42

Table 6: NPK and Ca content of soil under different cropping systems.

Cropping systems	N (%)	P ₂ O ₅ (Kg/ha)	K ₂ O (Kg/ha)	Ca (ppm)
Cashew alone	0.08	16.81	120.5	105
Cashew + pineapple	0.09	43.80	112.5	108
Cashew + acacia	0.06	10.50	92.5	78
Cashew + subabul	0.09	8.22	84.3	143
Cashew + casuarina	0.08	7.52	120.3	124
Cashew + covercrop	0.14	20.20	133.4	124

orchard life. This is also reflected in N & P₂O₅ content of the soil in the above cropping system (Table 7).

Nutrient content of the soil in the cropping system

The soil samples taken for microflora studies were also analysed for nutrient content to understand the effect of growing intercrops on the nutrient content of soil. It has been found that nitrogen content was maximum in plot where previously acacia, subabul and casuarina were grown for the first five years as intercrops (Table 8). The P₂O₅ content in the case of tree species plots was also less. This is in conformity

with the reduced population of phosphorus solubilising bacteria and fungi in those plots where tree species were grown with cashew (Table 6). Phosphorus content in pineapple plot (cashew + pineapple) was fairly high. This was mainly due to the build up of P content in soil as a result of yearly application of phosphorus in the form of rock phosphate over a period of five years in the cropping system where pineapple is grown as intercrops from 1987.

Yield (Main crop)

Yield data during the first seven years after planting and two years after the removal of tree species (acacia + subabul + casuarina) are presented in Table 8. In plots where tree species

Table 7: Microbial population in different cropping systems

Cropping systems	Bacteria	Fungi	Actinomycetes	P.Solubilizing fungi	P-solubilizing bacteria	N ₂ fixing bacteria
Cashew + Monocrop	18.87 x 10 ⁵	24.12 x 10 ³	34.25 x 10 ⁴	19.5 x 10 ³	22.87 x 10 ³	16.87 x 10 ³
Cashew + Pineapple	29.5 x 10 ⁵	23.75 x 10 ³	34.75 x 10 ⁴	19.75 x 10 ³	17.37 x 10 ³	16.37 x 10 ³
Cashew + Subabul	21.62 x 10 ⁵	25 x 10 ³	38.13 x 10 ⁴	18.25 x 10 ³	19.25 x 10 ³	15 x 10 ³
Cashew + Acacia	14.13 x 10 ⁵	17.25 x 10 ³	16.87 x 10 ⁶	19.5 x 10 ²	12.25 x 10 ³	7.75 x 10 ³
Cashew + Casuarina	11.25 x 10 ⁵	13.75 x 10 ³	17. x 10 ⁶	25.25 x 10 ²	4.27 x 10 ³	9.13 x 10 ³
Cashew + Mucuna	17.50 x 10 ⁵	27.25 x 10 ³	35.75 x 10 ⁴	21.19 x 10 ³	13.25 x 10 ³	13.62 x 10 ³

were grown for the first five years, pineapple suckers were planted in trenches dug out across the slope between two rows of cashew one year after the removal of tree species (acacia, subabul and casuarina). The yield of main crop (cashew) increased considerably (12.12, 10.32 and 13.15 kg/plot in the plots intercropped, with acacia, subabul and casuarina respectively) when pineapple was planted after the removal of tree species. The yield recorded from the plot intercropped with pineapple right from 1987 was significantly higher than that of other plots. Lowest yield was recorded from the plot intercropped with acacia even two years after the removal of this tree species. However, the yield of cashew in the plot where acacia was grown for the first five years and removed later has increased over the previous year almost by five folds.

This quantum jump in yield over the previous year is not observed in the case of other

plots where cashew alone, cashew with pineapple, cashew with casuarina and cashew with subabul were grown. This indicates that though acacia affected yield of main crop initially, after the removal of this tree species, the yield of cashew increased considerably. This is in conformity with the observations on photon flux density and net photosynthetic rate in the above plot. Subsequently, eight years after planting the yield did not increase in the plots where tree species were grown previously. The difference in yield among different treatment was not significant. In the plot where cashew was grown with pineapple cashew yield was significantly superior to all other plots. Cumulative yield for the first eight years also showed that cashew + pineapple combination from 1987 resulted in highest yield of 73.7 kg/plot. Minimum yield was obtained from cashew + acacia combination (21.86kg/plot) (Table 8).

Table 8: Effect of cropping system on cashewnut yield from 3rd to 8th year after planting and cumulative yield per plot (6 plants) and per ha (200 plants).

Cropping system	3rd year	4th year	5th year	6th year	7th year	8th year	Cumulative yield/plot	Cumulative yield /ha.	% Control
Cashew + annuals ⁰¹	2.31	3.20	4.60	6.70	8.5	12.5	37.81	983.06	85.7
Cashew + annuals ⁰²	1.75	3.40	3.60	6.80	6.2	10.5	32.25	749.84	73.11
Cashew + pineapple	4.51	5.40	8.80	14.37	28.34	12.29	73.71	1916.46	167.1
Cashew + guava*	2.98	3.30	5.30	5.94	13.58	9.79	40.189	1063.14	92.7
Cashew + acacia*	0.40	1.33	2.03	2.15	10.32	5.63	21.86	568.36	49.5
Cashew + casuarina*	0.85	2.56	4.06	6.73	12.12	10.23	36.55	950.30	82.9
Cashew + subabul	1.38	2.60	4.12	5.44	13.15	8.23	34.88	906.88	79.1
Cashew + mucana	2.06	4.13	4.46	8.43	15.32	14.31	48.71	1266.46	110.4
Cashew alone	2.54	4.40	5.60	7.78	14.42	9.37	44.11	1146.86	
CD (5%)	0.94	1.03	2.56	3.27	7.07	NS			

* Inter crops existed only upto 5 years and pineapple was planted after the removal of tree species in the same plots. Annual⁰² sweet potato and cucumber were raised only for 2 years and prior to this castor and sun flower were grown which were a failure. Among the annual crops⁰¹ tapioca and pigeon pea were grown initially for the first 2 years.

Yield of intercrops

Yield of different intercrops are presented in Table 9 & 10. Among fruit crops, pineapple yielded 16880 kg/ha in the plot originally planted with cashew + pineapple. Pineapple planted after the removal of forest tree species yielded differently in different plots originally planted with cashew + acacia, casuarina and subabul. In cashew + subabul plot pineapple fruit yield was higher compared to other plots (1960 kg/ha in cashew + acacia plot, 8554 kg/ha in cashew + casuarina plot).

Economics

Economics worked out for the first eight years of cropping system showed that growing pineapple from the beginning as intercrop with cashew fetched maximum profit of Rs.57965/ha.

Next to this, growing casuarina as intercrop for the first five years and subsequently growing pineapple in the same plot with cashew was found to fetch net profit of Rs. 41269/ha.

SUMMARY

In order to utilise interspace and to check soil erosion during initial stages of cashew, planting different annuals, biennials and perennials were evaluated. While soil erosion could be checked using cover crop, sustained

additional income can be obtained by growing intercrops. The crops tested were pigeon pea, tapioca and sweet potato (food crops), castor and sun flower (oil seed crops) and biennial and perennial intercrops such as pineapple and guava, and the pulp and fuel wood perennials like acacia, casuarina and subabul.

During the initial eight years significant increase in growth, light interception, photosynthesis characteristics and yield in the main crop was observed when pineapple was grown as an intercrop. Growing tree species affected the main crop in terms of growth, photosynthetic character and yield in comparison to cashew alone, cashew + pineapple and cashew + mucuna. Pineapple and mucuna improved soil moisture and nutrient content aiding microbial activity leading to a positive effect on main crop.

Pineapple fetched a maximum profit of Rs. 57965/ha till eight years followed by growing casuarina for first five years and subsequently growing pineapple in the same plot which led to a profit of Rs. 41269/ha.

Though profit is substantial by growing tree species like casuarina and acacia the cumulative yield in main crop reduced significantly compared to cashew + pineapple and cashew + mucuna and cashew alone plots.

Table 9: Cumulative yield of intercrops in cashew based cropping system

Cropping system	Yield (Kg)		Useful poles per plot (no.)	Useful poles per ha (no.)
	Per plot	Per ha		
Cashew + pineapple	649	16880	--	--
Cashew + guava	154	3998	--	--
Cashew + acacia (for the first 5 years) and pineapple subsequently	460	11960	52	2392
Cashew + casuarina (for the first 5 years) and pineapple subsequently	329	8554	72	1872
Cashew + subabul (for the first 5 years) and pineapple subsequently.	502	13052	35	910

Table 10: Benefit cost analysis for the cropping systems/ha for the first 8 years.

Cropping systems	Cumulative cost of cultivation Rs./ha		Yield from main crop Kg/ha	Value (Rs.)	Yield of intercrops		Value (Rs.)	Total income from cropping systems (Rs.)	Profit
	Main crop	Inter crop			Total	t/ha.			
Cashew alone	23243	--	1147	37168	--	--	--	37168	13925
Cashew + annual crops ⁰¹	23243	7344	984	31922	1.25	--	10000	41922	11335
Cashew + annual crops ⁰²	23243	6722	838	27098	0.30	--	4800	31898	1933
Cashew + aineapple	23243	32922	1916	6219	16.88 (F)	4500	51841	114030	57965
Cashew + guava	23243	14400	1063	34509	3.998	--	23988	58447	20854
Cashew + acacia (for 5 years and pineapple subsequently)	23243	70691	568	19072	9.4 (FW)	2392(P)	38700 + 53824	132532	30198
Cashew + subabul (for 5 years and pineapple subsequently)	23243	77995	906	29838	0.50 (FW)	910	13800 + 78312	121950	20712
Cashew + mucuna (cover crop)	23243	--	1266	41565	--	--	--	41565	18322

⁰¹ = Annual crops in the first 2 years tapioca and subsequently 2 years castor and 5th & 6th year in cumumber

⁰² = Annual crops in the first 2 years pigeon pea and subsequently 2 years sunflower and 5th & 6th year sweet potato

FW = Fuel wood sold @ Rs. 300/ton; F = Pineapple fruit sol @ Rs. 2.50 in the first 2 years and Rs. 6.0/kg in subsequent years.

P = Poles of 3m length sold @ Rs. 30/pole; S = Suckers in nos. sold @ Rs. 0.50/ sucker on 5th year after planting and @ Rs. 1.0/sucker subsequently. Guava fruits were sold @ Rs. 6.0/kg.

Price of cashew nuts for different years were as follows:

3rd year (1990-91) = Rs 25/kg ; 4th year (1991-92) = Rs. 30/kg ; 5th year (1992-93) = Rs. 30/kg

6th year (1993-94) = Rs 30/kg ; 7th year (1994-95) = Rs. 35/kg ; 8th year (1995-96) = Rs. 35/kg

2. Cashew with forest tree species

Leader : N. Yadukumar (1990-1998)

INTRODUCTION:

Forest trees species as intercrops in cashew plantation were evaluated, for the first time to know the effect on cashew and to workout economics of different cropping systems.

MATERIAL AND METHODS

This experiment was laid out by adopting randomised block design with three replications during 1990. The treatment consisted of cashew as the main crop planted in hedge row system with

a spacing of 10 x 5m. The plant rows are aligned along north-south direction to get maximum incident sun light. The forest tree species tried were acacia and casuarina, bamboo, ailanthus and subabul. Normal planting with 10 x 5m spacing of cashew alone was tried as control plot along with a high density planting of 5 x 5m. Although the spacing adopted for cashew remained the same the spacing adopted for forest species (as intercrops) varied. The population of forest tree species ranged from 6 to 78 per plot of 300 sq.m. (Table 1).

Table 1: Spacing of intercrops in cashew based cropping system with forest species

Intercrops in cropping system	Forest species	Spacing within the row (m)	Spacing between two rows (m)	Spacing between paired rows (m)	No. of plants/plot of 383 m ² area
Acacia + casuarina	Acacia	2.5	10.0	--	42
	Casuarina	2.5	2.5	7	39
Casuarina + acacia	Casuarina	1.25	10.0	--	42
	Acacia	2.5	2.5	7	42
Ailanthus	Ailanthus	2.5	2.5	7	57
Subabul	Subabul	1.25	1.25	5	225
Bamboo	Bamboo	5.0	10.0	--	15

Note: Spacing adopted for cashew was 10 x 5m in all cropping systems whereas, in high density it was 5 x 5m.

Growth

Observations on stem girth, height, spread and ground coverage of the main crop were taken on 4, 6 and 8 years after planting.

Physiological characters

Observations on photosynthetic characters like photon flux density (PFD), photosynthetic rate, transpiration and stomatal conductance and intercellular concentration were recorded using LCA-3 photosynthesis system II during February (10am to 11am). Observations were taken selecting 2 to 3 month old matured 3rd to 5th leaf from the top. Observations were taken from all the four sides of two plants in each treatment

from 4th year of planting. Soil moisture content was also determined at different depths.

Nut yield

Nut yield for main crop was recorded tree-wise as well as plotwise from four to eight years after planting.

Fuel wood and pole yield from intercrops

Biomass of the forest tree species removed was determined and number of useful poles and weight of fuel wood was recorded for calculating the economics.

Economics

Benefit cost ratio for different cropping

systems was determined for eight years after planting.

RESULTS AND DISCUSSION

Growth

Growing forest species with cashew did not affect height and spread significantly after four years after planting. However, its influence on total ground coverage was evident in high density system of cashew alone. Growing forest tree species as casuarina and acacia affected girth of cashew tree leading to significantly lower girth than the cashew + ailanthus, cashew + bamboo, cashew high density, cashew + subabul and cashew alone plots (Table 2).

Photosynthetic characters

Except intercellular CO₂ concentration all the other physiological parameters varied significantly in different cropping systems. Photo flux density, transpiration, stomatal conductance and net photosynthesis were significantly lower in cashew + acacia (1 row) + casuarina, cashew + casuarina (1 row) + acacia (2 rows) than all other plots (Table 3). This indicates growing acacia and casuarina as an intercrop is not feasible beyond four years in cashew gardens. The yield also reduced significantly due to growing of tree species as intercrops in cashew.

Soil moisture:

No significant differences was observed in

Table 2: Growth parameters of cashew as affected by growing forest species in the interspace.

Treatment	Population/ plot (300 sq.m)	Girth (cm)	Height (cm)	Spread (cm)	Ground coverage	
					m ²	%
Cashew + casuarina + acacia	6+12+13	22.86	203	273	5.83	11.6
Cashew + acacia + casuarina	6+7+14	25.40	245	314	7.75	15.2
Cashew + ailanthus	6+32	33.53	216	326	8.34	16.7
Cashew + bamboo	6+6	32.00	231	360	10.19	20.3
Cashew high density	12	32.51	219	330	8.54	34.2
Cashew + subabul	6+78	33.02	221	329	8.51	17.0
Cashew alone	6	33.27	221	329	8.51	17.0
CD		6.25	NS	NS	NS	

Table 3: Effect of growing forest trees species in cashew orchards on photosynthesis, PAR, transpiration, stomatal conductance.

Treatment	PAR		Transpiration (M mol H ₂ O m ⁻² s ⁻¹)	Gs (Mol m ⁻² s ⁻¹)	CO ₂ concentr- ation (ppm)
	(μmol m ⁻² s ⁻¹)	(μmol CO ₂ m ⁻² s ⁻¹)			
Cashew + casuarina + acacia	758	7.02	6.1	0.38	241
Cashew + acacia + casuarina	724	5.83	7.1	0.30	240
Cashew + ailanthus	1333	8.57	9.1	0.53	256
Cashew + bamboo	1320	7.60	8.9	0.66	260
Cashew high density	1350	8.30	7.0	0.33	224
Cashew + subabul	8.2	7.32	6.2	0.23	220
Cashew alone	1357	8.25	6.3	0.30	208
CD	191	2.80	1.03	0.123	

soil moisture level at three different depth among different cropping systems except the plot where subabul was grown as intercrop. Here subabul was grown upto eight years after planting and while taking observation intercrop was existing. The moisture content in subabul plot was 3 to 7 per cent more than the plot where cashew alone was grown (Table 5).

Yield and Economics

Cashewnut production per plot as well as per ha. was significantly lower in cashew + casuarina (2 rows) + acacia (1 row) and cashew + acacia (2 rows) + casuarina (1 row), than in plots where all other tree species were grown as intercrops. Three years after removal of the tree species no significant increase in cashew yield was recorded. Poles and fuel wood realised from intercrops are presented in Table 5. It was observed that maximum number of useful poles and fuel wood was produced in cashew + acacia (2 rows) + casuarina (1 row) fetching a total revenue of Rs. 40505/ha. Maximum profit of Rs. 15902/ha was realised where two rows of acacia

and one row of casuarina were grown as intercrops. The profit realised when cashew was grown alone under normal spacing was Rs. 4624/ha and under high density planting was Rs. 15378/ha (Table 6).

SUMMARY

Growing tree species like acacia and casuarina as intercrops led to reduced yield of cashew. Reduction in yield of cashew continued for three years after removal of these tree species. However, ailanthus, subabul and bamboo did not influence cashew yields for the first six years. The total income from cashew intercropped with ailanthus, subabul or bamboo was lower. Cashew in combination with casuarina + acacia for the first six years and growing cashew alone after removal of tree species upto eight years is not desirable as it affects main crop yield. It is beneficial to take up high density planting of cashew rather than going in for forest tree species as intercrops in cashew plantation under normal spacing (main crop).

Table 4: Effect of growing forest species as intercrops on cashew yield (kg/ha) for the first 9 years.

Cropping system	Mean yield kg/ha						Cumulative yield (kg/ha)
	4 YAP	5 YAP	6 YAP	7 YAP	8 YAP	9 YAP	
Cashew + casuarina (2 rows) + acacia (1 row)	60.7	96.6	24.2	20.9	30.7	132.6	365.7
Cashew + acacia (2 rows) + casuarina (1 row)	69.3	116.6	54.8	45.5	44.5	131.0	461.7
Cashew + ailanthus	76.7	229.8	88.2	73.4	106.1	251.3	825.5
Cashew + bamboo	63.3	193.1	102.2	109.0	228.7	277.0	973.3
Cashew (high density)	125.0	433.0	203.5	194.4	477.1	541.8	1974.3
Cashew + subabul	67.3	209.8	107.7	85.7	102.8	242.3	813.6
Cashew (normal spacing)	94.0	239.8	80.3	92.4	180.5	212.7	899.6
CD (5%)	19.8	34.3	21.6	97.1	254.6	100.2	

YAP: Year after planting

Table 5: Cost benefit analysis (Rs.) for the first 9 years in cashew based cropping system.

Cropping systems	Cost of production of main crop	Cost of production of intercrop	Returns from Main crop	Returns from Intercrop	Total Profit
Cashew + casuarina (2 rows) + acacia (1 row)	26862	14300	12798	33375	5011
Cashew + acacia (2 rows) + casuarina (1 row)	26862	13900	16159	40505	15902
Cashew + bamboo	26862	11578	28891	12400	2851
Cashew + ailanthus	26862	6578	34066	9900	10526
Cashew + high density	53724	--	69102	--	15378
Cashew + subabul	25862	10500	28476	11500	2614
Cashew alone	26862	--	31486	--	4624

3.1 Formulating IPM schedules for stem and root borers infesting cashew

Leaders : N.Baktavatsalam (1990-91)
P.Shivarama Bhat (1992-96)
TN. Raviprasad 1996-98

Associates : T.N.Raviprasad (1993-96)
K.V.Nagaraja (1993-95, 1997-98)
D.Sundararaju (1997-98)

INTRODUCTION

The cashew stem and root borers (CSRB) attack primary roots, damage the collar portion of the main stem and hinder translocation of plant nutrients leading to loss of vigour and gradual death of the yielding trees. Both species viz., *Ploceaderus ferrugineus* and *P. obesus* are serious pests of cashew due to difficulty tracing out their incidence as their feeding damage is internal and external damage symptoms are visible normally during the later stages of attack. Non-disposal of infested trees with severe attack beyond recovery from the cashew plantation adds to the build up of pest inoculum in the field.

Various approaches such as use of mechanical barriers, pesticidal swabbing on the main stem and exposed roots, as well as pesticidal drenching of the tree base were evaluated.

Information about population dynamics of CSRB to schedule crop protection activity and standardising rearing technique to provide adults for trials on attractants and sex pheromones were attempted in the present project initiated in 1990.

OBJECTIVES

- a) To evaluate the efficacy of various curative and prophylactic measures in checking pest incidence.
- b) To record the population dynamics of the pest.

- c) Standardization of mass rearing technique for the pest under laboratory conditions.
- d) Identification of indigenously existing natural enemies on the pest and evaluate entomopathogenic fungii against the different stages of the pest.
- e) To investigate the presence of response inducing volatiles and sex pheromones in CSRB species.

MATERIAL AND METHODS

Various methods adopted under different trials in this project are presented in brief.

a) Curative control trials

The infested trees were treated with various fumigants (viz., EDB, aluminium phosphide tablets, chloroform, petrol and kerosene) and stem swabbing with carbaryl, (0.2 and 1%), lindane, monocrotophos, chlorpyrifos (all at 0.2%), and carbaryl 0.2% + soil application of 75g/tree of sevidol 4G. Neem based pesticides such as Limanool (0.5%) and neem oil (5%) were also evaluated during different years, besides applying spawn of *M. anisopliae* at 250g/tree along with 500g neem cake. The recovery levels of treated trees were observed, at intervals of three months. The trees with infestation were treated again and observed further.

b) Prophylactic control trials

Stem swabbing of neem based pesticides

such as neem oil (2, 4 & 6%) (500 and 1000g/tree), neemark EC (0.04%) and soil application of granules (100g/tree) were evaluated along with BHC dust (500g/tree), phorate (150g/tree), stem swabbing with BHC (2%), aldrin (0.2%) stem swabbing, coal tar + diesel (1:2) stem swabbing for checking fresh incidence of CSRB. Emphasis was laid on utilising neem based commercial formulations as Limanool (0.5%) and Godrej Achook (0.5%), RD-9 Repelin (0.5%), Nimbecidine (0.5%) and neem oil (6%) as prophylactic treatments during 1993-96. The duration of effective repellancy as indicated by the absence of fresh attack was recorded at monthly intervals.

c) Population dynamics of CSRB

The presence of different stages of the pest in trees having various intensities of attack were studied at monthly intervals. Cashew plantations of Karnataka Cashew Development Corporation (KCDC) at Koila, Kunthur and Alangar as well as both campuses of NRCC were surveyed for the purpose.

The tree with infested bark was chiselled carefully at the infested zone and grubs present below the bark were collected for establishing lab culture of the pest. The grub stage as nascent / young / older grubs were recorded. Prepupae or pupae if present were also recorded. The information was tabulated for different months and possible period of fresh incidence was estimated.

d) Survey for indigenous natural enemies

Different stages of CSRB which were suspected to have any infection were kept for observation under isolated condition. Further emergence of natural enemies from the pest stages was recorded and the species identified.

e) Standardisation of rearing techniques

Field collected grubs were maintained on host bark. The adults collected were allowed for egg laying and the durations of egg, grub and pupa as well as biological details were recorded. A 2 cm cotton tape was wound snugly around a stout cashew twig for facilitating insertion behaviour of females for egg laying, and compared along with other substrates as cashew bark pieces, branch pieces and frass material for distribution of egg laying. The duration of feed change for young and old grubs using host bark as feed and application of water to maintain edibility of bark were standardised for maximising grub survival to pupal stage.

f) Evaluation of entomopathogenic fungi

Three entomopathogenic fungi, *Beauveria bassiana*, *Beauveria brongniarti* and *Metarhizium anisopliae* were evaluated for their pathogenicity and mycosis against grubs of CSRB. Virulence was evaluated by topical application of spore solution, spore mixing, suspension in saw dust and dipping of bark in suspension, later provided as feed.

LD₅₀ for the virulent fungal species was also calculated through probit analysis. The survival of fungal spores mixed in soil, or along with adjuvants was also evaluated. Virulence of fungus after mixing it with soil was also recorded by allowing grubs to crawl on the soil treated with spores at different durations.

g) Investigations on attractants and sex pheromones

A wind tunnel glass olfactometer of 30 x 30 x 150 cm was fabricated at this institute. Various plant parts of cashew such as healthy

cashew bark, bark of infested tree, exuded gum and fresh frass were placed in the bait chamber and male and female adult beetles were released in the test chamber. The response of the beetles (viz., antennal movement, body raising and movement to source) was duly recorded in diffused light conditions.

Ovipositional preference of mated female beetles was studied by allowing them for 48 h in an escape proof room having the above mentioned plant materials.

Preliminary investigation on sex pheromones was conducted by olfactometer trials. Mated and unmated beetles of both the sexes were tested for their response inducing ability from the opposite sex.

RESULTS AND DISCUSSION

a) Curative control trials

Among the various fumigants tested, maximum grub mortality was recorded in chloroform (71.8%) followed by placement of

EDB ampoules (59.2%). Mortality occurred only in those grubs within 30 cm of placement of fumigant, which maybe due to lesser diffusion of toxic fumes due to plugging of tunnel by frass material by CSRB grubs.

Of the curative treatments evaluated, carbaryl swabbing of infested portion and application of Sevidol 4G (75g/tree) resulted in maximum recovery (83.3%) of the trees in initial stage of attack, which was equal to the recovery observed in chloropyriphos (0.2%) swabbing. Limanool (0.5%) resulted in 66.7 per cent recovery of the infested trees in initial stages of attack (Table 1).

Higher levels of recovery were recorded in trees having initial attack when treated with stem swabbing of lindane 0.2% (88.9%), monocrotophos 0.2% (87.5%) and chlorpyriphos 0.2% (87.5%), while neem oil 5% swabbing led to 28.6% recovery and application of *M. anisopliae* spawn 250g/tree led to 16.6 per cent recovery.

Table 1: Recovery of infested trees under different curative treatments during 1993-98.

Treatment	% recovery in initial stages			
	93-94	94-95	95-96	97-98
Chlorpyriphos (0.2%)	70.0	83.3	66.7	87.5
Carbaryl (0.2%)	70.0	75.0	75.0	83.3
Carbaryl (0.2%) + Sevidol 4G (75g/tree)	80.0	83.3	--	--
Limanool (0.5%)	70.0	66.7	75.0	--
Lindane (0.2%)	--	--	--	88.9
Monocrotophos (0.2%)	--	--	--	87.5
Neem oil (5.0%)	--	--	--	28.6
<i>M. anisopliae</i> spawn 250g/tree	--	--	--	16.6
Check	10.0	16.7	16.7	11.1

Note: Trees in moderate and severe stages of attack showed less than 25 per cent recovery.

The trees in moderate and severe stages of attack showed less than 25.0 per cent recovery. This indicates that trees can recover and respond to treatment upto a certain level of bark damage beyond which the damage is irreparable.

b) Prophylactic control trials

Various materials were tested as prophylactic treatments, viz. coal tar + diesel (1:2), neem based pesticides / commercial formulations, aldrin, BHC, carbaryl in mudslurry as well as two entomopathogenic fungal spawn of *B. bassiana* and *M. anisopliae* and physical barriers of cement slurry and wrapping of polythene sheets over the stem, during 1991-98.

The treatments as coal tar + diesel (1.2), neem mark 0.4% and aldrin (0.2%) showed repellancy upto 30 days of treatment while neem oil 6% swabbing, Limanool 0.5%, Nimbecidine 0.5%, Godrej Achook 0.5%, RD-9 Repellin fresh

infestation upto 60 days after treatment.

It was observed that various treatments evaluated did not show a consistency in results, which may be influenced by the local pest population.

c) Population dynamics of the pest

Population dynamics of the pest was studied from 1993 to 1998. Eggs were observed in the field during February to May indicating this duration as period of fresh incidence. Younger grubs (<30 days) were noticed till July. There was a slight overlap of several generations of the pest during monsoon months (June-September) beyond which mature grubs, pre-pupae and pupae were collected from infested trees (Fig.1).

The stage of infestation recorded in field conditions showed a similar trend with the initial stages of attack being noticed during February to June months and moderate stage of attack being

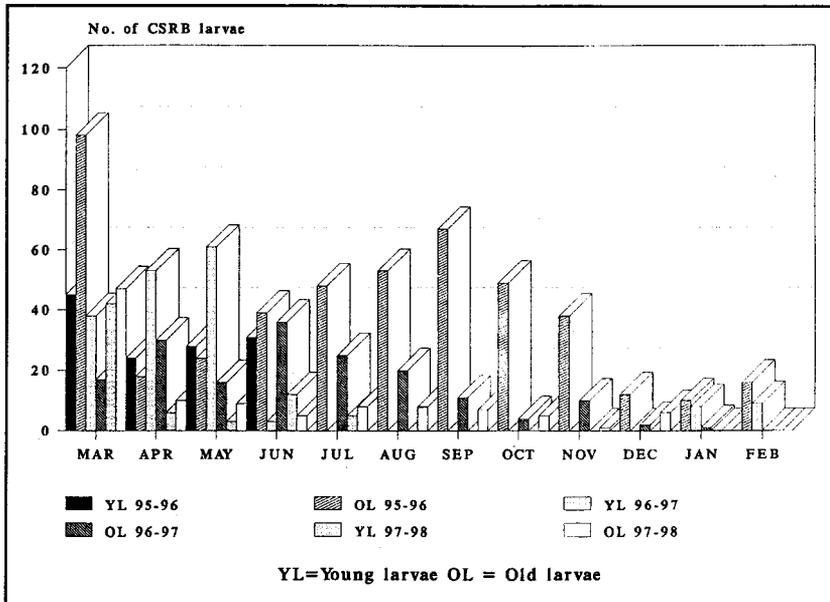


Fig.1: Population dynamics of CSRB (1995-98)

Table 2: Efficacy of egg collection technique for CSRB

Month of observations	1993-94				1994-95			
	<i>Placcaederus ferrugineus</i>		<i>Placcaederus obesus</i>		<i>Placcaederus ferrugineus</i>		<i>Placcaederus obesus</i>	
	On cotton tape wrapped twig	Laid else where	On cotton tape wrapped twig	Laid else where	On cotton tape wrapped twig	Laid else where	On cotton tape wrapped twig	Laid else where
January (1994)	70.1	29.9	75.0	25.0	--	--	--	--
February	79.1	20.9	68.5	31.5	--	--	--	--
March	63.0	36.9	62.7	37.3	--	--	--	--
April	71.2	28.8	69.5	30.5	--	--	--	--
August	--	--	--	--	73.8	26.1	68.4	31.5
September	--	--	--	--	84.7	15.2	68.4	31.5
October	--	--	--	--	84.8	15.1	78.2	21.7
November	--	--	--	--	82.9	17.1	80.0	20.0
December	--	--	--	--	79.0	20.9	76.8	23.1
January (1995)	--	--	--	--	77.7	22.0	74.3	25.7
February	--	--	--	--	83.0	16.9	76.7	23.2

higher during July to October followed by trees being in severe stage of attack during October to March. It was also noticed during 1996-97 certain trees continued in initial stage even during the monsoon months, which may be due to the lesser pest load in such trees.

Eggs were laid in bark crevices at the collar region and soil close to bark. Also *P. ferrugineus* and *P. obesus* eggs were obtained on uninfested trees indicating the primary pest status of both species. A maximum grub population of 130 was collected in 25-30 year old cashew trees at KCDC plantations.

d) Survey for indigenous natural enemies

During the surveys, an egg parasitoid *Avetieniella batocerae* was obtained from eggs

of *P. ferrugineus* collected from KCDC plantations. A field strain of entomopathogenic fungus, *Metarhizium anisopliae* was also obtained and multiplied under lab conditions and used in further lab and field evaluations.

e) Standardisation of rearing technique

The egg collection technique for CSRB was developed using a stout twig wrapped with 2cm wide cotton tape which facilitated more egg laying and easy displacement of egg (Table 2). The durations of feed change (host cashew bark) and watering for young grubs in petriplates was standardised at eight days with daily watering and for older grubs in glass bottles at 10 days with water application on alternate days (Table 3). Initiation of pupation was made out by

Table 3: Grub survival at different durations of changing feed and water application.

Duration of change (days)		No. of grubs surviving on 25th day	
Feed	Water	<i>P. ferrugineus</i>	<i>P. obesus</i>
4	Nil	81.7	85.0
	Daily	91.7	93.3
	Alt. days	90.0	93.3
6	Nil	76.7	75.0
	Daily	96.7	95.0
	Alt. days	93.3	93.3
8	Nil	66.6	75.0
	Daily	80.0	80.0
	Alt. days	83.3	73.3
10	Nil	43.3	36.7
	Daily	50.0	43.3
	Alt. days	51.7	45.0
12	Nil	26.7	35.0
	Daily	30.0	28.0
	Alt. days	30.0	30.0

calcium smearing on walls of the bottle and such bottles were examined for cocoon completion. It was observed that completion of cocoons occurred by 60th day after initiation and such cocoons were kept *en masse* to conserve space. Adults were provided with various solutions as adult feed and honey solution (10%) which

resulted in maximum longevity and fecundity in both species of CSRB.

The rearing technique of both species of CSRB on host cashew bark was standardised and the biology details of various stages were recorded (Table 4).

Table 4: Biology of CSRB under laboratory conditions (duration in days)

Stage of pest	<i>P. ferrugineus</i>	<i>P. obesus</i>
Egg	6.3 (5-9)	6.0 (5-10)
Larva	196.6 (144-223)	210.0 (140-251)
Pupae	186.5 (96-197)	116.3 (85-180)
Adult male	14.8 (5-32)	12.0 (5-30)
Adult female	20.5 (5-50)	18.0 (5-43)
% grub survival to adult hood	71.7	63.8

Note: Values in paranthesis are the range of the duration

f) Evaluation of entomopathogenic fungi

Three entomopathogenic fungal species viz. *B. bassiana*, *B. brongniartii* and *M. anisopliae* were evaluated for their ability to induce mycosis in grubs of CSRB. The topical application of spore suspension of *B. bassiana* resulted in highest mortality. LD₅₀ values were calculated for this fungus as 1.41 x 10⁶ spores/ml.

The survival of *B. bassiana* and *M. anisopliae* in soil alone was lower when compared to survival in soil amended with FYM

or neem cake upto 60 days. *P. obesus* grubs had a higher mortality (40% in comparison to *P. ferrugienus* grubs (10%). When allowed to crawl in soil + FYM mixed with *M. anisopliae* spawn (4:1). This indicated that survival of fungal inoculum was better when a soil amendment was introduced; upto 60 days after application (Table 5).

g) Studies on attractants and sex pheromones

Under olfactometer trials for attractants, fresh frass attracted maximum response from both

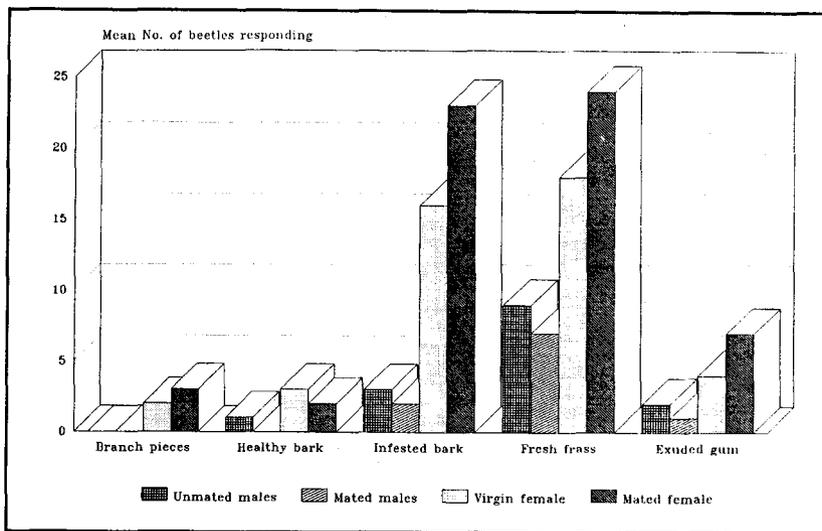


Fig. 2: Response of CSRB beetles to different plant parts under olfactometer trials

Table 5: Mycosis CSRB grubs treated with different methods of spore applications

Mode of application	<i>B. bassiana</i>			<i>B. brongniarti</i>			<i>M. anisopliae</i>		
	15 DAT	30 DAT	45 DAT	15 DAT	30 DAT	45 DAT	15 DAT	30 DAT	45 DAT
Topic appl.	70	80	90	20	20	50	60	60	60
Soaking the feed (bark)	20	40	60	10	10	20	10	20	20
Mixing in saw dust & grub crawling	0	20	60	10	10	20	0	10	20
Untreated	0	0	0	0	0	0	0	0	0

males and female adult beetles. The response of female beetles was higher than that of males to both substrates (Fig. 2).

The free choice trials for oviposition indicated significantly higher oviposition on bark of infested tree (23.5 & 23.6 per cent in 1995-96 and 30.3 & 27.6 per cent in 1997-98 for *P. ferrugineus* & *P. obesus*. (Table 6). The preliminary observations on sex pheromones indicated the possible presence of a sex pheromone in the female beetles.

h) Studies on light traps and CNSL traps

CNSL traps, as well as pitfall traps having fresh frass could not attract and trap adult beetles under field conditions.

SUMMARY

During the tenure of the project, various approaches to manage the cashew stem and root borer, *Plocaederus* spp. were evaluated. Among

the fumigants tested EDB ampoules and chloroform induced the highest mortality (71.8 and 59.2 per cent respectively). Recovery was higher in trees having initial attack only, wherein stem swabbing of lindane 0.2% resulted in 88.9 per cent recovery followed by monocrotophos 0.2% (87.5%), chlorpyriphos 0.2% (87.5%) and neem oil 5% (28.6%). Trees in moderate or severe stages of attack showed less than 25.0 per cent recovery, which indicates trees can respond to treatment upto a certain level of bark damage beyond which the damage is irreparable. The prophylactic control trials indicated varying efficacies of the treatments evaluated during different years, which may be influence of local pest population during that year.

Observations on population dynamics of the pest indicated a mixed field population of two species *Plocaederus ferrugineus* and *P. obesus*. Attack was mainly noticed in the collar region, followed by root and stem regions. The

Table 6: Ovipositional preference of CSRB beetles under free choice trails

Test material	1995-96		1997-98	
	<i>P. ferrugineus</i>	<i>P. obesus</i>	<i>P. ferrugineus</i>	<i>P. obesus</i>
Cashew branch pieces	5.5 be	4.2 b	-	-
Bark of healthy tree	8.8 bc	8.5 b	15.6 b	14.1 b
Bark of infested tree	23.5 a	23.6 a	30.3 c	27.6 c
Freshly collected frass	6.9 bc	5.7 b	17.6 c	12.9 b
Exuded cashew gum	16.7 ab	30.9 a	-	-
Eggs laid elsewhere	7.1 bc	5.3 b	7.0 a	5.5a

young grubs occurred during February to June months indicating this duration as the period of infestation.

Under the trials conducted on standardising a rearing technique, an egg collection method using cotton tape wrapped onto the cashew twig, was developed which enabled elicited maximum egg laying. Durations of feed change (host bark) and application of water were standardised at 8 days with daily water spray and 10 days with water spraying on alternate days for grubs of less than 24 days age and for grubs beyond 25 days of age, respectively.

An egg parasitoid *Avetiniella batocerae* was recorded on eggs of *P. ferrugineus*, collected from KCDC plantations. An entomopathogenic fungus *Metarhizium anisopliae* was collected

from field conditions on grubs of CSRB. Laboratory evaluation of three entomopathogenic fungi namely, *Beauveria bassiana*, *Beauveria brongniartii* and *M. anisopliae* revealed *B. bassiana* to be most virulent with a LD_{50} of 1.41×10^6 spores/ml.

A wind tunnel glass olfactometer was designed at NRCC and utilised for preliminary studies on responses of adult beetles regarding plant volatiles and sex pheromones. Fresh frass and bark of infested tree elicited maximum response from both male and female adult beetles. Under free choice conditions, bark of infested tree elicited highest egg laying. The preliminary observations for sex pheromones suggested the possibility of the pheromone in female beetles.

3.2 Evaluation and mass multiplication of biocontrol agents against tea mosquito bug (*Helopeltis antonii*)

Leader : D.Sundararaju (1990-1993 ; 1996-1998)

Associate : T.N.Raviprasad (1996-1998)

OBJECTIVES

To identify and utilize suitable parasite or predator against tea mosquito bug (TMB) and other sucking pests as a component (biological control) to develop integrated pest management strategy.

MATERIAL AND METHODS

The cashew plantations were surveyed at fortnightly intervals for documenting the natural enemies of TMB and other sucking pests. The eggs, nymphs and adults of TMB and mealy bugs were collected and observed for the presence of exoparasitoids and endoparasitoids. The predators preying on TMB and mealy bugs were collected. All the natural enemies, encountered were identified. The extent of egg parasitism of TMB was estimated by dissection. Attempts were made to study the life history of egg parasitoids and to mass multiply by following all conventional laboratory methods with common insect hosts (eggs of red cotton bugs, *Dysdercus cingulatus*, *Corcyra* moth). Efforts were made to estimate the extent of egg parasitism under protected and unprotected condition.

In order to estimate the extent of damage and population of TMB, various dispersion parameters of TMB were worked out. The weather parameters were correlated with extent of egg parasitism of TMB as well as with population of TMB. The extent of infestation by TMB and yield were also estimated in a cashew accession (Goa 11/6) which was maintained under unprotected condition.

RESULTS AND DISCUSSION

Natural enemies of TMB and other sucking pests

The survey undertaken at two locations (Panemangalore and Konaje) revealed the existence of four species of hymenopterous egg endoparasitoids of TMB viz., *Telenomus* sp. *laricis* group (Scelionidae), *Chaetostricha* sp. (Trichogrammatidae), *Erythmelus helopeltidis* and *Gonatocerus* sp. (Mymaridae). Among them, *Telenomus* sp. was the dominant species occurring throughout the year. The extent of parasitism was estimated based on number of adult parasitoids emerging from the total number of eggs collected. The extent of parasitism ranged from 1.8 to 45.5 per cent (Table 1). When egg parasitism was estimated through dissection i.e., the plant parts (leaf midribs, petioles and tender shoots of cashew) containing the eggs were dissected after the completion of observation on emergence of adult egg parasitoids. It was repeatedly detected that adults of certain egg parasitoids failed to emerge due to desiccation and in certain cases, prolonged emergence of adult parasitoids continued upto a maximum of 104 days (Table 2-3). The egg parasitism could be estimated accurately, by dissection method.

Egg parasitism of TMB in the treated (monocrotophos 0.05% / carbaryl 0.1%) and untreated plots was in the range of 14.3 to 68.9 and 26.0 to 59.0 per cent respectively (Table 2 & 3). Egg parasitism was recorded in

Table 1: Survey on seasonal activity of egg parasitoids during 1990-92 in unsprayed plots.

Months	% egg parasitism *			
	Pane Mangalore		Konaje	
June 1990 & 91	7.7	(30)	45.5	(11)
July	7.2	(130)	36.4	(110)
August	7.9	(95)	13.5	(391)
September	8.3	(61)	39.1	(35)
October	32.2	(93)	8.3	(13)
November	8.1	(138)	12.5	(96)
December	17.0	(238)	11.6	(112)
January 1991 & 92	13.9	(183)	6.8	(144)
February	4.5	(294)	13.6	(266)
March	1.8	(256)	8.8	(227)
April	3.7	(41)	13.8	(63)
May	8.1	(83)	22.9	(163)

* Figures in parenthesis represent the number of eggs observed and extent of parasitism was estimated based on emergence of adult parasitoids.

Table 2: Survey on seasonal activity of egg parasitoids during 1992-93 in sprayed plots.

Months	Egg parasitism * (%)		Maximum days for adult parasitoids emergence
August 1992	45.8	(37.2 - 54.3)	25 - 48
September	42.4	(32.6 - 50.6)	23 - 42
October	41.3	(28.4 - 51.0)	15 - 66
November	29.0	(14.3 - 34.9)	16 - 78
December	30.2	(27.3 - 33.1)	28 - 53
January 1993	28.4	(21.8 - 37.3)	13 - 23
February	26.2	(16.2 - 45.3)	8 - 33
March	17.7	(12.6 - 30.3)	9 - 32
April	37.2	(26.5 - 47.8)	16 - 24
May	39.1	(28.1 - 50.0)	6 - 18
Mean/range	33.7	(12.6 - 54.3)	6 - 78

Figures in parenthesis indicate the range. * Estimated based on dissection method.

Table 3: Survey on seasonal activity of egg parasitoids during 1996-97 in sprayed and unsprayed plots.

Months	Egg parasitism (%) * in		Maximum days for emergence of adult parasitoids	
	Treated plots	Untreated plots (Goa 11/6)	Treated plots	Untreated plots
August 1996	52.4 (50.2 - 55.7)	49.5 (40.0 - 59.0)	19 - 32	3 - 16
September	30.1 (25.4 - 38.4)	46.0	30 - 50	50
October	49.3 (44.6 - 56.6)	I.S	10 - 48	I.S
November	45.6 (36.8 - 59.8)	I.S	23-35	I.S
December	50.6 (39.7 - 57.9)	I.S	12 - 68	I.S
January 1997	40.1 (31.5 - 54.8)	I.S	--	I.S
February	44.8 (27.4 - 55.4)	31.9 (26.0 - 37.7)	26 - 47	22
March	61.0 (45.3 - 68.9)	I.S	2 - 57	I.S
April	47.7 (37.8 - 54.4)	I.S	52	I.S
May	34.2 (27.3 - 43.4)	I.S	9 - 104	I.S
June	39.9 (26.8 - 51.8)	I.S	5 - 94	I.S
July	45.5 (26.8 - 60;2)	33.3	26 - 70	--
August	49.2 (41.6 - 63.0)	I.S	16 - 44	I.S
September	40.9 (25.0 - 61.3)	I.S	8 - 25	I.S
Mean / range	45.1 (25.0 - 68.9)	40.2 (26.0 - 59.0)	2 - 94	3 - 50

Figures in parentheses indicate the range I.S: Inadequate sample * Estimated based on dissection method

Goa and the extent of egg parasitism recorded in six locations was in the range of 22.8 - 45.8 per cent. It was therefore evident that the egg parasitoids of TMB act as constant mortality factor in reducing the population of TMB.

Two species of spiders (*Oxyopes* sp. and *Plexippus* sp.), two species of reduviid predators (*Panathous bimaculatus* Dist. and *Sycanus collaris* (F.)) were recorded as predators of TMB, nymphs and adults. One species of ectoparasitic mite (*Bochartia* sp.) was also encountered on nymphs and adults of TMB. A nymphal adult

endoparasitoid *Leiophron* and one nymphal adult endoparasitic mermithid nematode earlier reported from *H. theivora* on tea were also recorded from *H. antonii*. However, occurrence of all these predators and parasitoids was found to at a very low level when compared to the egg parasitoids of TMB.

Among other sucking pests, the outbreak of mealy bug *Ferrisia virgata* was noticed for only one year (1990-91). From this, three species of hymenopteran encyrtid endoparasitoids (*Aenasius advena*, *Anagyrus quadri* and *Blepyrus*

insularis) one species of hymenopterous signiphorid hyper parasitoids (*Chartocerus*) and three species of insect predators viz. *Mallada boninensis* (Neuroptera : Chrysopidae), *Nephus* sp. and *Scymnus coccivora* (Coleoptera : Coccinellidae) were recorded. The endoparasitoids were found to be quite promising, as at the end of season more than 90 per cent mealy bugs were naturally parasitised. In subsequent years, very low incidence of mealy bugs were recorded.

Life history and mass culturing of *Telenomus* sp.

The longevity of adult parasitoids ranged from 2-9 days (mean 6.1 days) and 1-8 days (mean 2 days) for female and male respectively. One day old female adult parasitoid exhibited oviposition activities. Maximum of eight adults had emerged out from TMB eggs which were parasitised by a single parasitoid. The oviposition behaviour of adult parasitoid in the laboratory and field were observed. To complete oviposition in a single host egg, the parasitoid took 30-60 min. and the movement of ants due to feeding on extra floral nectaries on the leaves and panicles was found to be hindering the oviposition activities of *Telenomus* sp. and as such, the oviposition activities were prolonged for more than three hours for completing the oviposition in a single egg of TMB. In order to prevent the movement of ants, ant exclusion studies were undertaken.

Among various materials tested for ant exclusion by applying at the base of the cashew tree (band of petroleum lubricant oil, petroleum grease, swabbing the trunk with aldrin or carbaryl 2% or molasses baited with carbaryl or soil application of phorate 10% granules or turmeric powder as band at the base of tree and tightly tying the trunk with sticky adhesive paper), the sticky adhesive paper was most effective. However, it

was found to be ecologically harmful, as a number of other adult parasitoids, spiders, *Mellipona* bees were entangled in the sticky trap.

The laboratory culturing of *Telenomus* sp. was attempted in the eggs of mirids (*Helopeltis* spp. and *Pachypeltis mesaerum*, red cotton bug (*Dysdercus cingulatus*) and rice moth (*Corcyra cephalonica*). The oviposition activity of the parasitoid was observed only on eggs of *Helopeltis* spp., whereas it was totally absent on all other eggs indicating genus specificity of *Telenomus* sp. under laboratory condition, the emergence of adult parasitoid was quite negligible due to desiccation of plant parts containing the host eggs. Due to this phenomena, mass multiplication was not feasible mainly due to its requirement of specific host plant condition. When the eggs of TMB laid in cashew/cotton seedlings were periodically exposed near the periphery of cashew plantation, natural egg parasitism of upto 51.4 per cent was observed in June (Table 4). This provides a scope for enhancement of natural biological control of TMB through host enrichment technique .

Distribution of TMB on cashew trees

In order to understand the effectiveness of natural enemies of TMB, the distribution parameters of TMB were worked out. For this purpose, the total population from 14 trees and sample population and damage on 48 leader shoots situated in four quadrants of 20 trees aged three years were estimated for eight months (September 1992 to April 1993). The results revealed that TMB follows contagious distribution. For estimation of its population and damage, 52 leader shoots from any one of the quadrants of the tree were found to be the optimum sample size.

Table 4: Egg parasitism by *Telenomus* sp. in host eggs laid in cashew/cotton seedlings (host enrichment technique).

Months	No. of eggs exposed	Parasitism (%) **
+ April '92	33	42.2
+ May	42	45.3
+ June	37	51.4
+ July*	136	41.9
+ August*	123	6.5
September*	162	3.1
October	53	0.0
November	78	0.0
December	60	0.0
January '93	86	0.0
February	57	5.3
March	101	4.0
April	67	37.3
Total / Mean	1035	18.2

* Host egg laid in cotton seedlings, + Oviposition by adult parasitoid was visually confirmed, ** Estimated by dissection method

Influence of weather parameters on egg parasitism and population of TMB

The weather parameters (temperature and relative humidity) did not exert any influence on the extent of egg parasitism (Table 5). The multiple regression analysis worked out by involving the weekly populations of TMB and weather parameters (temperature, relative

humidity, rainfall, windspeed and sunshine) for 31 weeks, was found to be non significant. The weekly population of TMB was negatively influenced with first previous weekly mean of certain weather parameters (temperature, relative humidity and number of rainy days) and no such influence was observed with second previous week of weather parameters (Table 6).

Table 5: Relationship between weather factors and egg parasitism during 1990-92

Locations	Temperature °C		Relative humidity %		Total rainfall (mm)
	Maximum	Minimum	Forenoon	Afternoon	
Pane Mangalore	-0.060	-0.09	0.194	0.035	-0.104
	N.S	N.S	N.S	N.S	N.S
Konaje	-0.384	0.252	0.193	0.387	0.354
	N.S	N.S	N.S	N.S	N.S

N.S - Not significant

Table 6 Regression coefficient for weather factors and weekly population of TMB during 1992-93 (September-April) in 31 weeks.

Period	Temperature		Relative Humidity (%)		Rainfall		Wind speed	Sunshine (h)
	Max.	Min.	Morning	Evening	Total (mm)	No. of days	km/h	
Weather data of 1st previous weeks	-0.037 N.S	-0.428*	-0.381*	-0.402*	-0.290 N.S	-0.425*	0.178 N.S	0.448*
Weather data of 2nd previous weeks	-0.205 N.S	-0.282 N.S	-0.206 N.S	-0.203 N.S	-0.213 N.S	-0.214 N.S	0.010 N.S	0.255 N.S

N.S Non Significant * Significant at 5% level

Infestation of TMB and yield under unprotected condition on TMB susceptible cashew accessions (Goa 11/6)

The information on pest incidence and yield collected from third year and fifth year onwards on 21 grafts and seven top worked trees of Goa 11/6 respectively revealed that the intensity infestation of TMB was severe in the initial years and it was lower from fifth year onwards. On seventh and eighth year, mean yield of 6-7 kg/tree has been recorded under unprotected condition (Table 7). However, the extent of egg parasitism of TMB was recorded maximum upto 59.00 per cent which is an equal to protected plot (Tables 2 & 3). The reduced pest incidence and higher yield may be due to certain pseudo-resistance (escapism) characters of Goa 11/6, which needs to be explored.

SUMMARY

Existence of four species of hymenopteran egg endoparasitoids of *Helopeltis antonii* viz.,

Telenomus sp. *laricis* group (Fam : Scelionidae), *Chaetostricha* sp. (Fam : Trichogrammatidae), *Erythmelus helopeltidis* Gah. and *Gonatocerus* sp. (Fam : Mymaridae) was documented. Among them, *Telenomus* sp., *Chaetostricha* sp. and *Gonatocerus* sp. are new records from India. *Telenomus* sp. was found to be dominant species and encountered throughout the year. The highest egg parasitism upto 68.9 per cent even in the insecticidal treated plot was recorded. All these parasitoids were not amenable for mass multiplication under conventional laboratory methods due to its specific requirement of host eggs and also the host plant conditions. One unidentified species of nymphal - adult parasitoid was also encountered for the first time. However, its parasitism was extremely low. From mealy bug, *Ferrisia virgata*, three species of hymenopteran encyrtid parasitoids (*Aenasius advena* C. *Anagyrus quadrii* (H, A & A) and *Blepyrus insularis* C.) and three species of predators viz., *Mallada boninensis* (O) (Neuroptera :

Table 7: Infestation of TMB and yield recorded on Goa 11/6 under unsprayed condition

Age of the tree and year of observation	No. of tree with TMB damage				Yield kg/tree		
	VL	L	M	S	Mean \pm S.D	R.V. (%)	Range
Grafts							
III year - 1992	2	3	3	13	1.1 \pm 1.4	27.3	0.0 - 4.6 (3)
IV year - 1993	3	7	7	4	0.8 \pm 1.0	29.4	0.0 - 4.1 (4)
V year - 1994	10	7	1	3	4.4 \pm 1.9	9.2	0.5 - 7.1
VI year - 1995	6	12	3	--	3.6 \pm 0.9	5.2	1.9 - 5.9
VII year - 1996	10	7	4	--	7.2 \pm 2.2	6.6	3.2 - 11.5
VIII year - 1997	7	10	4	--	6.2 \pm 2.6	9.3	3.1 - 13.3
Mean Cumulative yield (kg/tree)					12.2 \pm 7.4	6.9	9.4 - 36.2
Top worked*							
V year - 1994	--	3	1	3	0.7 \pm 0.5	26.7	0.2 - 1.7
VI year - 1995	--	4	3	--	2.4 \pm 1.0	15.6	0.7 - 3.4
VII year - 1996	2	5	--	--	4.7 \pm 2.5	20.0	2.1 - 9.7
VIII year - 1997	3	2	2	--	4.8 \pm 1.8	14.2	2.1 - 8.5
Mean Cumulative yield (kg/tree)					12.6 \pm 4.8	14.4	8.2 - 21.3

* Top worked on IV year (1993)

VL Very low < 10% shoots and panicles damage

L Low > 11% < 25% shoots and panicles damage

M Moderate > 26% < 50% shoots and panicles damage

S Severe > 50% shoots and panicles damage

R.V Relative variation (standard error/mean x 100)

S.D Standard deviation

Figures in paranthesis indicate number of trees recorded 100% loss in yield.

Chyrosopidae), *Nephus* sp. and *Scymnus coccivora* A. (Coleoptera : Coccinellidae). Based on the analysis of spatial distribution it was found that TMB follows contagious distribution. For estimation of its population and damage, 52 leader

shoots from any one quadrant of the tree can be used. Goa 11/6, a TMB escape accession recorded an yield of 6-7 kg/tree even under unprotected condition in 7th-8th year of planting.

7. EDUCATION AND TRAINING

7.1 Training

Two special courses on cashew production technology (CPT) and one each on refresher course on CPT and vegetative propagation of cashew (VPC) were conducted during the year. A total of Rs. 28,500 was collected through course fees by different training courses which were

sponsored by Directorate of Agriculture, Govt. of Goa, Department of Soil conservation, Govt. of Meghalaya and Plantation / Forest / Cashew Corporations and Directorate of Horticulture / Agriculture, Government of Andhra Pradesh, Karnataka and Tamil Nadu. Details of participation are in Table 1.

Table 7.1: Participation in training courses (1998-99):

State	VPC	CPT (Refresher course)	CPT (Special course)	Total
Andhra Pradesh	5	1	-	6
Goa	-	-	10	10
Karnataka	-	6	-	6
Meghalaya	-	-	8	8
Tamil Nadu	-	6	-	6
Total	5	13	18	36

8. LINKAGES/COLLABORATION

- o Annual Cashew Day was organised in collaboration with Directorate of Cashewnut and Cocoa Development, Kochi during March 1999.
- o Demonstration plots laid out in association with Sri Kshetra Dharmastala Rural Development Project, an NGO were monitored during the year.

9. AICRP CENTRES

Headquarters

Project Coordinator(Cashew)
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PUTTUR 574 202, DK, Karnataka.
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OUAT Phone No. (0674) - 402669.
3. Agricultural Research Station
(University of Agricultural Sciences)
CHINTAMANI 563 125, Kolar District,
Karnataka.
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4. Zonal Agricultural Research Station
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5. Regional Research Station
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hargram Farm, PO JHARGRAM - 721 507.
Midnapore District, West Bengal.
Phone No. (03221) - 55593.

6. Cashew Research Station
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7. Regional Agricultural Research Station
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Phone No. (0499) - 760554, 760 632.
8. Regional Fruit Research Station
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Sindhudurg District,
Maharashtra
Phone No. (02366) - 62234
9. Regional Research Station
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TAMIL NADU.
Phone No. (04143) - 60231, 60412

10. GENERAL INFORMATION

10.1 List of Publications

10.1.1 Research / Popular Publications

Bhaskara Rao, E.V.V., Uma Raghunathan, and Prakash Ambekar 1998. काजू की अधिक पैदावार कैसे लें । फलफूल Jul-Dec. 1997. 30.32.

Bhaskara Rao, E.V.V. 1998. National Research Centre for Cashew, Puttur. Proceedings of National Consultation on Horticultural Research, Development and Export.

Bhaskara Rao, E.V.V. 1998. National perspective for cashew development in India. *The Cashew*. 12(3):31-52.

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

Bhat, M.G., Kumaran, P.M., Bhaskara Rao, E.V.V., Mohan, K.V.J. and Thimmappaiah 1998. Pollination techniques in Cashew. *The Cashew*. Vol.12(4):21-26.

Raviprasad, T.N. and Yadukumar, N. 1998. Plant Protection Campaign by NRCC. *The Cashew*. XII(1) p.21.

Nagaraja, K.V. 1998. Quality of cashew kernels in relation to export. *The Cashew*. XII. No.3. 143-48.

Sundararaju, D. 1998. Studies on parasitoids of tea mosquito bug, *Helopeltis antonii* Sign. (Heteroptera : Miridae) on cashew with special reference to *Telenomus* sp. *J. Biol. Control*. 7:6-8.

Thimmappaiah and Shirly Raichal Anil. 1999. *In vitro* regeneration of cashew (*Anacardium occidentale* L.). *Indian J. Exp. Biol.* 37:384-390.

10.1.2 Papers presented in Symposia / Workshop / Seminar

Dixit, S. and Bhaskara Rao, E.V.V. 1998. Problems in cashew cultivation : Farmers' perspective. Presented in National Seminar on Extension Education for Sustainable development, Mumbai, 29-31 Dec. 1998.

Raviprasad, T.N. and Shivarama Bhat, P. 1998. Laboratory rearing techniques for cashew stem and root borer, *Placaederus ferrugineus* Linn (Coleoptera : Cerambycidae) *Abst. PLACROSYM XIII*, Coimbatore, 16-18 Dec. 1998. p.47.

Shirly Raichal Anil, Thimmappaiah and Rohini Iyer. 1998. Vesicular Arbuscular Micorrhizal Association in Cashew (*Anacardium occidentale* L.). *PLACROSYM XIII*. (Abst.No.90) Coimbatore, Dec. 16-18. p.53.

Sundararaju, D., Raviprasad, T.N. and Shivarama Bhat, P. 1998. Preliminary studies on distribution of *Helopeltis antonii* Sign. and estimation of its population on cashew. Abst. PLACROSYM XIII, Coimbatore. p.42.

Thimmappaiah and Shirly Raichal Anil. 1998. Micropropagation in mature tree of cashew. PLACROSYM XIII. (Abst.No.11) Coimbatore, Dec.16-18. p.6.

10.1.3 Book / Chapters

Bhaskara Rao, E.V.V. 1998. National Research Centre for Cashew. **In : 50 years of Hortil. Research** (Eds: SP Ghosh, PS Bhatnagar and NP Sukumaran) Div. of Horti., ICAR, New Delhi. 124-8.

Bhaskara Rao, E.V.V. 1998. AICRP on Cashew. **In : 50 years of Hortil. Research** (Eds: SP Ghosh, PS Bhatnagar and NP Sukumaran) Div. of Horti., ICAR, New Delhi. 215-7.

Thimmappaiah, Shirly Raichal Anil and R.D.Iyer. 1999. Biotechnology of cashew. In **Biotechnology of Horticultural Crops**. (Eds.-Bose, T.K.). (In press).

10.1.4 Technical Reports / Bulletins / Compendia

Swamy, K.R.M., Bhaskara Rao, E.V.V. and Bhat, M.G. 1998. **Catalogue of Minimum Descriptors of Cashew (*Anacardium occidentale* L.) Germplasm Accessions-II**. National Research Centre for Cashew, Puttur, Karnataka, Oct.1998. 54p.

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

Dixit, S. (Ed.) 1999. Farmers' Questions and NRCC Answers on Cashew cultivation. NRCC **Tech.Bull.No.7**. 24.p.

National Research Centre for Cashew. 1998. **Annual Report 1997-98**. Puttur, Karnataka. 99p.

All India Coordinated Research Project on Cashew. 1998. **Annual Report 1997-98**. Puttur, Karnataka. 98p.

National Research Centre for Cashew. 1999. **Research Highlights 1998-99**. Puttur, Karnataka. 17p.

National Research Centre for Cashew. 1998. **The Cashew News**. Newsletter No.1 Vol.3. Puttur, Karnataka.

National Research Centre for Cashew. 1998. **The Cashew News**. Newsletter No.2 Vol.3. Puttur, Karnataka.

10.2 LIST OF ONGOING RESEARCH PROJECTS

Project No.	Project Title	Project leader/associate
1. CROP IMPROVEMENT		
1.1	Collection, conservation, cataloguing and evaluation of cashew germplasm	KRM Swamy MG Bhat D Sundararaju KV Nagaraja Shirly R Anil
Adhoc Research Project	Collection of cashew germplasm from Forest Plantation in Karnataka	KRM Swamy
Adhoc Research Project	Network programme on collection of cashew germplasm from east coast and west coast regions of India	MG Bhat EVV Bhaskara Rao KRM Swamy
1.2	Varietal Improvement of Cashew	MG Bhat KRM Swamy KV Nagaraja
1.3	Tissue culture studies for micropropagation and somaclonal variation	Thimmappaiah Shirly R Anil
2. CROP MANAGEMENT		
2.1	Propagation and rejuvenation studies in cashew	KRM Swamy TN Raviprasad
2.2	Planting systems and spacings trials in cashew	N Yadukumar
2.3	Canopy management studies in cashew	KRM Swamy KV Nagaraja Shirly R Anil
2.5	Economic feasibility of drip irrigation and graded doses of NPK on the productivity of cashew	N Yadukumar
2.6	Development of suitable cashew based cropping system	N Yadukumar
2.7	Integrated nutrient management for sustainable production of cashew	N Yadukumar KV Nagaraja

Project No.	Project Title	Project leader/associate
2.8	Efficacy of soil and water conservation with organic and inorganic manuring in cashew garden grown in slopy areas	N Yadukumar
2.9	Root-stock scion interaction in cashew	KRM Swamy
3. CROP PROTECTION		
3.4	Integrated pest management of cashew stem and root borer	TN Raviprasad D Sundaraju TN Raviprasad
3.5	Integrated pest management of tea mosquito bug	D Sundaraju TN Raviprasad
4. POST HARVEST TECHNOLOGY		
4.4	Functional properties of defatted cashew kernel meal	KV Nagaraja
5. TRANSFER OF TECHNOLOGY		
5.1	Research cum demonstration plots	Sreenath Dixit

10.3 RAC, MANAGEMENT COMMITTEE, SRC, QRT MEETINGS ETC. & SIGNIFICANT DECISIONS.

10.3.1 Research Advisory Committee

Dr.M.Aravindakshan Chairman, (Retd.) Coconut Development Board, Cochin, Kerala-682 011	Chairman
Dr. C.C. Abraham Associate Dean (Retd.) College of Horticulture KAU, Vellanikkara- 680 652	Member
Dr. A.G. Mathew Plant Lipids Ltd. Kadayiruppur Kolencherry-683 311	Member
<i>Dr. R.T. Gunjate</i> 6, Nutan Co-op. Housing Society Sabniswada, Sawanthwadi-416 510	<i>Member</i>
Dr. R.D. Iyer CP VIII/113, Indiranagar Kasaragod - 671 541	Member
Sri. Md. Alai Baig Vil: Garare, Via: Jale District Darbhanga, Bihar	Member
Sri Shashikanth Choudhari Vill: Brahmapur, P.O.: Ratanpur Dist: Darbhanga, Bihar	Member
Dr. R.N. Pal ADG (PC), ICAR, New Delhi	Member
Dr. E.V.V. Bhaskara Rao Director, NRCC, Puttur	Member
Dr. M.G. Bhat Sr. Scientist, NRCC, Puttur	Member-Secretary

Significant Decisions

- o DNA finger printing work may be done in collaboration with UAS, Bangalore.
- o Corrosive principle and phenolic compounds and organic acids of cashew apple should be characterised.
- o In cashew germplasm collection ad-hoc schemes, collection of types which are already existing in National Cashew Gene Bank to be avoided through use of ready reckoner of characteristics or core collections.
- o Organoleptic studies for assessing the quality of kernels may be initiated.
- o Effect of juvenility on regeneration through tissue culture be studied by sequential multiple grafting of scion on young seedlings.
- o Study on somatic embryogenesis from maternal tissues such as nucellar tissues be initiated.
- o Time of imposition of pruning treatments be investigated.
- o Potential yield increases due to drip irrigation and fertilizer application to be confirmed, preferably in some farmers' field.
- o If land is to be committed for long term, cashew cultivation is found desirable.
- o A group meeting of experts in the field of soil and water conservation, soil chemistry, agronomy and microbiology need to be convened.
- o Recommendation / technology based on the findings of the concluded project on "Formulating IPM schedules for cashew stem and root borer (CSRB) infesting cashew" may be given.
- o Phytotoxicity of Dillapiole from Dill oil and efficacy of lower concentrations may be studied.
- o Cashew butter may be extracted from baby bits.
- o Cashew apple processing needs special emphasis.

10.3.2 Institute Management Committee (1997-2000)

- | | | |
|----|--|----------|
| 1. | Director
NRCC Puttur | Chairman |
| 2. | Joint Director of Horticulture (P.C.)
Directorate of Horticulture
Govt. of Karnataka
Lalbagh, Bangalore - 560 004 | Member |
| 3. | Special Secretary of Agriculture
Govt. of Kerala
Thiruvananthapuram - 695 001 | Member |

4.	Head, Division of Horticulture College of Agriculture UAS, GKVK, Bangalore - 560 065	Member
5.	Sr. MD. Alai Baig Vil: Garare, Via: Jale District Darbhanga, Bihar	Non-official member
6.	Sri Shashikant Choudhari Vill: Brahmapur, P.O: Ratanpur Dist: Darbhanga, Bihar	Non-official member
7.	Asst. Director General (PC) ICAR, Krishi Bhavan New Delhi 110 001	Member
8.	Dr. KRM Swamy Sr. Scientist, NRCC, Puttur	Member
9.	Sri N. Yadakumar Sr. Scientist, NRCC, Puttur	Member
10.	Dr. Thimmappaiah Sr. Scientist, NRCC, Puttur	Member
11.	Dr. Sreenath Dixit Scientist, NRCC, Puttur	Member
12.	Sr. Finance & Accounts Officer CPCRI, Kesaragod	Member
13.	Sr. K. Sanjeeva Asst. Administrative Officer NRCC, Puttur	Member Secretary



Institute management committee meeting up in progress

Significant decisions

The committee twice during the year and assessed the progress of research projects and ad-hoc projects. It also accorded approval for the purchase of equipment and reappropriation proposals.

10.3.3 Significant decisions of Eleventh Staff Research Council Meeting held on 15-16 May 1998.

- o Data collected for germplasm characterisation may be subjected to principal component analysis to know the set of characters influencing yield.
- o Core collections may be identified from 67 germplasm accessions planted in 1988 to conserve diverse types of cashew.
- o Principal component analysis for yield in recommended varieties may be carried out to know the cluster of characters contributing to the yield.
- o Physiology of flowering in terms of its biochemical characterisation may be studied.
- o Grafting may be carried on tissue cultured plants using them as root stocks.
- o Details of rootstock-scion interaction studies / screening of root stocks may be carried out.
- o Tea mosquito bug infestation in high density planting may be documented.
- o Weed biomass in each plot may be quantified in plots with different density of plants.
- o NPK content of leaves may be analysed before and after pruning to know the effect of nutrient accumulation in giving out flowering and non-flowering laterals.
- o Economics of different cashew based cropping systems may be calculated.
- o Protocol for vermicomposting may be standardised by taking up an observational trial.
- o Post treatment prophylactic control by using chlorpyrifos, lindane, polythene wrapping, carbaryl in mud slurry, lime swabbing and use of snowcem may be evaluated.
- o Spraying of *Metarhizium anisopliae* spore suspension may be taken up to identify residual action, if any.
- o In laboratory trials on bio-products under synthetic pesticides for ovicidal action, oviposition deterrence and residual toxicity may be evaluated for TMB nymphs and adults to know the efficacy of treatments.
- o Project on investigations into causes for nut rejects during harvest, storage and processing may be concluded.
- o Oil from tree nuts such as macadamia and almond may be included for comparison in studies on functional properties of defatted cashew kernel meal.

10.3.4 Institute Joint Council (IJC)

Official side

Dr.EVV.Bhaskara Rao	Chairman
Dr.MG.Bhat	Member
Sri.K.Sanjeeva	Member
Sri.A.K.Shabaraya	Member
Sri.K.Muralikrishna	Member
Dr.TN.Raviprasad	Secretary

Staff Side

Sri.KM.Jayarama Naik	Member
Sri.KR.Padmanabhan Nair	Member
Sri.K.Umanath	Member (CJSC)
Sri.N.Narayana Naik	Member
Sri.K.Annu	Member
Sri.OG.Varghese	Secretary

The IJC met twice during this year to discuss about staff welfare activities.

10.3.5 राजभाषा कार्यान्वयन समिति

डा. ई. वी.वी. भास्कर राव	अध्यक्ष
डा. श्रीनाथ दीक्षित	सदस्य
डा. टी. एन. रविप्रसाद	सदस्य
श्री. एच. मुरलीकृष्णा	सदस्य
श्री प्रकाश व. आंबेकर	सदस्य
श्री प्रकाश भट	सदस्य
श्री के. उमानाथ	सदस्य
श्री उमानाथ शेड्डी	सदस्य
कु. लीला एम.	सदस्य
श्री के. संजीवा	सचिव/संयोजक

गतिविधियाँ एवं प्रगति:

दि. 14.09.98 से 26.9.98 तक केंद्र में 'हिन्दी पखवाडा' मनाया गया। पखवाडे के दौरान कर्मचारियों हेतु सुलेखन स्पर्धा, भाषण स्पर्धा, नोटिंग एवं पत्र मसौदा लेखन स्पर्धा तथा फ्लिज् स्पर्धा का आयोजन किया गया। इन स्पर्धाओं में वैज्ञानिक, तकनीकी एवं प्रशासनिक कर्मचारियों ने स्वयंस्फूर्ति के साथ हिस्सा लिया।



हिन्दी पखवाडा कार्यक्रम

10.4 PARTICIPATION IN SYMPOSIA/ CONFERENCES / SEMINARS / MEETINGS

Dr.E.V.V.Bhaskara Rao Dr.M.G.Bhat Dr.Thimmappaiah Dr.D.Sundararaju Dr.T.N.Raviprasad Ms.Shirly Raichal Anil	Plantation crops Symposium (PLACROSYM XIII) held at Coimbatore	16-18 Dec.1998
Dr.K.R.M.Swamy	National Seminar on "Cashew Development in India - Challenges and opportunities", Panaji, Goa	1-2 May 1998
Dr.K.R.M.Swamy	National Seminar on "Bharathiya Krishi ka Bhavi Swarup", IARI, New Delhi	11-13 Aug.1998
Dr.K.R.M.Swamy	XVII Meeting of ICAR Regional Committee No.VIII, Chennai	5-6 Jan.1998
Dr.K.R.M.Swamy Dr.M.G.Bhat	Meeting on the Parliamentary Sub- Committee on Commerce and Supply, Mangalore	3 Feb.1999
Dr.K.R.M.Swamy	Joint Executive Committee Meeting of the Indian Society for Plantation Crops, CPCRI, Kasaragod	8 Feb.1999
Dr.E.V.V.Bhaskara Rao	National Consultation Seminar on Horticultural research, development and export, Bangalore	7-8 Aug.1998
Dr.E.V.V.Bhaskara Rao	NATP Workshop, New-Delhi	6-7 Oct.1998
Dr.E.V.V.Bhaskara Rao	Executive Development Programme, NAARM, Hyderabad	28-31 Jan.1999

10.5 WORKSHOPS, SEMINARS, FARMERS' DAY

Annual Cashew Day - 20th March 1999 at NRC Cashew, Puttur and Exptl. Station, Shantigodu

10.6 RADIO TALKS / INTERVIEW

Dr.K.R.M.Swamy	Naati nantarada geru gidagala aaraike- Maintenance of cashew plants in field after transplanting, AIR, Mangalore	14 July 1998
Dr.T.N.Raviprasad	Keeta niyanthranada nootana vidhanagalu - New approaches in Pest Management, AIR, Mangalore	22 July 1998

10.6.1 Guest Lecture delivered

Dr.K.R.M.Swamy	Softwood grafting technique in Cashew” Science Forum, St.Philomena College, Puttur	7 Oct.1998
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10.7 DISTINGUISHED VISTORS

24-4-1998	Dr.C.P.Iyer Formerly Director CIHNP, Lucknow	
27-5-1998	Dr.V.Ramanatha Rao IPGRI Kuala Lumpur	
13-7-1998	Dr.G.K.Vasantha Kumar Joint Director Directorate of Horticulture Govt.of Karnataka, Bangalore	
1-9-1998	Prof.M.S.Kuruvinashetty Head, Dept.of Biotechnology UAS, Dharwad	
13-9-1998	Dr.G.K.Veeresh Formerly Vice Chancellor UAS, Bangalore	
13-9-1998	Dr.L.Venkataratnam Ex.Hortil. Advisor Govt.of India, Hyderabad	
10-2-1999	Dr.N.M.Nayar Scientist Emeritus TBPGRI, Trivandrum	
4-3-1999	Dr.J.L.Karihaloo Director NRC for DNA FP, New Delhi	

10.8 PERSONNEL

Managerial

Director

Dr. EVV.Bhaskara Rao

Scientific

Discipline	Scientist	Scientist (Sr. Scale)	Sr. Scientist	Pr. Scientist	Total
Agricultural Engg. (ASPE)	D. Balasubramanian ^o		--	--	1
Agril. Entomology	--	P. Shivarama Bhat* T.N. Raviprasad	D. Sundararaju	--	3
Agril. Extension	--	Sreenath Dixit	--	--	1
Biochemistry (Pl.Sci)	--	--	KV Nagaraja	--	1
Biotechnology	--	--	Thimmappaiah (Gen. & Cyto.)	--	1
Computer Appl.	Vacant	--	--	--	1
Genetics & Cytogenetics	Shirly R Anil	--	--	--	1
Horticulture	MG Nayak *	--	MG Bhat (Pl. Br.) Vacant	KRM Swamy	4
Plant Physiology	Vacant	--	--	--	1
Soil Science	--	--	N Yadukumar (Agron.)	--	1
Soil & Water cons. Engg.	Vacant	--	--	--	1
TOTAL					16

* On Study leave ; ^otendered resignation, pending acceptance with council.

TECHNICAL

Sri B.Nagaraja	Sr. Farm Superintendent (T-8)	(Till 28.2.1999)
Sri K. Muralikrishna	Farm Superintendent (T-6)	
Sri H. Muralikrishna	Technical Information Officer (T-6)	(From 1.9.1998)
Sri. A. Padmanabha Hebbar	Technical Officer (Elec.) (T-5)	(From 1.1.1999)
Sri R. Arulmony	Technical Officer (Lib.) (T-5)	(From 1.1.1999)

Sriyuths Prakash G Bhat, N. Manikandan, R. Muthuraju, K. Setharama (T-4); Prakash V Ambekar, Lakshmi pathi, R. Lakshmi sha, K.V. Ramesh Babu, Sardar Baig, R. Shekara Naik (T-II-3); KR. Padmanabhan Nair, A. Poovappa Gowda (T-I-3); Ravishankar Prasad, K. Babu Poojary, Bejmi Veigus, K.K. Madhavan, K. Umanath (T-1).

ADMINISTRATIVE

Sri K. Keshava Shabaraya,	Asst. Fin. & Accnts. Officer
Sri. K. Sanjeeva,	Asst. Admn. Officer.

Sri V. Ahmed Bava, Sr. Stenographer; Sri K.M. Jayarama Naik, Superintendent; Smt. B. Jayashree, Sri OG. Varghese. Stenographers; Sri MS. Satyanarayana, Assistant, Sri K.M. Lingaraju, Sr. Clerk; Ms. M. Ratna Ranjani, Miss. Winne Lobo, Sri Rosario Mascarenhas, Miss. Leela, Sri Uma Shankar, JR- Clerk; Sri. K. Balappa Gowda, Gestetner Operator.

10.9 INFRASTRUCTURE DEVELOPMENT

- * ARIS Cell installed with LAN facility having five terminals
- * Guest house cum trainees hostel is nearing completion

11. MISCELLANEOUS

11.1 Graft production

During the year 1998-99 a total of 1,50,787 grafts of different varieties (59,855 + 90,932) worth Rs. 22,61,805 were sold to development agencies and farmers in Karnataka, Kerala and Tamil Nadu. A total of 47,240 side grafts and 32,753 softwood grafts and 17,855 grafts of different varieties were prepared of which 50,000 grafts are expected for sale during 1999 planting season.

11.2 Weather data (1998-99)

Months	Temperature °C		Humidity %		Total rain fall (mm)	Rainy days	Sunshine Hours	Evaporation	Wind velocity /Hour
	Max.	Min.	FN	AN					
Apr. 98	37.7	25.7	89	46	006.0	00.0	08.6	06.1	04.0
May	35.0	25.2	91	56	248.8	09.0	06.3	04.5	03.4
Jun.	31.0	23.6	96	80	1204.4	25.0	03.1	02.3	03.4
Aug.	29.7	23.6	97	83	1231.6	27.0	02.0	01.8	03.7
Sept.	29.2	23.2	96	88	658.0	25.0	01.8	02.2	02.7
Oct.	30.4	22.9	95	74	263.7	12.0	04.6	02.7	02.4
Nov.	32.2	23.2	90	62	168.0	10.0	05.4	03.1	01.8
Dec.	33.2	17.8	91	43	041.2	2.0	07.3	04.4	02.0
Jan. 99	33.8	17.8	91	43	000.0	0.0	09.6	04.0	02.3
Feb.	36.3	20.2	92	44	000.0	0.0	09.9	05.3	02.8
Mar.	36.7	23.5	92	42	000.0	0.0	08.5	05.8	03.5
Total					4329.5				

सारांश

इस अनुसंधान केन्द्र के उद्देश्य प्राप्त करने हेतु 19 अनुसंधान परियोजनाओं में कार्य जारी रहा। इनमें पाँच फसल सुधार में, आठ फसल प्रबंधन में, तीन फसल सुरक्षा में, दो कटाई उपरान्त प्रौद्योगिकी तथा एक प्रौद्योगिकी हस्तांतरण में शामिल थे। इस साल फसल सुधार तथा फसल प्रबंधन में प्रत्येक, फसल सुरक्षा में तीन और कटाई उपरान्त प्रौद्योगिकी में एक परियोजनाएँ संपन्न हुए। इसके अतिरिक्त फसल प्रबंधन और फसल सुरक्षा में प्रत्येक दो एवं कटाई उपरान्त प्रौद्योगिकी में एक नये परियोजनाएँ शुरू हुए।

कर्नाटका, केरल एवं तमिलनाडु में किसानों के बागान और अरण्य विकास निगमों के बागानों से 24 भिन्न प्रकार के काजू संग्रहित हुए। इस साल में 29 कृतक एक्सेशनस के रोपण के साथ राष्ट्रीय काजू जीन बैंक में 392 प्रकारों के काजू संग्रहण उपलब्ध हैं। छटवी कटाई की बाद पूर्वरोपित 97 एक्सेशनस का जरिबर्णन किया गया तथा उनका कैटलॉग प्रकाशित किया गया। सस्वरूपात्मक गुण और उपज विशेषण के आधार पर 56 एक्सेशनस के प्रधान घटक विशेषण किया गया। किस्म सुधार परियोजना के अंतर्गत 56 किस्म, 8 सेल्फ्स और 43 संकरण संयोगों का मूल्यांकन किया गया। विशिष्ट 14 किस्मों में VTH - 539/2 का उपज अत्यधिक रहा जो VRI - 2 की तुलना में 36 प्रतिशत अधिक था। शिफारित किस्मों में VRI-1 का फलन तीव्रता प्रति वर्ग मी. अधिक (6.8%) और BLA 39-4 में अत्यधिक उपज प्रति वर्ग मी. (40.2ग्रां) रहा।

BLA - 39-1 तथा VRI - 2 में प्रधानता से मिश्र पुष्पण अवस्था पाया गया। छिलके का गरी से चिपकाव के बारे में जानने हेतु 27 किस्मों को परखा गया जिनमें, 7 ढीले 9 मध्यम और 11 चुस्त चिपकाववाले थे। 20 किस्मों में तेल, शर्करा एवं प्रोटीन अंश का चरित्र वर्णन किया गया। प्राथमिक मूल्यांकन में H-46 H-1346 और H-1354 अपने मादा जनिता से गुठली वजन में 84-88 प्रतिशत बढ़ोतरी, दर्ज की गयी।

NRCC - 1 तथा Ullal - 2 के वयस्क वृक्षों से परखनली कल्चर्स स्थापित किये गये। भूरा प्रतिरोधक रसायनिको PVP - 360 और PVVP - उपयुक्त साबित हुए। जड़स्थित कवकजाल के चार प्रबंधों को काजू उगानेवाली मुदा से विविक्त किया गया। पिछले साल रोपित परखनली वर्धित काजू पौधों में जड़ धनत्व अन्य बीजप्रजनित या कलमित पौधों से अधिक रहा। परखनली वर्धित पौधों को प्रकन्द बनाकर 80-100 प्रतिशत सफलता मिली। लम्ब और अल्प लम्ब गूटी प्रकन्दों को NRCC-1 से स्वस्थाने कलमन करने पर कोयी पारस्परिक परिणाम नहीं दिखाई दी। पिछले नौ सालों से स्थापित पुनश्चेतित बागानों और पुनरोपित बागानों का तुलनात्मक अध्ययन में समानता प्राप्त हुई। पैकलोबुद्रासॉल की छिडकाँव एवं मुदा प्रयोग से पहली साल में कोई परिणाम दिखाई नहीं दी। छतरी प्रबंधन में चार काजू किस्मों को विविध छंटाई स्तरों के साथ अध्ययन किया गया, जिसके अंतर्गत प्राथमिक वर्षों का उपज में अंतर पाया गया। रोपण पद्धति के प्रयोग में 5 x 4 मी. पद्धति सबसे लाभदायक रहा। जिस फ्लाटो में उर्वरक और सिंचाई लगाया गया, उनमें छतरी का विस्तार का अत्यधिक बढ़ोतरी हुई। अधिक स्तर का सिंचाई (60-80 ली/पेड) और मध्यम तथा

अधिकतम उर्वरक स्तर से प्रकाश-संश्लेषण, प्रस्वेदन और कार्बोक्सिलेशन क्षमता में बढ़ोतरी पाया गया। बिना उर्वरक केवल सिंचाई से उपज में 38-72 प्रतिशत बढ़ोतरी दर्ज की गई तथा 60-80 ली/पेड (चार दिन में एक बार) सिंचाई के साथ अत्यधिक स्तर का उर्वरक देने 132.8 से 157.7 कि.ग्रां. अधिक उपज मिला। पैदावार पद्धति के अध्ययन में अकेशिया कैशूरिना, सूबाबूल, आईलांतस और बाँस के विविध सम्मिश्रण से काजू उपज पर बुरा असर हुआ। प्रति दो काजू पंक्तियों के बीच दो पंक्ति अकेशिया और एक पंक्ति कैशूरिना उगाना अत्यधिक लाभदायक था। काजू जड़ और कांड छेदक का कवक रोगजनक (मेटाराईजियम अनिसोफिल्लये) श्रेत्र उत्तर जीवितावधि 120 दिन तक रहा परन्तु उसका संक्रामक शक्ति 60 दिन तक ही रहा। काजू जड़ और कांड छेदक बाधित पेड़ों का भौतिक लक्षणों से यह पता चला कि कीट आक्रमण बेतरतीब रहा। दस साल से कम ऊम्र के पेड कीट आक्रमण को प्रवृत्त थे।

चाय मच्छर के नैसर्गिक अंतरपरोपजीवि की जाँच करने हेतु एक तकनीक की मानकीकरण किया गया। मोनोक्रोटोफॉस तथा कार्बारिल सिंचित बागानों में भी टेलीनोमस तथा कीटोस्ट्रायिका प्रबेध जीवित रहे। नैसर्गिक परजीवीकरण हेतु अनावुत्त चाय मच्छर के अंडे सभी महीनों में परजीवित हुए। जहाँ ईकोफिल्ला स्मारगदिना चींटो का बसेरा था, वहाँ चाय मच्छर का घटन तीव्रता कम पाया गया।

काजू आटे का क्रियात्मक गुणो का अध्ययन में, काजू आटों अन्य आटों के तुलना में (सोया आटा, बदाम आटा) बेहतर पाया गया। प्रौद्योगिकी हस्तांतरण में इस वर्ष, मुदा और जल संरक्षण के बारे में अभियान तथा काजू दिवस के संदर्भ में किसान गोष्ठी का आयोजन किया गया था। इसके अलावा विकास विभागों के अधिकारियों के लिए चार प्रशिक्षण शिविरों का आयोजन भी किया गया था।