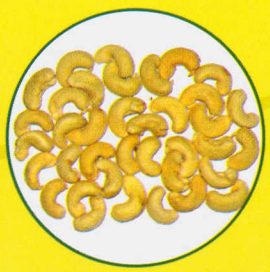
Technical Bulletin No. 17

GLIMPSES OF CASHEW RESEARCH IN GOA



ICAR RESEARCH COMPLEX FOR GOA
(Indian Council of Agricultural Research)
Ela, Old Goa - 403 402, INDIA

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Shri Digambar Kamat
Chief Minister
Government of Goa

FOREWORD

I am delighted to know that ICAR Research complex for Goa is publishing Research Bulletin titled "Glimpses of Cashew Research in Goa" to highlight the cashew research carried out in Goa by the institute.

Goa is one of the major cashew growing states in the country. Cashew is an important horticultural crop of Goa. Of late, cashew has gained special status in the international scenario as a crop having potential to earn considerable foreign exchange. Due to ever growing demand in the world market, there is a tough competition among the cashew producing and exporting countries and therefore India should revitalize the research strategies to achieve the higher productivity levels in a sustainable manner.

This compilation of cashew research in Goa can serve as a benchmark document for formulating future research and production strategies and to provide the relevant information to researchers and farming community.

I am sure, that this Research Bulletin will be useful source of reference to all those involved in cashew industry and will go a long way in enhancing cashew production and in improving the lively hood security of small and marginal farmers.

I extend my best wishes on the occasion.

March, 2009

(Digambar Kamat)
CHIEF MINISTER

Preface

Cashew being an exotic species, after introduction in the 16th Century for the first time in Goa, has very well adapted to agro-climatic conditions of peninsular India, thereby making a significant contribution to foreign exchange earnings of the country. In the state of Goa also, cashew being the major plantation crop is bringing in considerable exchequer to the state's economy, besides providing employment opportunities in the rural sector. Though, cashew was introduced over four hundred year ago, till recently, it was grown as waste land crop. Cashew Research in Goa, in fact, was initiated about three decades ago in 1976. It was the time when there were no recommended package of practices, improved varieties and standard propagation techniques available in the state and cashew growers were unaware of the real economic potential of this crop. At such a crucial point of time, ICAR Research Complex for Goa launched the research programmes on cashew in the state of Goa. Since then, research efforts at various levels have given a renewed direction to this crop for enhancing the production and productivity in the state.

This Research Bulletin is a compilation to recapitulate the salient features of cashew research in Goa. The research efforts during the last three decades and the achievements thereby, are compiled decade-wise so that apprehensions of the gaps and needs would pave the way for drawing the future course of research endeavours in this crop of utmost economic importance for the benefit of cashew growers, processors and exporters alike.

While bringing out this bench mark document, I sincerely acknowledge the opportunity and encouragement extended by the ICAR, New Delhi for carrying out research on cashew crop.

I take this opportunity to express my sincere gratituded to Dr V S Korikanthimath, Director, ICAR Research Complex for Goa for his inspiration and encouragement to specially take up latest research programmes on molecular breeding, *in situ* grafting and mixed cropping with spices in cashew and in compilation of the voluminous data on cashew research of more than three decades in Goa.

My sincere thanks are due to Dr P G Adsule and Dr D G Dhandhar, the former Directors of the Institute for their continuous support in taking up cashew research in Goa which is compiled in this Bulletin. I thank Dr S Subramanian, Principal Scientist (Fisheries Science) and Head, Technical Cell and his team for their assistance in compilation of this document. The Research contributions of Dr D G Dhandhar, Dr Nagabhushanam, Dr P A Mathew and Dr Sundarajan, involeved in earlier research programmes in Goa are duely acknowledged. The co-operation extended by Dr S Manivannan for carrying out physiological studies in soil & water consurvation experiment and the impeccable timely support by Dr J R Faleiro, Dr E B Chakurkar, Dr S B Barbuddhe, Mr Chidanad Prabhu and Dr Avinash Nirmale are gratefully acknowledged. Timely help and co-operation of my colleagues Dr J Ashok Kumar, Mrs Priya Devi, Dr S P Sing, Mr H R Prabhudesai, Dr B L Manjunath and Mr V Y Gaonkar in carrying out various research activities are copiously acknowledged. Invaluable dedicated services of Shri Ashok Desai (Tech. Asstt.) in this endeavour are cherished forever.

I thank the Directors, Deputy Directors and all the Zonal Agriculture Officers and their teams, Directorate of Agriculture, Government of Goa, for their whole-hearted assistance, especially in collection of local cashew germplasm, that imparted strength to our crop improvement programmes. The cooperation extended and enthusiasm evinced by the progressive farmers, Shri Prabhakar Keni, Fr Inacio Almeida, Shri Shailesh Kholker and others need special appreciations for whose noble cause this document is dedicated eventually.

A R Desai

CONTENTS

INTRODUCTION

A native of North East Brazil in Latin America, cashew (*Anacardium occidentale* L., Anacardiaceae) is an evergreen tree of tropics cultivated in tropical region on either side of the equator for its delightful nutritious kernels and apple, besides its byproducts like cashew nut shell liquid (CNSL). Ancient sea-route traders were responsible for the spread of cashew to other parts of tropical and sub tropical regions. Portuguese, the erstwhile rulers of pre-independent Goa, introduced cashew into India on the Arabian sea coasts of Goa in 1570 AD. Since then cashew has adapted very well to Indian conditions. Unlike its image as "a crop for afforestation and soil conservation" at the time of its introduction on Indian coasts, cashew as on today, has gained special status in the international scenario, as a plantation crop of considerable foreign exchange earner (Rs.2500 crores). India entered into international cashew trade a century ago and continues to be one of the major players even today. At present, this crop is cultivated in more than 28 countries of Latin America, Asia, Africa and Australia, in an area of about 38.17 lakh hectares with an annual estimated global production of 31.86 lakh tons of raw nuts (FAO, 2007). India, a major producer of raw nuts in the world till the recent past, has slipped down to the second position (6.2 lakh tons from 8.55 lakh ha. and 725 kg/ha.), due to stiff competition from Vietnam (9.61 lakh tons of raw nuts from 3.48 lakh ha.), a new entrant in cashew cultivation and trade, which achieved a productivity level of 2.76 tons/ha. within a short period.

In India, the states *viz.* Kerala, Krnataka, Goa and Maharashtra on West Coast, and Tamil Nadu, Andhra Pradesh, Orissa and West Bengal on East coast are the major cashew growing states. Maharashtra leads in area, production and productivity with 1.64 lakh hectares, 1.97lakh MT and 1.5 MT/ha respectively (DCCD, 2006-07). In Goa, cashew crop is cultivated in about 55,000 ha. with an annual raw nut production estimated at 29,000 MT with the productivity level of 527 kg/ha. (DCCD, 2007).

There are about 1800 cashew nut processing units in India with processing capacity of about 12 lakh MT annually. Indigenous production, however, is far inadequate to meet the raw nut requirement of these processing industries. Therefore, India is depending on large scale imports of raw nuts, mostly from African countries, for utilizing the processing industry to its full capacity. Since, some of the African countries have taken up cashew processing themselves, availability of raw cashew nut to import may gradually decline. Further, as there is a stiff competition for India by Vietnam for the import of raw nuts available from other countries, the need for boosting the indigenous production of raw nuts has attained greater importance in order to sustain the

cashew industries in India and to retain the premier position in the international cashew trade. At micro level, the scenario is all the same in Goa too. There are as many as 84 cashew nut processing units in Goa with processing capacity of 100 to 16000 kg of raw nuts per day. State's domestic production is not sufficient to meet the raw nut requirement of the processing units in the state and thus depends on imports of raw nuts from African countries.

Ever since the nutritional qualities of dietary importance were realized, there has been considerable awareness about the consumption of cashew kernels in the world, especially in the developed countries. This has set an increasing trend in export of kernels from the major kernel producing countries to meet the escalating demand for kernels in the international market. In order to encash this global opportunity, the cashew producing countries have been laying greater emphasis on strengthening their research programmes, to enhance the production many folds.

Consequent upon its recognition as a foreign exchange earning crop, cashew sought the attention of researchers in India in 1950s. Then onwards cashew became an important commercial plantation crop in the coastal states of peninsular India in general and Goa in particular. A tiny state on the west coast, receiving annual rainfall of 2500-3000 mm, Goa lies between the latitudes 14°53'54" and 15°40'00" N and longitudes 73°40'33" and 74°20'13" E and is surrounded by the Arabian Sea on the West, State of Maharashtra on the North and Karnataka on East and South. The state has a total geographical area of 3,61,113 hectares with a coastal line of 105 km long. Goa region forms a part of Western Ghats in Konkan belt and endowed with wealth of horticultural crops, of which cashew has the lion share (55,000 ha.). At present, cashew occupies more than 50 per cent of the total area under horticultural crops in Goa.

It is noted that seed propagation resorted to, from the time of its introduction into the state of Goa and allogamous nature of the crop have led to the inadvertent spread of non-descript seedling progeny throughout the state, however, with enormous natural genetic variability in it. The seedling progeny in Goa, thus, is the vital source of potent natural recombinants possessing desired commercial traits, besides having the potential genotypes for specific characters such as resistance or tolerance to biotic / abiotic stress. By and large, majority of cashew plantations in Goa exist on wasteland, hilly terrains and marginal lands without much attention towards its crop management and production aspects. Paramount research scope, in view of the above, was aptly envisioned in cashew since this plantation crop prompted continued sustainable support to the states economy in general and farming community of Goa in particular.

2. Initiation of cashew research in Goa

Though cashew was introduced into Goa way back in 16th century, till recently, it was grown as waste land crop. Cashew Research in Goa, in fact, was initiated about three decades ago in 1976. At that time, the cashew plantations in Goa occupied an area of 32,580 ha. with the production levels estimated at about 7500 tonnes. It was the time when there were no recommended package of practices, improved varieties and standard propagation techniques available in the state. Cashew growers being ignorant of improved production technologies were simply practicing the habit "gather the apple for feni and sell the nut for money" without knowing the real economic potential of this crop.

At such a crucial point of time, ICAR Research Complex for Goa ushered the research programmes in 1976 on cashew in the state of Goa. Since then, research efforts at various levels have given a renewed direction to this crop for enhancing the production and productivity in the state.

This Research Bulletin is an attempt to recapitulate the salient features of cashew research in Goa. The research efforts during the last three decades and the achievements thereby, are compiled decade-wise so that apprehensions of the gaps and needs would pave the way for drawing the future course of research endeavours in this crop of utmost economic importance for the benefit of cashew growers, processors and exporters alike.

2.1 First phase of cashew research in Goa (1976 –1985).

Research on cashew crop was initiated at ICAR Research Complex for Goa, in 1976 under the first research project entitled, **"Selection of high yielding trees and vegetative propagation of cashew by veneer grafting and patch budding."** It is very evident that the initial emphasis in this research programme was mainly on identifying the naturally available pre potent mother trees from among the seedling progenies for further commercial exploitation and introducing the promising varieties from other places. And there was a need for a viable propagation technique for large scale multiplication of selected promising mother trees, since the **"air layering technique"** , practiced at that time, was tedious and had its own limitations in large scale multiplication.

2.1.1 Local survey for and introduction of promising cashew genotypes

In the maiden efforts of search for potential cashew genotypes, 50 high yielding mother trees were identified in cashew plantations in Sanguem and Salcete Talukas during 1976. These trees were in the age group of 10 –30 years with the raw nut yield in the range of 8 -16 kg/tree.

Besides this, attempts were made simultaneously to introduce several promising accessions, varieties and hybrids from different cashew research stations, for evaluating their performance under agro-climatic conditions of Goa (Table 1).

Table 1. Introductions of cashew genotypes from different cashew research stations during 1976-85.

Year of introduction	Accessions / Varieties / Selections	Source	Remarks
1977	H 3-13, H 3-17, H 3-19 & H 4-7	Cashew Research Station, Anakkayam, Kerala.	Planted in Kaley Farm
1982	Guntur Selection	Andhra Pradesh	,, ,,
	Gubbi	Mysore State (Karnataka)	,, ,,
1983	Vengurla-1, 2, 3 & 4	RFRS, Vengurla, Maharashtra	Planted in ICAR Res. Farm at Ela.
1984	M/44, BLA 139/1	Shantigodu, (CPCRI) cashew research Station	,, ,,
	Vengurla-5	RFRS, Vengurla, Maharashtra	,, ,,
1985	VTH-125, 154, 30, 50, 539, 174,M 10/4	Shantigodu, (CPCRI) cashew research Station	,, ,,

2.1.2 Studies on propagation of cashew

Different propagation techniques *viz.* veneer grafting, patch budding, epicotyl grafting and soft wood grafting were studied for standardizing a propagation technique for large scale multiplication of cashew varieties (Table 2). Veneer *in situ* grafting and soft wood grafting recorded higher success of more than 90 per cent. The period from June – September was considered the best time for soft wood grafting under Goan conditions

Table 2. Propagation studies in cashew during first decade (1976-85)

Year	Method	Results
1976-79	Veneer Grafting	I n pots- 36 % success In situ – 92 % ,,
	Patch budding	In pots – 61 % ,, In situ - 62 % ,,
1982-83	Epicotyl grafting	45 –68 % ,,
1985	Soft wood grafting	75 – 85 % ,, June – Sept : Best time

2.1.3 Screening of cashew accessions against Tea Mosquito Bug

Since, majority cashew plantations in Goa were of seedling origin, a survey was undertaken to identify the promising cashew genotypes to overcome the problem of tea mosquito bug (TMB). Eleven trees with **"low pest incidence"** were identified by Sundaraju (1983) in severely affected area in Cancona taluk. Subsequently, three trees were selected for further evaluation which recorded low score values of 0.11 – 0.48 against the 0.78 – 4.0 in control trees on 0-4 scale. This study eventually resulted in a selection of a promising accession - "Goa 11/6" which was observed to escape the onslaught of TMB besides high yielding ability. Later, this selection was released as a recommended variety under the name "Bhaskara" by National Research Centre for Cashew, Puttur, Karnataka.

2.1.4 Achievements at the end of First decade

- **Total introductions : 14 genotypes**

  RFRS, Vengurle : V-1 to V-5
  Shantigodu : 9 accessions / varieties

- **Identification of Goa 11/6 vis-à-vis TMB**
- **Standardization of Soft wood grafting technique for V-1 and V- 4 (Response: 60 – 92 % between June – Sept.)**

2.2 Second phase of cashew research in Goa (1986-95)

Subsequently, local survey was intensified along with introductions from other research stations. During this period, evaluation of varieties introduced previously was continued and propagation techniques were adopted for expansion of future research programmes.

2.2.1 Local Survey and collection of promising accessions

In the second decade, local survey for search of potential cashew genotypes was intensified and 42 local accessions were collected clonally, one set of which was also passed on to National Cashew Germplasm Bank maintained at NRCC, Puttur, Karnataka. Important genotypes of this survey are listed in Table 3. Balli-1, Balli-2, Farmagudi-6, Ganje-1 and 2, and Karapur-1 and 2 showed promising trend in the initial stage with respect to nut size, nut yield and apple size.

Table 3. Potential local cashew genotypes identified during 1986-95

Accession name	Branching	Nuts / panicle	Av. nut wt. (g)	Yield (Kg)	Apple	TSS (^{o}B)
1986-89 : 9 Accessions collected						
Balli -1	Intensive	8-9	8.6	42	Big & juicy	12.2
Balli -2	Intensive	5-8	7.83	45	Big & juicy	12.0
Balli -3	Extensive	8-12	9.39	35	Moderate	10.3
Betul -4	Intensive	5-6	10.60	35	Big, Juicy	11.2
Chicherwal -5	Extensive	2-3	12.28	25	Juicy	12.0
Farmagudi -6	Intensive	3-4	13.25	25	Moderate	10.7
Khederm -7	Intensive	3-4	13.05	35	Moderate	11.8
Mardol -8	Intensive	1-2	12.72	25	Moderate,Juicy	12.2
Shirlim -9	Intensive	1-2	12.00	30	Juicy	11.0
1990 -91 : 8 Accessions collected						
Verna 1 & 2	Intensive to Extensive		8 – 15	High yielding	110-140 g	11 -12
Keri 1 to 6			8 -11	High yielding	70 – 120 g	10.2-11.5
1992 : 9 Accessions collected						
Dhave-1 to Dhave-3	Semi Intensive		Bold nut	High yielding	Big & juicy	10-12
Karapur 1&2	Extensive		,,	,,	,, ,,	10-12.5
Ganje 1 & 2	Extensive		,,	,,	,, ,,	10-11
Curti 1 & 2	Extensive		,,	,,	,, ,,	11-12

Preliminary observations revealed that Balli-1 and Balli-2 with bold nut size, and bigger and juicy apples besides higher nut yield trend could be promising genotypes for commercial cultivation in future. An evaluation trial was initiated in 1994, which comprised of 11 selected accessions of local cashew, ***viz***. Ganje-1, Ganje-2, Bakhle-1, Karapur-1, Karapur-2, Dhave-1, Dhave-2, Dhave-3, Paikul-1, Balli-1 and Balli-2 along with Vengural-4 as check, in RBD with three replications

2.2.2 Introduction of cashew genotypes from different cashew research stations during 1986-95

In second phase of introduction, 14 cashew genotypes (Table 4) comprising of six varieties and five hybrids from Cashew Research Station, Madakkathara (Kerala), three hybrids from Regional fruit Research Station, Vengurla and one variety from Cashew Research station, Ullal, Karnataka were introduced for further evaluation under agro-climatic conditions of Goa.

Table 4. Cashew genotypes introduced from different cashew research stations during 1986-95

Year	Genotypes	Source
1986	6 varieties: BLA 139/1, K-22-1, NDR-2-1 , H-3-13, H-3-17, M10/4	C R S, Madkkathara, KAU, Kerala
1989-92	5 Hybrids: HB-1600, HB-1608, HB-1610, HB-1598 & HB-1591	,, ,, ,,
1994	3. Hybrids: H-255, H-220, H-205	RFRS, Vengurla,
1994	Ullal-1	C R S, Ullal, Mangalore

2.2.3Outcome / Results of previous introductions

Plate 1. Introduction of Vengurla - 4 cashew hybrid.

From among the first set of introductions, Vengurla-1, Vengurla-4, BLA 139/1,and M 10/4 showed better performance with nut yield in the range of 4.6 kg/tree in M 10/4 to 8.8 kg/tree in Vengurla-1 and Vengurla-4. Although, V-1 and V-4 showed better nut yielding ability and were thus, accepted by the farmers, because of the smaller size of apple and nut in the former, Vengurla-4 with better nut size (> 7.5 g) became ruling variety. Though apple size in Vengurla-4 is moderate, apples are not juicy due to puffiness.

2.2.4 Adoption of propagation techniques

Response of Vengurla varieties to 'Soft Wood Grafting' was in the range of 60 – 92 % during June – September under Goan conditions. Considering the limitations of the availability of genuine planting material of high yielding varieties, a 'Scion Bank' of Vengurla – 4 was established for large scale multiplication of grafts. Further, top working of inferior poor yielding trees with improved varieties was standardized and 63 unthrifty trees were top worked with V- 4 scions. Feasibility of top-working was demonstrated in four locations namely, Sanvordem, Raia, Chodan, and Aquem : with V-4 during 1988 with more than 75% success during June – August. However, it was observed that top worked trees required utmost care to overcome the problem of cashew stem and root borer (CSRB).

2.2.5 Achievements at the end of second decade

- Local germplasm collection : 42 Accessions
  Balli-1, Balli-2 : showed promising trend.
- A replicated trial of 11 local accessions was initiated in 1994
- Introductions : 28 varieties / Accns./ hybrids:
- Besides V-4, HB-1600, HB 1598 recorded good performance, but nut size : medium – small
- Scion bank of V-4 was established
- Top-working was standardized

2.3 Third phase of cashew research in Goa (1996 - 2005)

2.3.1 Ad-hoc project on cashew survey and classificatory analysis of cashew germplasm accessions

Goa being a small and highly dynamic tourism destination, rapid infrastructure building activities in the state are dwindling the cashew plantations. This rapid urbanization is a cause of utmost concern as regards the vital cashew genetic resources possibly possessing the rare and potential genotypes. Considering the dire consequences of erosion of such vital genetic material, local survey was further intensified under an ad-hoc project launched during 1996-2001, with the objective of collection and establishment of cashew germplasm bank. Ninety mother trees were identified based on three basic traits – nut yield, nut size and apple size, in different zones (Table –5) all over the state and the clonal germplasm bank of these accessions was established in Institute's Farm.

Table 5. Zone-wise distribution of germplasm accessions.

Zone	Number of accessions collected
Bardez	11
Bicholim	5
Ponda	2
Tiswadi	5
Cancona	22
Salcette	15
Quepem	9
Sattari	14
Sanguem	3
Pernem	4
Total	**90**

In order to understand the broad genetic spectrum of the germplasm, the accessions were subjected to "Metroglyph Analysis" which, based on average nut weight and nut yield per tree, scattered all the accessions in to 15 clusters (Fig. 1). However, there was a negative trend line, in general, among the accessions for the above two characters. Two accessions namely Valpoi –5 (No 70) and Bardez – 9 (No. 6) were the solitary clusters to form extreme groups (Groups I and XV). These represented the distant genetic relationship in respect of mean weight of nuts and nut yield per tree. Other groups namely XII, XIII and XIV also consisted of only one accession each namely Tiswadi-3 (No.42), Tudal – 4 (No.21) and Valpoi – 4 (No.69) respectively, which were distinctly away from other clusters in terms of nut weight and nut yield per tree, but possessed higher total index scores in the range of 15-16. The other promising groups identified in the study were - cluster IV with 9 accessions, cluster V with 8 accessions, cluster VI with 4 accessions, cluster VIII with 3 accessions and cluster XI with 11 accessions.

In group IV, the accessions had the yield range from 15 to 18 kg/tree with average weight of nuts ranging from 7.2 to 8.13 g (Table 6). Ashley-1 (No. 55) and Bardez-6 (No. 4) were prominent in this group with the highest index score of16 points followed by SB-2 (No. 24), Malwada-2 (No. 37) and Pernem-2 (No. 83) with total index score of 15 each. Flowering intensity, Number of rachis per inflorescence and shelling percentage were important in contributing ultimately to nut yield per tree, which varied from 15 to 18 kg in this group (Table 7).

Eight accessions with nut yield potential in the range of 18.6 to 21 kg per tree and average nut weight in the range of 8.08 to 9.44 g got clustered to form group V (Table 6). Khola-3 (No. 39) and Khola-1 (No. 29) were the important accessions with total index score of 19 and 17 respectively. Such characters as flowering intensity, number of rachis per inflorescence, number of flowering laterals, shelling percentage and average kernel weight were prominent in contributing to the higher index score in this group (Table 7).

Group VI was identified for the accessions with very bold nuts and higher yield ranging from 8.5 to 11.01 g and 14.4 to 18.0 kg per tree respectively. Kholker-1 (No.57) and Sanguem –2 (No. 81) were prominent accessions in this group with higher index score of 17 each, due to maximum contribution by number of nuts per panicle, shelling percentage, flowering intensity and number of flowering laterals per m^2 canopy.

On the other hand, Tiswadi-2 (No.20) and Kholker-4 (No.63) were identified as promising accessions with 16 index score each in group VIII. Similarly, Group XI had the accessions very bold (10.6g) to ultra-bold nut size (12.55g) with yield potential varying from 12.8 to 18.0 kg per tree. The promising accessions were Sarvan-3 (No.12) with total index score of 16 and Valpoi-1 (No. 67), Valpoi-2 (No. 68), Sarvan-1 (No.44) and Pernem-4 (No. 85) with total index score of15 each.

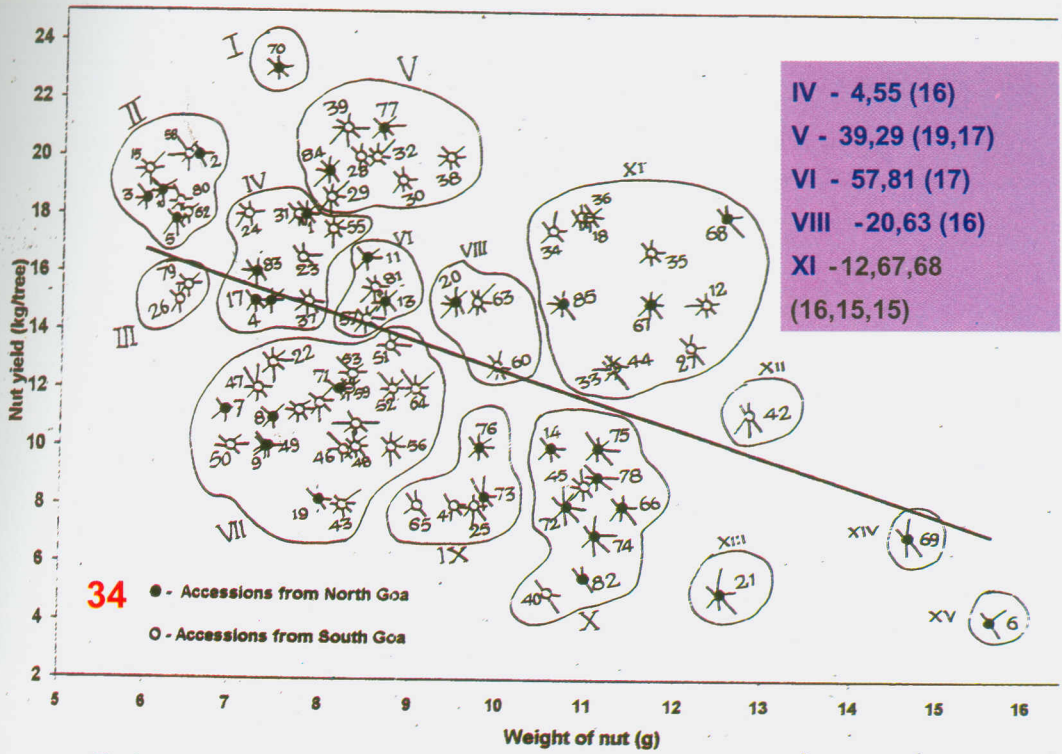


Fig 1. Metroglyph scatter diagram of cashew germplasm accessions based on nut yield and weight of nut.

Table 6. Prominent groups of cashew Germplasm accessions

Group	Group IV	Group V	Group VI	Group VIII	GroupXI
Range of Nut wt. (g)	7.2- 8.1	8.1- 9.4	8.5 - 11.0	8.0 - 9.8	10.6- 12.5
Range of Yield(kg/tree)	15 -18	18.6 - 21.0	14.4 - 18.0	11.5 - 15.0	12.8 - 18.0
Prominent accessions	Ashley-1(55), Bardez-6 (6)	Khola-3 (39) Khola-1 (29)	Kholker-1(57), Sanguem-2(81)	Tis - 3 (20), Kholker - 4(63)	Sarvan-3(12), Valpoi-1(67), Valpoi-2 (68)
Total Index Scores	!6 Scores each	19 & 17 Scores resp.	17 scores each	16 score each	15 scores each

Table 7. Important traits of promising accessions.

Group	Accession	T.I.S	Traits with higher score
V	Khola-3(39)	19	No..rachi/Infl.(3); Fl. Lateral(3); Fl.Int (3); Shelling (3)
	Khola-1(29)	17	Flower. Int. (3); Floer. Lateral (3)
VI	Kholker-1(57)	17	No.nuts / panicle (3); Shelling (3)
	Sanguem-2(81)	17	Flower. Int. (3); Floer. Lateral (3)
VIII	Kholker-4(63)	16	Nuts/panicle (3)
IV	Ashley-1 (55)	16	Flowering Int. (3)
	Bardez-6 (4)	16	No. Rachis/Infl. (3)
XI	Sarvan-3(12)	16	inflorescence (3)
	Valpoi -1 (67)	15	Wt.of kernel (3), Shelling (2)
	Valpoi -2 (68)	15	Wt.of kernel (3), Shelling (2)

2.3.2 Release of Goa-1 (Balli – 2) cashew variety for commercial cultivation.

Based on the performance of higher nut yield coupled with bold nut size higher shelling percentage of exportable grade kernels, bigger and juicy apples (Table 8), the accession Balli-2 identified from Balli village in Quepem zone was released in 1999 under the name **"Goa-1"** for commercial cultivation in the state of Goa. Being a mid-season variety, Goa-1 is less affected by the TMB and has an edge over Vengurla-4 variety as far as per cent kernel recovery and bigger juicy apple are concerned. The details of the charactristic features of this variety are presented in Table 9.

Table 8. Performance of Goa -1 cashew at the age of 10 years.

Attributes	1995-96 (6^{th} year)	1996-97 (7^{th} year)	1997- 98 (8^{th} year)	1998- 99 (9^{th} year)	1999-00 (10^{th} year)	Mean
Nut yield (Kg/tree)	5.31	6.5	7.8	7.99	8.78	7.3
Cum. Yield (Kg/tree)	--	11.81	19.61	27.6	36.38	7.3
Av. Nut wt(g)	7.91	7.8	8.01	7.89	7.78	7.8
Shelling (%)		29.06	31.10	29.98	30.05	30.04
Apple Wt (g)	77.85	76.80	71.09	73.85	71.34	74.18

Plate 2. Goa - 1: A Promising Cashew variety released from the Institute

Table 9 Description of the cashew variety Goa -1

A) Plant height (At the age of 10 years)	:	**5.3m**
B) Morphological characters		
i) Branching pattern	:	Semi intensive
ii) Canopy	:	Semi spreading
iii) Leaf size and shape	:	Medium, Oblong
iv) No. of flowering laterals M-2 canopy	:	15.93
v) Panicle shape	:	Broadly pyramidal
vi) Sex ratio (male to female)	:	10.02:1
vii) Number of fruits per panicle	:	5.4 - 5.8
C) Season :-		
i) Time of flowering	:	December - February
ii) Duration of flowering (in days)	:	90-100
iii) Season of harvest (60 to 65days)	:	Mid March -Mid May
D) Quality of the produce		
i) Nut weight (g)	:	7.41 - 7.92
ii) Number of nuts/Kg	:	130 - 137
iii) Shelling percentage	:	29.82 - 30.05 %
E) Quality of kernel:		
i) Kernel weight (g)	:	2.02 - 2.56
ii) Whole kernel count/lb	:	W210 - W240
iii) Kernel grades		
180 counts/lb	:	15.63%
210 counts/lb.	:	38.24%
240 counts/lb.	:	26.91%
320 counts/lb.	:	19.19%
Others	:	Nil
iv) Kernel sugars (%)	:	6.16
v) Kernel protein (%)	:	34.93
vi) Total lipids (%)	:	44.91
F) Quality of apple :-		
i) Apple colour	:	Yellow
ii) Apple shape	:	Cylindrical
iii) Apple weight (g)	:	60.29 - 73.13
iv) Juice contents (%)	:	72.64 - 73.35
v) T.S.S. of juice (^{0} Brix)	:	12.0

2.3.3 Results of evaluation trial of selected local cashew accessions

In an evaluation trial of local cashew accessions, initiated in 1994, 12 accessions ***viz***. Ganje-1, Ganje-2, Bakhle-1, Karapur-1, Karapur-2, Dhave-1, Dhave-2, Dhave-3, Paikul-1, Balli-1, Balli-2 and Tiswadi-3 (included in 1998) along with Vengural-4 as check, were evaluated in the institute's farm till 2006 for a period of twelve years.

Long term results revealed that Ganje – 1, Ganje -2, Tiswadi-3, Balli – 1, Balli – 2, Karapur –1 and Karapur-2 showed higher nut yield trend from 2004 onwards. The accessions recorded higher nut yield in the range of 7.1 kg/tree (Karapur-1) and 12.5 kg/tree (Tiswadi- 3) as compared to 8.4 kg/tree in the Check (V – 4) during 2006-07 season (Fig 2). Similarly, the trend in respect of the cumulative nut yield for the last eight harvests, recorded the highest nut yield of 36.5 kg/tree in Balli - 1.

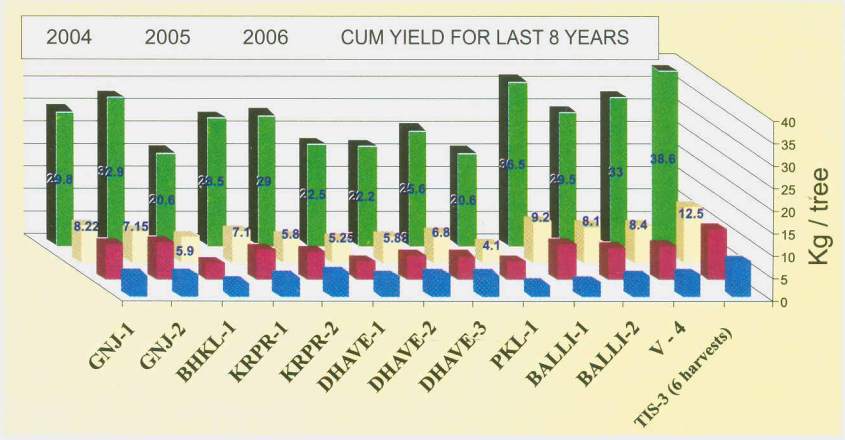
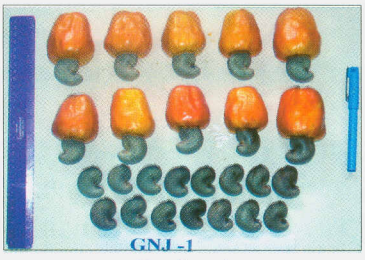


Fig.2 Nut yield performance (Kg/tree) of diferent accessions

Tiswadi - 3

Ganje - 2



Ganje - 1

Balli - 1

Ganje - 2

Plate 3. Promising local cashew accessions.

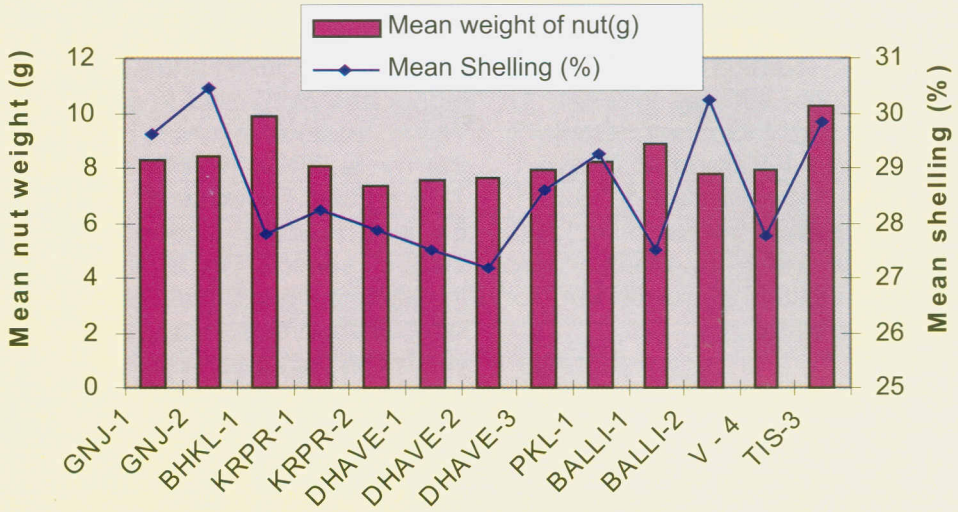


Fig. 3 Mean nut weight and shelling percentage of local cashew accessions during 2006

However, Tiswadi – 3, out performed other accessions by recording almost the same yield level (38.6kg/tree) within the last six cumulative harvests only, besides the highest mean nut-weight of 10.24g and shelling percentage of 29.85 (Fig 3). Further, mean delta in respect of nut weight and shelling percentage over last five years varied between 0.55 (Paikul – 1) and 1.86 (Bakhle -1), and 0.43 (Karapur – 2) and 2.18 (Dhave – 3) respectively (Figures 4 and 5). Balli -2 and Karapur-2 showed higher stability with respect to mean nut weight as well as shelling percentage as indicated by their lower mean delta values. Ganje-1, Ganje-2, Karapur-1 and Balli-1 in general, had moderate variation in mean delta nut weight and shelling percentage across the seasons.

Compared to mean apple weight of 59.5g in the standard check – V-4, in general, all the local accessions recorded the mean apple weight of more than 86 g with higher juice content (67.6% in Karapur 1 to 76.4 % in Dhave-2). Total soluble solid contents of cashew apple juice in the most promising accessions such as Ganje-2, Tiswadi-3, Karapur-1, Balli-1 and Ball-2 were observed to be 12.2, 10.8, 11.4 and 11.6° B respectively. Based on these concluding results of the evaluation studies the accessions such as Tiswadi-3, Karapur-1, Ganje – 1, Ganje – 2, Balli – 1 and Balli-2 were identified as the potential local Genotypes. Balli-2, under the name Goa-1, is already recommended for commercial cultivation in the state of Goa while Tiswadi-3 the other promising genotype is proposed for recommendation and release as a new variety for commercial cultivation in the state of Goa.

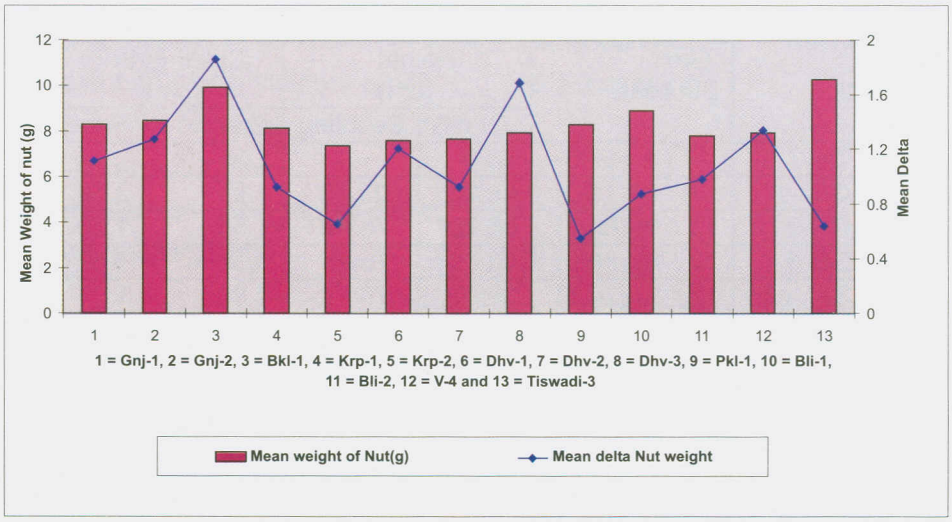


Figure 4. Mean nut weight and its stability pattern over last five years across local cashew accessions

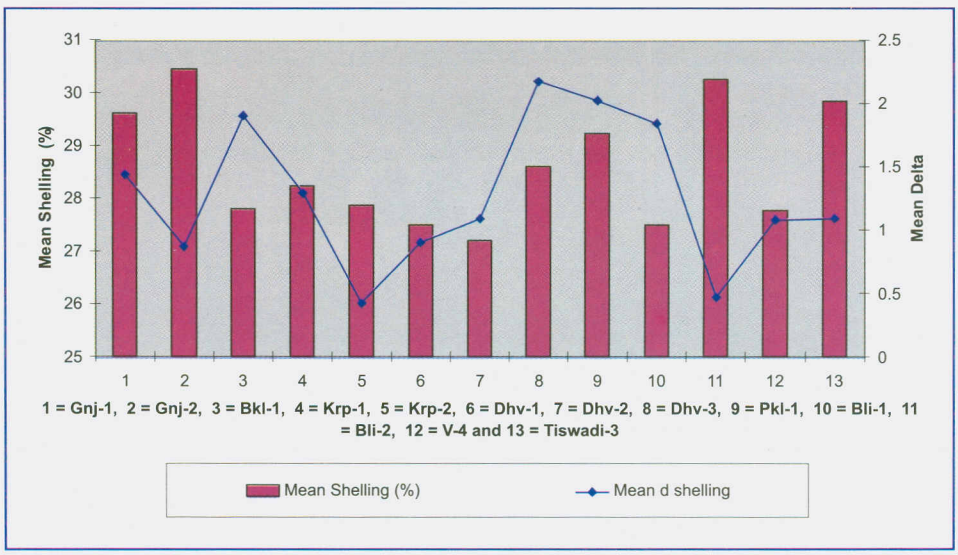


Figure 5. Mean shelling per cent and its mean delta pattern over last five years across local cashew accessions

2.3.4 Establishment of nucleus scion bank of Tiswadi-3 on the root-stocks of dwarf genotypes

Based on the promising results observed during the evaluation, a nucleus scion bank of Tiswadi-3, is established by ***in situ*** soft wood grafting on different root stocks of dwarf genotypes (Sattari dwarf, GB-2 & GB-5), and Tiswadi-3, Goa-1 (Balli-2) and V – 4.

Table 10. Growth of ***in situ*** soft wood grafts of Tiswadi -3 on different root-stocks.

Stionic combination	Graft Success	Height (cm)		Collar girth (cm)	
		Graft	Seedling	Graft	Seedling
Tis-3 on Tis-3	7 / 8 (87.5)	88.0	-	1.36	-
Tis-3 on Goa-1	6 / 8 (75.0)	85.25	105.40	1.9	2.58
Tis-3 on GB-2	13 / 15 (86.7)	66.20	76.00	1.51	1.50
Tis-3 on GB-5	12 / 15 (80.0)	58.80	75.28	1.36	1.57
Tis-3 on Sa ttari Dwarf	7 / 10 (70.0)	39.33	70.17	0.80	1.71
Tis-3 on V- 4	8 / 10 (80.0)	80.50	94.00	0.95	1.7

Success of *in situ* soft wood grafting of Tiswadi-3 varied from 70 – 87 per cent on different rootstocks (Table 10). The growth of grafts on rootstocks of Tiswad-3, Goa-1 and V-4 was observed to be vigorous unlike that of those on dwarf genotypes. Further studies are under progress.

Salient information about *in situ* soft wood grafting in cashew

- Age of the seedling should be 3 – 3.5 months (seed nuts sown in June).
- September – October period : ideal for ***in situ*** grafting
- Soil moisture, temperature and relative humidity will be congenial
- Tap root is intact. Hence, withstands the onslaught of uprooting by stormy winds
- May induce precocity
- Minimum size of canopy required for first harvesting is achieved in advance of one year
- If root stocks are standardized, this method offers scope for taking advantage.
- Cost effective.

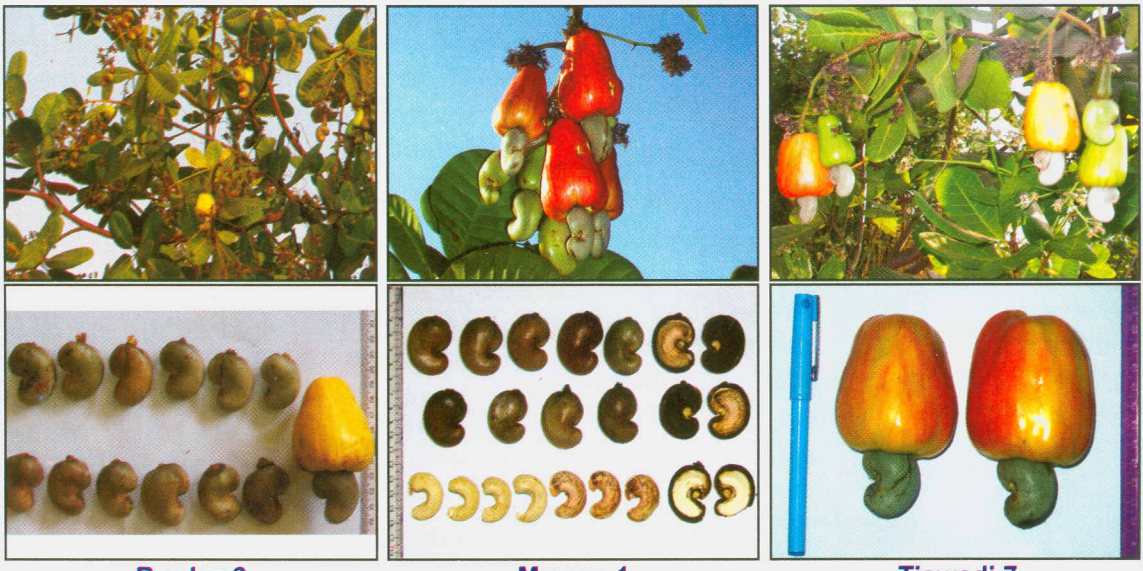
Plate 4. *In situ* grafting in cashew.

2.3.5 Core collection of local germplasm accessions

"Germplasm collection / bank" intends to preserve the valuable genetic diversity of crop species and their better utilization in future. Germplasm collections of crop plants continue to grow in number and size over a period of time. The very large size and heterogeneous structure of collections hinder the efforts in using gene bank material effectively in crop improvement. Recognizing this, Frankel (1984) and Brown (1989) emphasized that the collection could be pruned to what was termed as "A Core Collection", which would represent with a minimum of repetitiveness, the genetic diversity of a crop species and its relatives.

In our study, a total of 67 cashew genotypes formed the "Core Collection" of cashew accessions comprising of following different groups.

- Bold nut types : 16 accessions
- Bold nut and high yielders types : 16 accessions
- Medium nut and high yielders: 15 ,,
- Dwarf canopy types : 4 ,,
- Others (small nut & high yielders,
- bunch bearers,etc) : 16 ,,
- Total core collection : 67 ,,



Bardez 9 Mayem 1 Tiswadi 7

Plate 5. Boldnut local cashew accessions

2.3.6Achievements at the end of third decade

- **Establishment of clonal germplasm bank of local cashew genotypes and classificatory analysis.**
- **Release of Goa-1 cashew variety in 1999**
- **Tiswadi-3, Ganje-1 and 2, Balli-1, Karapur-1 and 2 : the promising genotypes.**
- **Nucleus scion bank of Tiswadi-3 established**
- ***In situ* soft wood grafting in cashew standardized**
- **A core collection of 67 cashew germplasm maintained**

3. Progress of research in cashew improvement (2006 onwards)

3.1 Evaluation results of clonal progeny of local genotypes

Clonal progeny of 57 genotypes, 55 local accessions of Goa and two recommended varieties (Goa-1 and Vengurla-4), planted during 1997-98 at 6 m × 6 m spacing in the clonal germplasm bank were studied for genetic variability at ICAR Research Complex for Goa.

Nut yield per tree is the targeted quantitative parameter which is dependent on several yield related attributes. The inherent yield related characteristics, at a given point of time, associate with one another to eventually decide the yield performance of the tree. Such a resultant nut yield is reported to vary with individual variety or genotype. The results on important yield attributes and nut yield pertinent to 57 genotypes identified that, some promising genotypes (Table 11) such as Tiswadi -3, Valpoi -7, Agonda-1, Ganje - 1, Ganje -2, Bardez-9 and KN -2/98 consistently recorded higher nut yields which were on par with both the checks. Tiswadi-3, surpassed the checks in the year 2006, with nut yield of 10.02 kg/tree and also with respect to total cumulative nut yield (21.83 kg /tree) for the last five consecutive harvests.

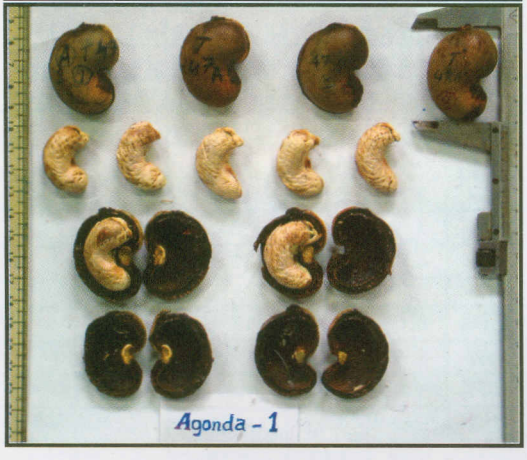
The differences in nut yield can be attributed to the inherent genetic make up of the genotypes or cultivars and their interaction with environment. However, the differences in nut yield, basically, may be related to differences in the yield related components such as nuts per panicle and average nut weight, which in turn are dependent on or influenced by the sex ratio, flowering intensity, *etc.* Vigour of the tree coupled with structural components of canopy (number of flowering and non flowering laterals per square meter canopy) and tree volume as a whole, decides the total nut yield out put however, through the expression of all the above-enumerated growth, flowering and yield components.

Under the above considerations, the genotypes in the present study showed significant variations in yield related characteristics which were reflected in the final cumulative nut yield per tree in the range of 6.18 kg per tree (Valpoi -2) to 21.83 kg per tree (Tiswadi-3). However, there were several intermediate genotypes of varied potential genetic make up for different traits at individual level. For instance, the genotype Valpoi -2, though with low yield, has basically the higher mean nut weight (12.26g). At the same time, this genotype recorded a moderate sex ratio of 0.283, coupled with low flowering intensity and lesser number of nuts per panicle (1.36). On the other hand, Tiswadi-3, which recorded the highest cumulative nut yield of 21.83 kg /tree at 8 years of age, appeared to be a potent natural recombinant for higher nut yield coupled with most desired commercial traits, like higher mean nut weight (10.60g), jumbo kernel size attributing to higher kernel weight (3.16g) which resulted in higher kernel recovery of 29.78 per cent. These characters in this genotype appeared to have been relatively complemented by higher level of flowering shoots per square meter canopy, (17.32) and flowering intensity (81.72%). Moderate sex ratio (0.293) and lesser number of nuts per panicle (1.28) appeared to have been compensated by very high level of flowering intensity. Similar trend of supplementary and compensatory association was observed among flowering characteristics

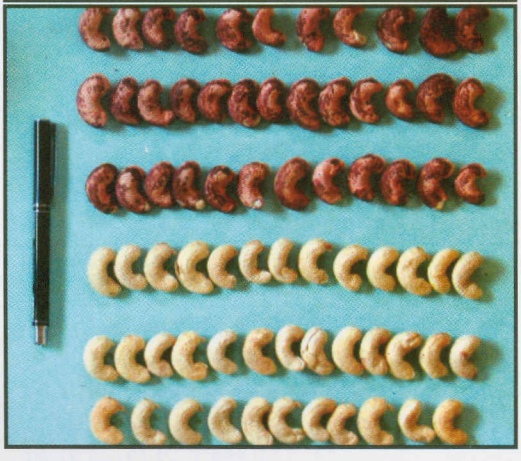
Table 11. Promising local cashew genotypes with salient features under different groups

Genotype groups		Flowering Intensity (%)	Sex ratio	Av nut weight (g)	Shelling (%)	Nut yield (Kg/tree)				Apple weight (g)	Juice content (%)
I. Bold nut accessions						2004	2005	2006	Cum. nut yield		
1	Tiswadi-3	81.72	0.293	10.60	29.78	3.81	5.60	10.02	21.83		
2	Bardez-9	74.02	0.397	13.77	26.60	2.99	4.53	6.13	17.81		
3	Agonda-1	79.26	0.297	12.58	28.58	2.92	4.63	7.43	17.97		
4	Tiswadi-7	73.08	0.403	10.22	30.33	1.23	2.83	4.10	11.15		
5	Agond-2	57.43	0.230	10.29	29.03	2.15	4.10	5.28	14.66		
6	Valpoi-2	46.29	0.283	12.26	31.01	0.28	1.40	3.15	6.18		
II. Medium nut accessions.											
1	Ganje-1	75.66	0.300	7.83	28.71	2.21	4.88	6.80	16.77		
2	Ganje-2	81.30	0.290	8.61	31.19	2.44	4.53	6.93	16.87		
3	Balli-1	83.33	0.323	9.53	27.80	1.22	3.90	6.93	14.32		
4	KN 2/98	74.68	0.497	8.85	29.92	2.89	5.08	6.16	17.34		
5	Valpoi-3	65.46	0.230	8.64	30.79	1.89	3.55	4.62	12.25		
6	Valpoi-7	81.45	0.240	8.39	30.58	3.04	5.36	6.96	19.12		
7	Maye-1	79.90	0.187	8.41	30.68	1.21	3.57	5.67	13.29		
8	Loutolim-3	57.53	0.143	7.75	30.75	2.02	4.23	5.68	12.94		
III. Small nut accessions											
1	Tiswadi-4	71.52	0.307	6.16	31.39	2.79	5.19	6.73	16.44		
2	Red Local	88.10	0.337	5.17	29.87	1.57	3.73	6.23	13.83		
3	Satari dw	77.56	0.337	5.04	32.86	2.34	4.25	5.68	13.37		
4	Bardez-6	59.51	0.220	7.21	30.08	0.82	2.65	3.95	9.17		
5	Kholker-1	64.83	0.443	6.75	31.93	0.98	1.93	4.09	9.23		
IV. Check varieties											
1	Goa-1	79.93	0.302	7.80	33.43	2.72	5.22	6.17	17.15		
2	Veng.- 4	81.17	0.344	7.63	29.54	2.26	5.57	6.70	17.25		
	SEm±	**6.854**	**0.041**	**0.271**	**1.474**	**0.598**	**0.739**	**1.018**	**1.639**	**6.115**	**2.500**
	CD (P=0.05)	**18.943**	**0.118**	**0.761**	**4.084**	**1.657**	**2.047**	**2.821**	**4.542**	**18.951**	**6.930**

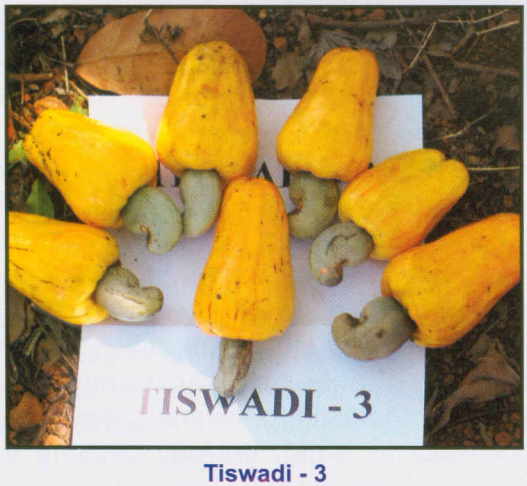
there by leading to higher nut yield in genotypes such as KN-2/98 (high sex ratio of 0.497 and higher number of nuts per panicle of 3.02), Ganje-2 (flowering intensity of 81.30%; sex ratio of 0.293 and 2.87 nuts/ panicle), Bardez-9, Agonda-1 and Valpoi-7, *etc.* This tendency was also observed to be very conspicuous in the check varieties (Goa-1 and Venugurla-4). Such a relation is also observed in the genotypes with low average nut weight, such as Sattari Dwarf (5.04 g), Red local (5.17 g), Bardez-6 (7.12 g) and Kholker -1 (6.75 g). In these genotypes, the higher number of nuts per panicle (3.21 to 5.26, cluster bearing habit) resulted due to higher sex ratio (0.320 to 0.443) might be partitioning the photosynthates in to several growing nuts (or fruits as sink), thereby causing the overall nut weight to be low.



Agonda - 1



KN - 2/98



Tiswadi - 3

Valpoi - 7

These are important hypothetical views, which need to be ascertained for their better handling, management and utilization as genetic resources. The attempt has been made in the present studies to unravel these underlying biological phenomena. Considerations are, therefore, necessary while utilizing the cashew genetic resources in the exercise of deliberate recombining of the desired traits (crop improvement) in to a single genotype.

These results thus, clearly indicated the complex nature and composition of 57 genotypes for varied growth and yield related characters, which need to be assessed through genetic variability parameters both at morphological and molecular level.

3.2 Proposal of Goa-2 (Tiswadi-3) cashew variety for release

Considering the nut yield performance during the last 10 years and its nut and apple characteristics, a proposal for releasing the accession Tiswadi-3 as a commercial variety for cultivation in the state of Goa under the name **Goa-2** was approved in the in the AICRP Biennial workshop on cashew held ICAR Research Complex for Goa during 22-24 November 2007. This selection is a high yielding early variety (mid February – April) coupled with bold nut and bigger apple size. Bold nuts yield jumbo sized kernels with exportable grade of W180 – W210 counts. This has extensive branching pattern with semi spreading canopy. The salient features of this variety are presented here under.

Plate 6. Tiswadi - 3 a promising local cashew variety in pipe line.

	Growth and flowering	
1.	Tree Height (at 10th year)	5.8 m
2	No. Flowering Laterals per M^2 canopy	18.86
3	Sex ratio (male to female)	11.54 : 1
4	Season of flowering	Dec – Mid February
5	Duration of flowering	70 – 80 days
6	Season of Harvest Nut yield	Mid Feb. – April 10.02 kg/tree

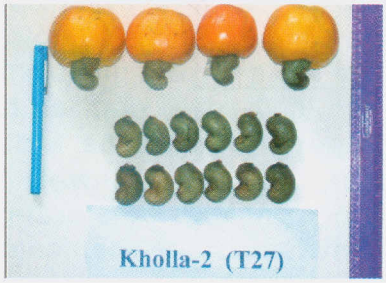
	Nut Characteristics	
7	Nut Weight.	9.2 - 10.6 g
8	Number of Nuts / kg	105 – 110
9	Shelling Percentage	29.25 to 29.55 %
10	Average Kernel weight	2.26 - 2.52 g
11	Whole Kernel Counts per lb	W 180 – W 210

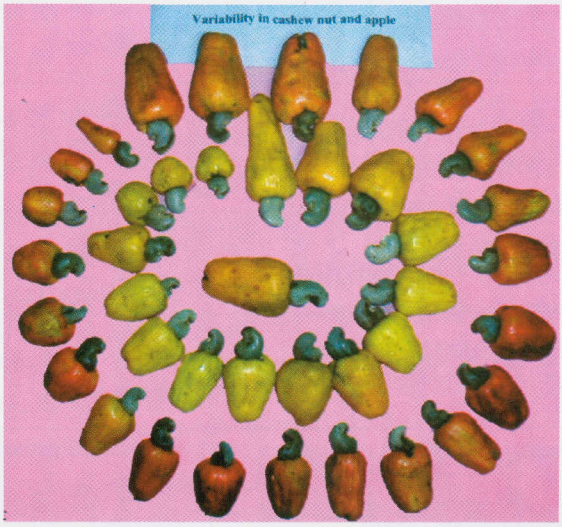
	Apple Characteristics	
12	Apple Colour	Yellowish orange
13	Apple Shape	Cylindrical
14	Weight of apple	100.5 – 110 g
15	Juice Contents	68.2 – 72.0 %
16	TSS contents	10.8 – 12.2 ^{O} B

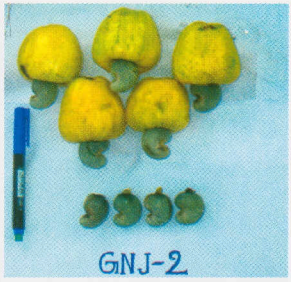
3.3 Estimates of genetic variability of cashew genotypes

Variability in the germplasm collection is the key factor for success of crop improvement programmes. Higher the variability in the genetic resources, better will be the options for meaningful, planned breeding programmes.

Results showed that all the 20 genetic characters exhibited significant differences indicating the presence of sufficient genetic variability in cashew genotypes. Higher heritability levels were observed (Table 12) for nut weight (97.62%), kernel weight, (94.62%), tree height (92.66%), nut yield per tree (87.26%), flowering intensity (84.23%), number of nuts / panicle (78.8%), flowering shoots per m^2 canopy (79.19%), total leaf area per twig (76.49%), and sex ratio (74.31%). Of these traits, only number of nuts per panicle, sex ratio, nut weight and number of flowering shoots per m^2 canopy showed higher genetic advance over mean of 59.53, 46.53, 41.87 and 38.35 per cent, respectively coupled with higher heritability, thereby indicating their importance in the selection. The selection based on these characters will bring about the enhancement in the genetic strength of the genotypes. High heritability with low GCV and genetic advance for other traits indicated little scope for selection in crop improvement.







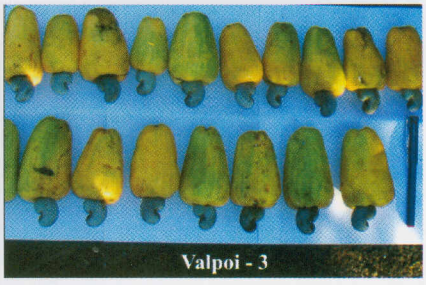


Plate 7. Variability in apple size, shape and colour in cashew germplasm.

Table 12. Estimates of variability components

Sl N0	Characters	Range		Mean	SEm±	GCV	PCV	h^2	GA	GA over mean
		Minimum	Maximum							
1	Tree height (m)	3.07	6.90	4.42	0.17	13.80	14.33	92.66	1.21	27.37
2	Canopy spread-NS (m)	3.16	8.96	5.52	0.51	12.86	15.87	65.68	1.19	21.48
3	Canopy spread-EW (m)	3.28	9.03	5.56	0.49	14.43	16.90	72.88	1.41	25.38
4	Number of shoots/m^2 canopy	10.50	33.00	19.07	1.93	12.20	15.91	58.83	3.68	19.28
5	Number of leaves/twig	9.38	20.46	14.64	1.02	8.63	11.15	59.99	2.02	13.78
6	Leaf area/twig (cm^2)	643.49	3230.49	1493.62	169.71	20.68	23.64	76.49	556.47	37.26
7	Flowering shoots/m^2 canopy	4.00	23.00	11.67	1.23	20.91	23.50	79.19	4.44	38.35
8	Flowering intensity (%)	30.49	93.75	67.14	4.44	15.41	16.80	84.23	19.57	28.14
9	Flowering duration (days)	56.00	134.00	87.91	7.25	10.85	13.68	63.01	15.6	17.75
10	Inflorescence length (cm)	10.30	29.00	18.18	1.59	14.43	16.96	72.81	4.61	25.38
11	Sex ratio	0.09	0.72	0.27	0.042	26.27	30.47	74.31	0.13	46.65
12	Nuts/panicle	1.05	8.39	2.27	0.38	32.55	36.67	78.8	1.35	59.53
13	Nut weight (g)	4.37	14.00	43.34	0.27	20.57	20.82	97.62	3.53	41.87
14	Shell thickness (cm)	0.22	3.41	0.42	0.28	15.17	64.75	5.49	0.03	7.32
15	Kernel weight (g)	1.38	3.89	2.54	0.11	18.95	19.48	94.62	0.96	37.96
16	Shelling per cent	25.01	34.62	30.08	1.46	4.34	6.54	43.97	1.78	5.92
17	Apple weight (g)	49.75	129.00	91.54	6.06	17.48	18.71	87.26	30.79	33.64
18	A:N ratio	6.07	17.54	11.12	1.02	10.72	14.13	57.51	1.86	16.74
19	Juice content (%)	55.80	90.50	70.24	2.48	3.32	4.87	46.5	3.27	4.66
20	Nut yield (kg/tree)	1.39	18.4	4.96	1.01	16.39	26.28	38.92	1.04	21.07

3.4 Character association in cashew

The nut yield per tree is in fact influenced and / or determined at a given point of situation, by various factors including that of plant factors. Nut yield per tree is the final out put, for which a series of pre requisite-growth, flower, and yield related parameters interact with one another in a supplementary and complementary pattern. Such an information on the mutually interactive association of all the plant characters in cashew will be of immense practical significance especially while making selection based on morphometric putative characters.

It was observed that the growth parameters such as tree height, canopy spread (N-S and E-W), number of leaves per twig and total leaf area per twig, showed significant positive association with nut yield per tree (Table 13). That means, any factor that impairs the performance of these parameters will ultimately affect the nut yield. Their association is least influenced by the environment as the correlation is strongly significant both at genotypic and phenotypic levels with high degree of relationship. Further, flowering related characters such as number of flowering shoots per m^2 canopy and flowering intensity, were observed to express high degree of positively significant relation with nut yield per tree at genotypic as well as phenotypic levels. Nut weight and number of nuts per panicle also showed the same trend with nut yield. It is interesting to note that the flowering duration showed negative association, though not significant, with nut yield. Sex ratio recorded positive and significant association only at phenotypic level, thereby, indicating its relation under the influence given environmental conditions.

Table 13. Significant Genotypic and phenotypic correlation coefficients among cashew genotypes.

Attributes		Correlation with yield	With other traits
Tree height	G P	0.55** 0.33**	
No. leaves/twig	G P	0.91* 0.47**	
Flr. Shoots / M	G P	0.90** 0.57**	-0.68* Canopyspread -0.51*
Flr. intensity (%)	G P	0.89* 0.63*	
Sex ratio	G P		0.73* Nuts / panicle 0.61*
Nut weight	G P		0.96** Kernel weight 0.91**
More difference between Genotypic and Phenotypic correlation Coefficients : more liable for environmental conditions			

r = 0.261 at 5 %, r = 0.339 at 1 % level of significance for n-2 d.f.
* Significant at 5 % level, ** Significant at 1 % level

Thus the present investigations on correlation studies in cashew genotypes of Goa revealed the importance of number of growth, flowering and yield related characters as selection criteria for improvement of nut yield in cashew genotypes.

3.5 Principal component analysis in cashew

The degree of relatedness among individuals within or between species or among genotypes within a breeding population can be approximated with principal component analysis. This analysis partitions the total variability in a population of genotypes into definite factors that are proportionally responsible for total variation and further within each, component factor, the individual variables and their contribution to the total variability are identified. Further, principal component analysis scatters the genotypes in question, in to important clusters based on their relatedness. Euclidean distances derived based on PCA in turn indicate how near or distant the clusters and the genotypes within cluster are (Iezzoni and Pritts, 1991).

In order to derive such an information on 57 cashew genotypes the PCA was carried out using 20 important growth, yield and yield related characters. The results identified first 14 principal components which accounted for about 96.52 per cent of variability (Table 14). Based on the loading of the eigene vectors for each character (variable) within each principal component, PC1 was identified as nut factor accountable for 20.62 per cent variability. Similarly, flowering factor (PC2), apple factor (PC3) and growth and yield factor (PC4) contributing 16.70, 10.50, and 8.25 per cent variability, respectively were identified. This information is very useful in the utilization of the genetic resources in the right direction in crop improvement programmes. The spread of the variation across many principal components suggested that in genetic variability study aimed at identifying parental lines or varieties, the phenotypic characters related to nut, apple, floral and vegetative traits (leaf, canopy, type, tree habit) should be emphasised, during selection.

Further, the PCA grouped all 57 cashew genotypes into six clusters (Table 15). The genotypes Tiswadi-4, Tiswadi -5, Sweet Round, Kuddi -1, Kuddi-2, Sattari-5, Valpoi-1, Valpoi-3, Valpoi-5, Tudal-3, Tudal -5 and Mayem -3 clustered together in cluster –I (Table15). These genotypes have such traits as small medium nut size, higher shelling percentage, shorter flowering duration, lesser N-S canopy spread and lower tree height in common (Table 16). In the same way, the genotypes, Red local, Goa-1, Vengurla-4 and Sattari Dwarf with higher number of shoots per m^2 canopy, number of leaves per twig, number of flowering shoots per square meter canopy, flowering intensity, sex ratio, nuts per panicle, and shelling per cent, but with smaller nut weight and kernel weight, came together in cluster VI, which was completely distinct from the cluster III. On the contrary, cluster IV had those genotypes with highest

nut weight, apple weight, kernel weight and distinctly higher yielding ones, with highest sex ratio. Tiswadi -3, Balli -1, Bandez-9, Agonda-1, KN -2/98 and Valpoi-7, were the conspicuously distinct genotypes compared to others. The clustering pattern of the genotypes probably reflected the genetic history of the genotypes. This pattern of clustering on the basis of previous breeding or genetic history, is similar to the report of Swamy *et al.* (2002) and Aliyu and Awopetu (2007) on cashew. It is important to note that the genotypes in clusters IV and VI were observed to be genetically very distant ones and crossing between these genotypes would yield very potential hybrid progeny (Table 17). Similarly, genotypes of clusters II and VI with genetic distance of 5.907 followed by clusters V and VI can be used as potential parents in hybridization programmes. Thus, in the present study, the distinct genotypes with potential genetic history for desired traits have been identified, which could be either useful in planning subsequent breeding programmes or could themselves be the evolved potential new varieties for cultivation on commercial scale.

Table 14. Eigen vectors for different characters in first 14 principal components

Sl. No	Characters	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11	PC12	PC13	PC14
1	Tree height (m)	0.258	0.369	0.334	0.101	0.263	0.239	0.352	0.370	-0.127	-0.098	0.220	0.061	0.012	-0.161
2	Canopy spread-NS (m)	0.211	-0.072	-0.091	-0.127	0.116	0.311	-0.161	-0.067	0.148	0.002	-0.036	-0.181	0.511	0.038
3	Canopy spread-EW (m)	-0.120	-0.067	-0.081	0.486	0.160	0.071	0.330	-0.080	0.304	0.357	-0.173	0.420	0.072	0.156
4	Number of shoots/m^2 canopy	-0.337	-0.245	-0.305	-0.243	0.061	-0.105	0.046	0.287	-0.185	-0.274	0.289	0.197	0.124	-0.008
5	Number of leaves/twig	0.149	0.029	-0.056	-0.258	0.299	0.291	-0.249	-0.058	0.095	0.007	-0.419	-0.021	-0.166	-0.112
6	Leaf area/twig	0.100	0.191	0.268	-0.050	0.351	0.147	-0.033	0.000	0.275	-0.475	0.017	-0.035	-0.048	0.579
7	Flowering shoots/m^2 canopy	-0.202	0.427	0.307	0.231	-0.045	-0.189	0.083	-0.146	-0.171	0.028	-0.064	-0.281	0.158	-0.027
8	Flowering intensity (%)	0.117	0.351	-0.035	-0.231	-0.150	-0.195	0.017	0.283	0.343	0.023	0.198	0.310	0.021	0.043
9	Flowering duration	0.124	-0.016	-0.045	-0.085	-0.127	0.012	-0.065	-0.030	0.464	0.323	0.303	-0.079	-0.068	0.164
10	Inflorescence length	-0.041	-0.186	-0.063	0.038	0.131	-0.038	0.099	0.033	-0.314	-0.092	-0.263	0.088	0.018	0.655
11	Sex ratio	-0.053	0.365	0.068	0.116	0.233	0.214	-0.194	-0.072	-0.134	-0.145	0.436	0.427	0.023	0.001
12	Nuts/panicle	0.234	0.346	0.189	-0.044	-0.133	-0.143	-0.159	0.143	-0.342	0.418	-0.196	0.404	0.096	0.124
13	Nut weight (g)	0.693	0.199	0.254	-0.248	0.287	0.127	-0.039	0.260	0.174	0.251	-0.012	-0.165	0.001	0.113
14	Shell thickness (cm)	-0.290	0.333	-0.083	-0.046	-0.219	0.003	-0.125	-0.165	0.217	-0.326	-0.352	0.373	0.095	-0.233
15	Kernel weight (g)	0.563	0.332	-0.092	-0.023	0.448	-0.632	-0.185	-0.263	0.072	0.022	0.146	-0.119	0.042	0.137
16	Shelling percent	-0.394	0.308	-0.091	0.002	-0.286	0.398	-0.117	-0.149	-0.263	0.270	0.239	-0.095	-0.040	0.197
17	Apple weight (g)	-0.109	-0.475	0.573	-0.071	-0.043	0.050	-0.255	-0.265	-0.045	0.095	0.147	0.140	0.058	-0.027
18	A:N ratio	-0.031	0.021	0.050	0.018	0.020	-0.065	0.001	-0.022	-0.024	-0.006	-0.064	0.047	-0.052	-0.032
19	Juice content (%)	-0.014	-0.019	0.320	-0.095	-0.027	0.026	0.050	-0.112	-0.019	-0.003	0.015	0.030	-0.785	0.002
20	Nut yield (kg/tree)	-0.003	0.002	0.010	0.632	0.007	0.021	0.078	-0.484	0.006	0.016	0.009	-0.017	0.110	-0.020
	EIGEN ROOTS	4.125	3.340	2.100	1.649	1.421	1.377	1.080	1.030	0.758	0.683	0.556	0.500	0.375	0.312
	% variation explained by each root	20.62	16.70	10.50	8.25	7.10	6.88	5.40	5.15	3.79	3.41	2.78	2.50	1.88	1.56
	Cumulative variation	20.62	37.32	47.82	56.07	63.17	70.05	75.45	80.6	84.39	87.8	90.58	93.08	94.96	96.52

Table 15: Distribution of genotypes in different clusters

Sl. No	Cluster No.	Number of genotype	Genotypes
1	I	13	Tiswadi-4, Tiswadi-5, Sweet Round, Kuddi-1, Kuddi-2, Sattari-5, Valpoi-1, Valpoi-3, Valpoi-5, Tudal-3 Tudal-5 Kholker-1 Mayem-1
2	II	9	Dhave-1, Dhave-2, Dhave-3, Karapur-1, Karapur-2, Ganje-1, Ganje-1-2, Ganje-2, Ashley-1
3	III	15	Loutolim-3, Loutolim-4, Tiswadi-2, Tiswadi-7, Agonda-2, Agonda-5, Sattari-1, Sattari-3, Sattari-4, Valpoi-2, Valpoi-4, Tudal-1, Tudal-4, Kholla-2, Kholla-3
4	IV	6	Tiswadi-3, Balli-1, Bardez-9, Agonda-1, KN 2/98, Valpoi-7
5	V	10	Bardez-6, Pernem-4, Zorinth-1, Zorinth-2, Loutolim-1, Sarvan-1, SB-2, Sattari-30/4, Silva-1/55, Sanguem-1
6	VI	4	Red Local, Goa-1 (check), Vengurla-4 (check), Sattari Dwarf

Table 16. Cluster means for different characters

Sl. No.	Characters	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI
1	Tree height (m)	3.92	5.29	4.41	4.73	4.16	4.32
2	Canopy spread-NS (m)	5.09	6.58	5.18	5.7	5.3	6.1
3	Canopy spread-EW (m)	5.25	6.76	5.02	5.7	5.47	5.96
4	Number of shoots/m^2 canopy	17.78	17.42	18.92	20.34	20.48	22.04
5	Number of leaves/twig	13.95	15.54	14.61	15.52	13.61	16.25
6	Leaf area/twig (cm^2)	1230.67	1809.01	1589.68	1691.63	1309.54	1441.62
7	Flowering shoots/m^2 canopy	10.94	11.86	9.96	14.55	10.77	16.49
8	Flowering intensity (%)	68.5	76.25	58.95	77.91	57.2	81.69
9	Flowering duration	73.08	87.22	94.04	91.06	99.03	82.17
10	Inflorescence length	16.5	15.85	19.65	17.61	19.83	20.16
11	Sex ratio	0.29	0.3	0.26	0.33	0.19	0.33
12	Nuts/panicle	2.1	1.99	1.9	2.55	2.47	3.95
13	Nut weight (g)	7.48	7.99	9.52	10.62	7.94	6.41
14	Shell thickness (cm)	0.33	0.32	0.36	0.4	0.31	0.28
15	Kernel weight (g)	2.3	2.44	2.86	3.07	2.34	2.05
16	Shelling percent	30.78	30.64	30.11	29.27	28.35	31.92
17	Apple weight (g)	84.94	93.02	102.38	107.56	82.54	67.5
18	A:N ratio	11.48	11.58	11.1	10.26	10.8	11.02
19	Juice content (%)	71.19	70.18	69.33	71.56	69.54	70.43
20	Nut yield (kg/tree)	4.54	5.42	4.34	7.27	4.11	6.2

Table 17. Distances between and within cluster centroids

Clusters	I	II	III	IV	V	VI
I	3.468					
II	4.091	2.824				
III	3.364	4.046	3.416			
IV	4.898	3.736	3.970	3.605		
V	3.852	5.053	3.161	5.312	3.859	
VI	4.795	4.732	5.907	5.979	5.718	2.866

3.6 Hybridization programme in cashew .

High yielding varieties as Balli-2, Vengurla-4 and Ganje – 2 were used for crossing with bold nut accessions *viz.* Tiswadi –3, Valpoi - 7 and KN 2/ 98. Evaluation of F1 hybrids of these parental combinations is under progress.

Table 18. Growth of F1 hybrid seedlings of cashew during 2006-07

S No.	Hybrid Nomenclature	Parental combination	Height (cm)	Collar girth (cm)	Remark
1	Hybrid – 5 / 05	Goa – 1 (B2) X Tis –3	97.0	1.2	Vigorous
2	Hybrid – 14 / 05	Goa – 1 (B2) X Tis –3	59.0	1.5	
3	Hybrid – 11 / 05	Goa – 1 (B2) X KN 2/98	104.0	2.4	Vigorous
4	Hybrid – 12 / 05	Valpoi-7 X V – 4	78.0	1.6	
5	Hybrid - 13 / 05	GNJ – 2 X Goa – 1 (B2)	95.0	1.0	Vigorous
6	Hybrid - 21 / 05	Valpoi – 7 X Tis – 3	206.0	3.5	V. vigorous
7	Hybrid - 22 / 05	Goa – 1 (B2) X Valpoi – 2	105.0	2.2	Vigorous
8	Hybrid - 23 / 05	Goa – 1 (B2) X Valpoi – 2	64.0	1.4	
9	Hybrid - 27 / 05	V – 4 X Tis – 3	124.0	2.1	Vigorous
10	Hybrid - 29 / 05	Goa – 1 (B2) X V – 4	125.0	3.1	Vigorous
11	Hybrid - 30 / 05	Goa – 1 (B2) X V – 4	94.0	2.3	Vigorous
12	Hybrid - 31 / 05	Goa – 1 (B2) X V – 4	110.0	2.5	Vigorous

After 10 months from date of planting (June 2006), the hybrid seedlings of cashew showed differential vigour in terms of height , collar girth and number of leaves. Height of hybrid seedlings ranged between 59 cm (Hybrid 14 /05) and 206.0 cm (Hybrid 21 / 05), while the collar girth varied from 1.0 cm (Hybrid 13 / 05) to 3.5 cm (Hybrid 21 / 05). Hybrids 21, 12 came to flowring and fruiting. During the flowering season (Nov 2006 – Feb. 2007), 909 crosses of 11different parental combinations were made. Fruit set was initially observed in 116 crosses and finally 42 F_1 seeds were obtained.

3.7 New evaluation trials initiated

a) Evaluation of local bold nut genotypes : A new evaluation trial comprising of 10 bold nut local cashew genotypes is laid out in RBD with three replications during the season 2006. KN 2/98, Tiswadi-7, Kholla-2, Tudal-1, Tudal-3, Farmagudi-1, Ponda-1, Valpoi-2, Bardez-9, Mayem-1 and Tiswadi-3 were included in the trial along with Balli-2 and Vengurla-4 as standard checks. Six grafts of each accession have been planted at 7m X 7m spacing.

b) Introduction and evaluation of new cashew varieties developed at other cashew research stations/ centres: New cashew varieties viz Vengural-8 from RFRS, Vengurla; Dhana, Raghava, Priyanka from Cashew Research station (KAU), Madakkathara; Bhaskara from NRC for cashew, Puttur and Ullal-3 from Cashew Research Station Ullal (Karnataka) have been introduced during 2006 for evaluation under Goa conditions.

4. Molecular diversity analysis of cashew genotypes

Lee (1999) observed DNA markers as fundamental links between plant breeding and plant biology. It was felt that hither to, success of plant breeding was accomplished in the total absence of basic knowledge of plant biology. Still many important biological phenomena like heterosis, epistasis, host-pest interactions, response to abiotic stress, *etc*, very often used in plant breeding programmes, are described in abstract concepts. But there is a need to generate precise and firm data for complete understanding of genetic gains. Basic biology, therefore, will be the source for much new information about genomes, genes, pathways and interactions of direct relevance to crop improvement. In many instances, DNA markers will be the vital and fundamental link between plant biology and main stream plant breeding.

Assessment of genetic relationship among the genotypes in any cultivar is dependent on the understanding of the genetic diversity among the materials, employing various means. The number of loci identified per RAPD, unknown genomic location, difficulty in reproducibility *etc.* are the important limiting factors to detect the genetic diversity among the genotypes to be studied. However, ease, simplicity of the technique as well as scoring and other factors drive researchers into using RAPDs, especially in the crops of interest, if necessary background work related to genome analysis and consequent marker information is not available.

4.1 Diversity analysis through RAPD marker

Seventy three RAPD primers identified many alleles among the 57 genotypes. The allele size ranged from 0.3 – 3.6 Kb across primers and genotypes of cashew studied. A total of 193 amplicon profiles were available for comparison of the accessions, of which 147 were polymorphic. On an average 5.05 numbers of amplicons per primer could be scored, all of which were major bands. Polymorphic level per primer was 3.97.

All the cashew accessions were observed to be in between the dissimilarity coefficients, fully bootstrapped (1000), of 0.09 and 0.51 which indicated 49 per cent of similarity at molecular level among the cashew accessions studied. The lowest dissimilarity of 0.09 was observed between the genotypes Kudi-1 and Kudi-2 (Sl. nos. 17 and 18), while the highest dissimilarity coefficient of 0.51 was between the genotypes Sarvan-1 and Agond-2 (Sl. nos. 27 and 32).

The weighted neighbour-joining diversity tree (Figure 6) constructed based on the RAPD data indicated two broad clusters among the 57 cashew genotypes. The Cluster 1, the broad group, comprised of 35 genotypes, while the cluster 2 had 22 genotypes. The first cluster could further be divided into as many as 8 sub-groups, though with relatively lesser confidence, compared to cluster 2. But a pair-wise similarity was more apparent within this broad group and pinpointed

five pairs, comprising of genotype numbers 37 & 38 (Sattari 4 & 5); 40 & 41 (Ashley 1 & Sattari 30/4); 26 & 25 (Lautolim 3 & 4); 8 & 9 (Ganje 1 & Karapur 2); as well as 17 & 18 (Kuddi 1 & 2).

While the Cluster 2 comprised of 22 genotypes, within which, at least three sub groups (Sub clusters 2.1, 2.2 and 2.3) comprising of five, four and 13 genotypes in each, could be recognized. Sub cluster 2.1 included genotypes viz. Kholla-3, Kholker-1, Tudal-4, Valpoi-4 and Kholla-2 (Sl nos. 54, 55, 51, 46 and 53 respectively) while Sub cluster 2.2 had four genotypes viz. Bardez-6, Zorinth-1, Tiswadi-5 and Karapur-1 (Sl nos. 19, 22, 6 and 7 respectively). Similarly, Tudal-3&1, Tiwadi-4, Mayem-1,Agonda-5, Tiswadi-7, Valpoi-1, Kn 2/98, Sanguem-1, Valpoi-7, Valpoi-5, Agonda-2 and Tudal-5 (with Sl. nos. 50, 49,5, 56, 33, 30, 43, 34, 57, 47, 48, 32 and 52 respectively) and in some instances, close relationship was implied (for example, genotypes 49 and 50 i.e., Tudal 1 & 3). However, a note of caution is to be kept in mind here, as the differences observed between and within the clusters is extremely low (implied by the 0 to 0.1 bar below the tree). However, the genotypes, Sarvan-1 (Sl. no. 27) of Sub cluster 1.3 and Agond-2 (Sl. no. 32) of sub cluster 2.3 were observed to be the most distant genotypes. This analysis pragmatically aids in the precise selection of parental combinations in classical breeding programmes.

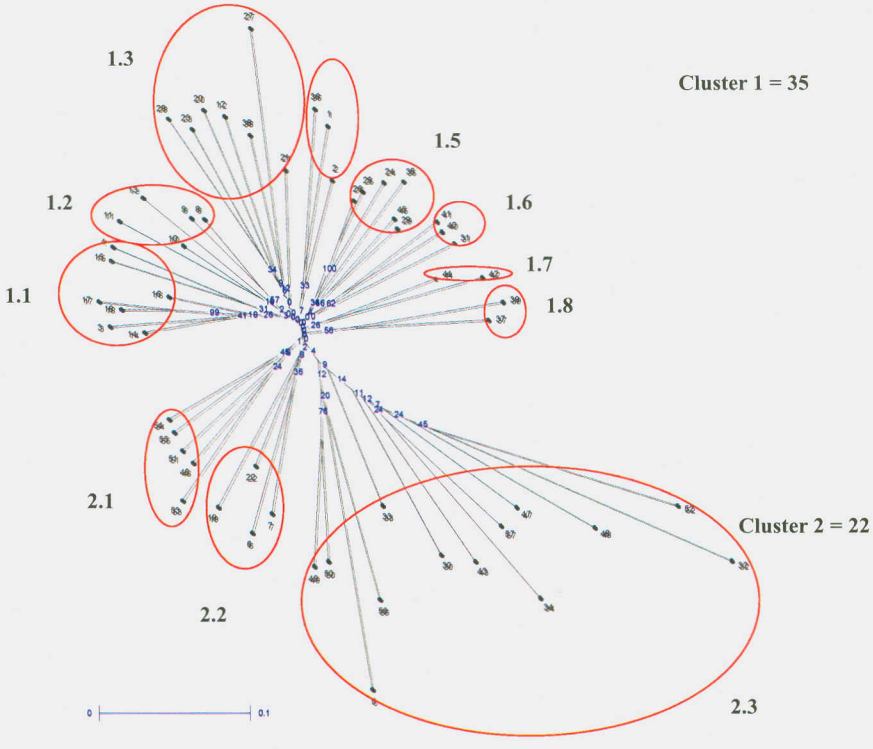


Figure 6. Weighted neighbour joining tree of 57 cashew genotypes based on RAPD data

4.2 Phenotypic inventory in the background of molecular diversity

Grouping of genotypes into six morphometric clusters and two molecular data based clusters substantiates the fact that morphometric variables are always under the influence of environment and thus often mislead in understanding the actual divergence and there lies, the significance of diversity at molecular level. On the other hand, it would be a great deal of task to actually interpret the molecular data in the total absence of morphometric data. It is therefore, felt that consideration of molecular data supplemented duly by morphological background would be precise practical solution in making the meaningful breeding programmes, since the QTLs (Quantitative Trait Loci) accounted ultimately are through morphological expressions. Although, classical phenotype features are extremely useful, the efficiency of selection may be reduced by age, developmental stage and by environmental effects on measured traits. Any breeding programme will require more reliable information about level of genetic diversity by both approaches (phenotypic and molecular) for practical significance.

In the present studies also, the partial consensus between the morphometric and molecular data is very evident. Such an information is presented in Table 19, which clearly relates to the necessity of precise understanding of genetic diversity. For instance, the cashew genotypes *viz.*, Red Local (No. 12), Goa-1 (No. 15), Vengurla-4 (No. 16) and Sattari Dwarf (No. 38) of cluster VI in morphometric grouping were also separately clustered in major cluster I of the molecular diversity tree, however scattered in sub-cluster 1.1 to 1.3 (Table 19). Similarly, the genotypes Tiswadi-5 (No. 6), Tudal-3 (No. 50), Tudal-4 (No. 5), Kholker-1 (No. 55), Mayem-1 (No. 56), Valpoi-1 (No. 43), Valpoi-5 (No. 47) and Tudal-5 (No. 52) of morphometric cluster I were separately grouped in cluster II of weighted neighbour-joining diversity tree (Fig. 6 and Table 15), which were inturn scattered in sub-clusters 2.1 to 2.3. This kind of partial agreement of diversity studies are also reported by Samal *et al.* (2003) in Indian cashew.

Table 19. Partial consensus in diversity approaches with respect to cluster components

Weighted neighbour joining tree cluster	Composition of sub-groups having consensus with morphometric groups		
	I	II	VI
Cluster I			
Sub-cluster 1.1	17, 18	3	16
Sub-cluster 1.2	13	8, 9, 10, 11	15
Sub-cluster 1.3		21, 28	12, 38
Sub-cluster 1.4		1, 2	
Cluster II			
Sub-cluster 2.1	55		
Sub-cluster 2.2	6		
Sub-cluster 2.3	50, 5, 56, 43, 47, 52		

5. Physiological response of cashew to *in situ* moisture conservation

In the name of "wasteland crop", for a long time, cashew remained away from the attention of plant physiologists till Subbaiah (1983 and 1984) and Balasimha (1991) attempted to study the photosynthetic characteristics in this crop. Subsequently, research on its response to various crop management practices including irrigation is being attempted in different cashew growing countries across the globe. Yet, there is a limited information on location and methodology specific research pertinent to cashew. Research efforts are being continued in different cashew growing states in India also. Goa, though receives high rainfall (2888 - 3100 mm) annually, has an unimodal pattern of rainfall almost confined to short period of four months from June – September. Considering the abundant rainfall, subsequent long dry spell during critical period of flowering and fruiting and hilly terrains of cashew plantations in Goa, a study was undertaken during 2004-05 and 2005-06, to assess the physiological response of cashew Cv. Goa-1 to ***in situ*** soil moisture conservation measures. The grafts, planted at a spacing of 6m x 6m in June 2001, were of four and half year's age at the start of this study. Five treatments of *in situ* moisture conservation measures were imposed, at the time of planting the grafts in 2001, the detailed specifications of which are given below.

Treatments	Specifications
T_1: Continuous Contour Trench + *Glyricidia maculata* (CCT+VB)	The trenches with top width of 45 cm, bottom width of 30 cm and depth of 45 cm were dug continuously along the contour line having vertical interval of 1m. *G. maculata* was planted at 50 cm spacing in a line on the down-stream side of each trench bund to serve as live vegetative barrier.
T_2: Staggered Contour Trench + *G. maculata* (SCT+VB)	The trenches of the length 2m, top width 45 cm, bottom width 30 cm and depth of 45 cm were prepared in a staggered manner of an aligned contour at a vertical interval of 1m. *G. maculata* was planted at 50 cm spacing on the down-stream side of each trench bund to serve as live vegetative barrier.

T_3: Crescent Shape Trench + *G. maculata* (CST+VB)	The trenches of the length 2m, top width 45 cm, bottom width 30 cm and depth of 45 cm were prepared in crescent shape on the upstream side of each graft. *G. maculata* was planted at 50 cm spacing on the down-stream side of each trench bund to serve as live vegetative barrier.
T_4: *G. maculata* alone (VB)	Only *G. maculata* was planted at 50 cm spacing along the contour line at 1m vertical interval to serve as live vegetative barrier.
T_5: Control	With out any *in situ* moisture conservation measure and no live vegetative barrier.

Soil moisture status under various *in situ* moisture conservation measures was monitored twice during the dry spell, once in December and again in April at two depths (30 cm and 60-90 cm), for each year. The mean soil moisture status is illustrated in Figure 7. The soil moisture at 30cm depth varied from 21.71 to 26.89 per cent in control and T_1 (CCT+VB) respectively, during December, while

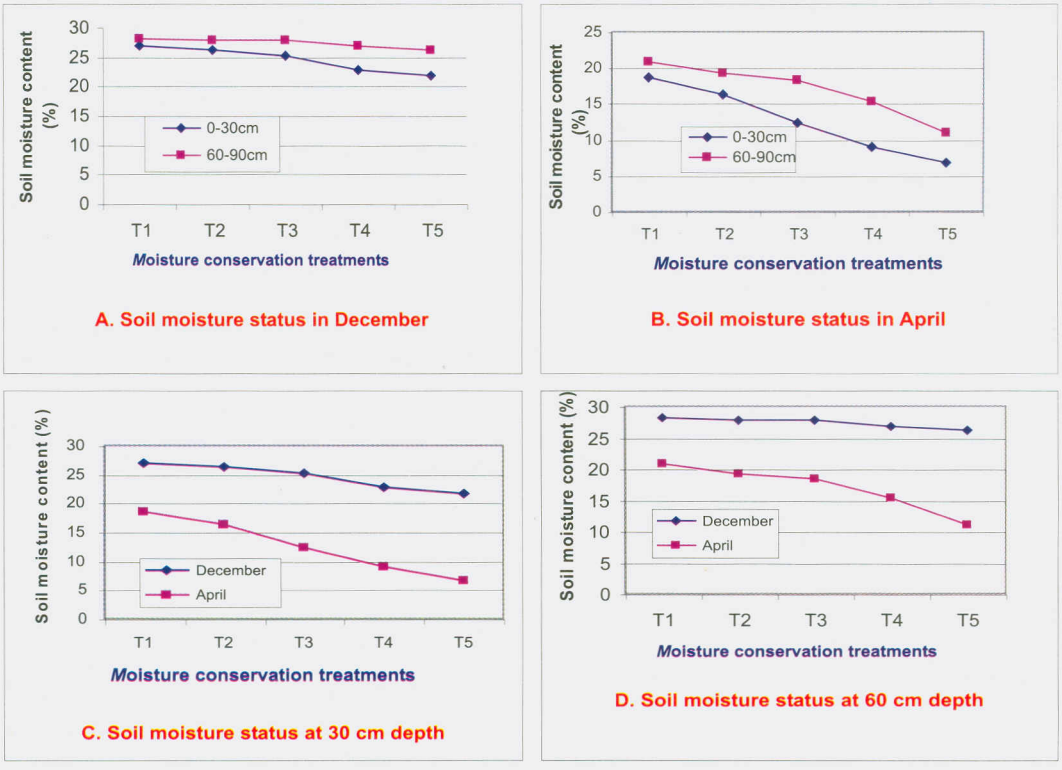


Figure 7. Soil moisture status in December and April at 30 and 60-90 cm depth under different *in situ* moisture conservation measures

the corresponding values at 60-90 cm depth were 26.16 and 28.15 per cent. Subsequently during April, soil moisture at 30 cm depth varied from 6.65 per cent (control plot) to 18.56 per cent in T_1 (CCT+VB), whereas the corresponding values at 60-90 cm depth were 10.97 and 20.78 per cent, respectively.

Chlorophyll content, Relative water content (RWC), Specific leaf weight (SLW) and Gas exchange parameters, under the influence of varied soil moisture regime, were recorded three times during the dry spell, in December, February and subsequently in April, for two consecutive years, the means of which were used for data analysis. Data was subjected to statistical analysis for "Factorial Randomized Block Design" (Gomez and Gomez, 1984). There were two factors *i.e., in situ* moisture conservation treatments at five levels and months at three levels. Observations on Number of nuts per panicle, Nut weight, Nut yield per tree, Shelling per cent and Apple weight were recorded during the season for two years. Nut yield per hectare was extrapolated based on tree spacing and nut yield per tree and data were analyzed as simple RBD with five *in situ* moisture conservation treatments each replicated four times.

5.1 Influence of *in situ* moisture conservation on physiological parameters

5.1.1 Chlorophyll content :

The treatments significantly influenced the total chlorophyll content in cashew leaves (Table 20), which was minimum in T_2 (SCT+VB) while, it was 1.271 mg/g in T_5 (Control). During the period from December to April there was increase in total chlorophyll content in cashew leaves from 0.747 mg/g to 1.581 mg/g, revealing the inverse proportion to the soil moisture status, unlike other parameters. Total chlorophyll content was the highest (1.271 mg/g fresh weight of leaf) in T_5 (control), where soil moisture was the lowest and it was minimum in T_2 (SCT+VB). Cashew leaves had the total chlorophyll content in the range of 0.568 – 0.891 mg/g leaf fresh weight in December. Hou *et al.* (1987) opined that drought tolerance was associated with increased chlorophyll content. This appears to be true in case of cashew. Further, Yadav *et al.* (1991) suggested that chlorophyll stability index could be used for rapid screening of germplasm for drought tolerance.

However, Latha and Abdul Salam(2003) reported a decrease in total chlorophyll content in leaves of cashew seedlings subjected to moisture stress which is contrary to the results of our study. Similarly, Mososjidek *et al.* (1991) observed 8-17 per cent decrease in chlorophyll proteins in Ps-II core of drought and light stressed plants.

Table 20. Influence of *in situ* moisture conservation measures on relative water content, specific leaf weight and total chlorophyll content

Treatment	Relative water content (%)				Specific leaf weight (g)				Total chlorophyll content (mg/g of fresh weight)			
	Dec.	Feb.	April	Mean	Dec.	Feb.	April	Mean	Dec.	Feb.	April	Mean
T_1 (CCT+VB)	90.22	88.08	85.23	**87.84**	18.17	16.47	15.88	**16.84**	0.652	1.147	1.436	**1.078**
T_2 (SCT+VB)	90.25	86.42	84.39	**87.02**	18.59	16.29	14.46	**16.45**	0.568	0.382	1.527	**0.826**
T_3 CST+VB)	89.67	85.31	76.34	**83.78**	16.66	15.51	13.73	**15.30**	0.891	1.097	1.492	**1.160**
T_4 (Only VB)	89.65	80.78	71.07	**80.50**	15.35	14.45	13.33	**14.38**	0.891	1.060	1.662	**1.205**
T_5 (Control)	88.79	84.39	72.76	**81.98**	15.42	14.48	7.54	**12.48**	0.735	1.290	1.788	**1.271**
Mean	**89.72**	**85.00**	**77.96**	**84.22**	**16.84**	**15.44**	**12.99**	**15.09**	**0.747**	**0.995**	**1.581**	**1.108**
	Treat	Month	T x M		Treat	Month	T x M		Treat	Month	T x M	
SEm±	0.307	0.237	0.531		0.531	0.411	0.919		0.086	0.067	0.149	
CD (P? 0.05)	0.888	0.688	1.538		1.537	1.191	2.663		0.250	0.193	NS	

CCT = Continuous contour trench; VB = Vegetative Barrier (*Glyricidia maculata*); SCT = Staggered contour trench; CST = Crescent shaped trench

5.1.2 Relative water content (RWC):

Significant differences in RWC were observed in cashew under the influence of different *in situ* moisture conservation measures in different months and also due to interaction (Table 20). RWC was significantly the highest (87.84%) in treatment T_1 (CCT+VB), followed by 87.02 per cent in T_2 (SCT + VB) which were at par. RWC decreased from 89.72 per cent in December to 77.96 per cent in April. Due to interaction effect of T x M, RWC significantly varied from 71.07 per cent during April in T_4 (VB) to a maximum of 90.25 per cent in T_1 (CCT + VB) during December. This variation is observed to have been influenced by the soil moisture status determined by the various *in situ* moisture conservation measures. However, within December, treatments did not influence RWC significantly. This can be attributed to fairly higher moisture status (26.16 – 28.15%) at 60-90 cm depth. However, RWC gradually decreased with advancement of time at varied levels under different *in situ* moisture conservation treatments. This degree of reduction was the highest (80.50%) in case of T_4 (only VB) and it was least (87.84) in T_1 (CCT+VB). Latha and Abdul Salam (2003) have also made similar reports about reduction in RWC in cashew in relation to soil moisture regime.

5.1.3 Specific leaf weight (SLW):

Treatments differed significantly with respect to specific leaf weight with a maximum of 16.84 in T_1 (CCT+VB) followed by 16.45 and 15.30 g in T_2 (SCT+VB) and T_3 (CST+VB) which were at par, against the lowest SLW of 12.48 in control plot (Table 20). SLW was maximum (16.82 g) during December while it was 12.99 g in April. Due to T x M interaction, SLW significantly varied from 7.54g in the trees in control plot, while it was the highest (18.59g) in T_2 (SCT + VB) which was on par with T_1 (CCT+VB) and T_3 (CST+VB). SLW also showed gradual reduction during December to April. But, here also degree of reduction was more pronounced (12.48g) in T_4 (only VB) than that in other treatments and control. SLW lesser than control, is a trend non proportional to soil moisture. This might be probably due to the competition for soil moisture exerted by Glyricidia, the only vegetative barrier component in the treatment 4(only VB). However, vegetative barrier component has been effective compared to control, in reducing run off and soil erosion (Manivannan *et al.*, 2003), though not better compared to T_1 and T_2.

5.1.4 Gas exchange parameters:

Photosynthesis provides a raw material and energy required for growth and all other biochemical processes. It is a light dependent process. Illumination of each green leaf in the canopy and the manner in which each leaf is illuminated could determine net photosynthesis, growth and yield (Kreidman and Smart, 1971).

Table 21. Influence of *in situ* moisture conservation measures on gas exchange parameters

Treatment	Photosynthetic rate (A) (µmole $CO_2/m^2/s$)				Stomatal conductance (moles/m^2/s)				Transpiration rate (mmoles $H_2O/ m^2/s$)			
	Dec.	Feb.	April	Mean	Dec.	Feb.	April	Mean	Dec.	Feb.	April	Mean
T_1 (CCT+VB)	12.19	13.71	16.88	**14.26**	0.453	0.52	0.657	**0.543**	8.44	9.71	11.25	**9.80**
T_2 (SCT+VB)	11.78	13.94	15.52	**13.75**	0.435	0.523	0.633	**0.531**	8.20	9.45	11.27	**9.64**
T_3 CST+VB)	12.15	13.16	15.15	**13.49**	0.537	0.487	0.53	**0.518**	9.48	8.73	10.13	**9.45**
T_4 (Only VB)	11.50	11.88	11.86	**11.75**	0.423	0.437	0.377	**0.412**	8.16	7.74	8.37	**8.09**
T_5 (Control)	11.95	10.69	10.71	**11.12**	0.383	0.43	0.337	**0.383**	8.12	7.42	7.31	**7.62**
Mean	**11.92**	**12.68**	**14.02**	**12.87**	**0.446**	**0.479**	**0.507**	**0.477**	**8.48**	**8.48**	**8.48**	**8.92**
	Treat	Month	T x M		Treat	Month	T x M		Treat	Month	T x M	
SEm±	0.096	0.073	0.164		0.021	0.016	0.037		0.211	0.163	0.365	
CD (P? 0.05)	0.274	0.212	0.475		0.057	0.045	0.100		0.611	0.473	1.058	

Range of PFD in December = 975-1025, February = 1130- 1170 and April = 1200 – 1325 µmol photons/m^2/s.
CCT = Continuous contour trench; VB = Vegetative Barrier (*Glyricidia maculata*);
SCT = Staggered contour trench; CST = Crescent shaped trench

In general, it was observed that the photosynthetic characteristics namely photosynthetic rate (A), stomatal conductance (gs) and transpiration rate (E) were significantly influenced by the *in situ* soil moisture conservation measures in cashew, months and their interaction (Table 21). By and large the transpiration rate and stomatal conductance increased with increase in photosynthetic rate. Net photosynthetic rate was maximum (14.26 µmol $CO_2/m^2/s$) in cashew trees in T_1 (CCT + VB), while it was minimum (11.12 µmol $CO_2/m^2/s$) in T_5 (control) plot. Across the different months, photosynthetic rate was minimum in December and maximum in April (14.02 µmol $CO_2/m^2/s$). Due to interaction of T x M the A varied from 10.71 to 16.88 µ mol $CO_2/m^2/s$ in T_1 (CCT+VB).

The cashew trees showed significantly higher stomatal conductance (g_s) of 0.543 moles/m2/s compared to the minimum of it (0.313 moles/m^2/s) in T_5 (Control plot) as indicated in Table 21. Between months, stomatal conductance was observed to be more in April (0.507 moles/m^2/s) whereas it was 0.446 moles/m^2/s in December. Stomatal conductance varied from 0.337 moles/m^2/s in T_5 (control) trees to 0.537 moles/m^2/s in T_2 (SCT+VB) due to interaction effect.

Variations in transpiration rate (E) in cashew trees were significantly influenced by the treatments, months and their interaction (Table 21). A maximum of 9.8 m moles $H_2O/m^2/s$ was recorded in cashew trees in T_1 (CCT+VB) followed by T_2 (SCT+VB) and T_3 which were at par, as compared to 7.62 m moles/$H_2O/m^2/s$ in T_5 (control) trees. Due to interaction, transpiration rate varied from 7.31 m moles $H_2O/m^2/s$ in T_5 (control) in April to 11.25 m moles $H_2O/m^2/s$ in T_1 (CCT+VB) in April.

A/g_s and A/E ratios indicate the water use efficiency. In the present study, both were not significantly influenced by the different *in situ* soil moisture conservation treatments, months and their interaction. However, with respect to intrinsic water use efficiency, the highest ratio (29.68) was observed in control plot followed by 28.94 in T_4 (Only VB) compared to all other treatments.

Similar results have been reported by Yadukumar and Balasimha (2006) and Bezerra *et al.* (2007). Further, variations in photosynthetic rates due to treatments were observed to be relative not only to the soil moisture but even to the total irradiance during the period of study. This was evident in the photosynthetic rate observed in December month, during which the photon flux density (PFD) was in the range of 985 – 1025 µmol photons/m^2/s. This is below than the light saturation requirements of cashew (Balasimha, 1991, Schaper and Chako, 1993). Steady state chlorophyll fluorescence also showed a high dependency on stomatal conductance (Medrano *et al.*, 2002)

Paralally, the stomatal conductance and transpiration rate were proportional to the photosynthetic

rate. It was also reported that the reduction in photosynthetic rate was attributed to concomitant reduction in stomatal conductance of leaves with decreased soil moisture (Lakso, 1985) and also opined that the maintenance of photosynthesis by leaves under water stress is the indication of higher WUE in plants. In the present study, the gas exchange parameters such as photosynthetic rate, stomatal conductance, and transpiration rate appeared to have influenced yield components and nut yield per tree. Stomata influence the rate of CO_2 fixation in leaf mesophyll cells. Stomatal aperture is a compromise between the needs to conserve water and to maintain the rate of assimilation at a level dependent on the intrinsic capacity of the leaf mesophyll tissue to fix carbon (Wong *et al.*, 1979).

5.2 Response of yield and yield components to *in situ* moisture conservation

The results presented Table 22 indicated that Number of nuts per panicle was observed to vary significantly from 2.12 in T_4(only VB) to 3.99 in T_2 (SCT+VB) followed by T_3 (CST+VB) and T_1 (CCT+VB) which were at par. compared to 2.96 in T_5(control). The highest mean nut weight of 8.22g was recorded in cashew trees in T_1 (CCT+VB) followed by 7.88 and 7.83g in T_3 (CST+VB) and T_1 (CCT+VB), respectively which were statistically at par. The lowest nut weight (7.03g) was in T_5 (control) which was on par with T_4 (only VB). The shelling percentage was maximum(31.41%) in T_5 which was observed to be on par with 30.06per cent in T_3 and it was minimum of 28.11 in T_4 which was on par with T_2.

Apple weight in cashew trees was also significantly varied from 84.0g to 68.1g in T_1 and T_4, respectively.

It was observed that *in situ* soil moisture conservation measures significantly increased nut yield per tree from 1.58 and 2.54 kg (control) to 2.97 and 4.41 kg in T_3(CST+VB), which were on par with T_1 and T_2, during 2005 and 2006, respectively. This resulted in per hectare yield level of 8.23 and 12.22 q during 2005 and 2006, respectively in T_3 plot as against the nut yield of 4.37 and 7.03 q/ha in T_5 in control. There was an increase of 46.8 to 65.08 per cent in nut yield due to T_3 over control plot during 2005 and 2006, respectively. Such increase in nut yield of more than 100 per cent was also reported by Ghosh (1999), when rain water harvesting methods (circular trenching, 9" width 9" depth, 4 feet away around the tree trunk and mulching with dry cashew leaves) were adopted in West Bengal. This can be attributed to availability of soil moisture in the deeper horizon and its favourable effect during the critical period of flowering and fruit development. Yadukumar (2003) also estimated an increase of 25-30 per cent in nut yield by adopting soil and water conservation methods in cashew in Karnataka. It is to be noted here that the yield attributing traits such as nuts per panicle, nut weight and shelling percentage were influenced by the *in situ* soil moisture conservation

measures in varied manner. Overall influence on photosynthetic characteristics at varied levels under different soil moisture conservation measures appeared to have been reflected in nut yield. These studies showed the benefit of the *in situ* moisture conservation under lateritic soils of Goa. Studies indicated that although, cashew has inherent drought tolerance and is thus considered a hardy species, its response to moisture availability during critical stages is tremendous.

Table 22. Impact of *in situ* soil moisture conservation measures on yield components and nut yield in cashew variety Goa-1

Treatments	Nuts per panicle	Nut weight (g)	Shelling (%)	Apple weight (g)	Nut yield (Kg/tree)		Nut yield (q/ha)	
					2005	2006	2005	2006
T_1 (CCT+VB)	3.30	8.22	29.77	83.05	2.80	3.82	7.75	10.58
T_2 (SCT+VB)	3.99	7.83	28.92	84.00	2.97	3.63	8.22	10.05
T_3 (CST+VB)	3.31	7.88	30.06	75.33	2.97	4.41	8.23	12.22
T_4 (Only VB)	2.12	7.24	28.11	68.10	1.79	2.76	4.96	7.64
T_5 (Control)	2.96	7.03	31.41	72.66	1.58	2.54	4.37	7.03
SEm ±	0.156	0.242	0.504	3.579	0.293	0.334		
CD (P = 0.05)	0.469	0.727	1.512	10.737	0.879	1.003		

CCT = Continuous contour trench; VB = Vegetative Barrier (*G. maculata*);
SCT = Staggered contour trench; CST = Crescent shaped trench

6. Intercropping in cashew

During the initial period of cashew plantations, several intercrops can be taken in the inter-space up to first three-four years. Considering the terrain of the land under agro-climatic conditions of Goa, high value crops such as turmeric, ginger, groundnut, vegetables like bhendi, cucumber and fruit crops like pine-apple, papaya can be taken up. This practice not only provides considerable income from intercrops, even will have complementary beneficial effects on cashew grafts during the initial period of growth and development, besides providing employment opportunities, during the gestation period.

Prabha & Pratibha Turmeric Varieties inter-cropped in cashew

Varada Variety of Ginger: A profitable inter-crop in cashew

It has been observed that turmeric varieties such as Sudarshan, Prabha, Pratibha, Kedaram, Alleppey and RCT-1, and ginger variety- Varada can be successfully cultivated as intercrops in cashew plantations during gestation period, with rhizome yield of 18 – 24.5 tonnes per hectare with one protective irrigation during October or November in case of long duration varieties. Similarly, Confectionary type of groundnut varieties like Asha and TPG-40 can also be successfully cultivated as intercrop in cashew plantations for considerable income.

7. Concluding summary

After realization of the international trade and the importance of the actual place where cashew was originally introduced through seeds, research on cashew was initiated in Goa about three decades ago in 1976 at ICAR Research Complex for Goa, when farmers were ignorant of the real economic potential of this crop. The research efforts in the last three decades and the subsequent salient achievements are summarized here under.

7.1 First phase of cashew research in Goa.

It is evident in the first decade that the initial emphasis in this research programme was mainly on identifying the naturally available pre potent mother trees from among the seedling progenies for further commercial exploitation and introducing the promising varieties from other places. And there was a need for a viable propagation technique for large scale multiplication of selected promising mother trees. Fourteen genotypes (5 from RFRS, Vengurla and 9 from CPCRI, Shantigodu were introduced and Goa 11/6 was identified as a promising local genotype to overcome the problem of TMB. Soft wood grafting techniques for Vengurla-1 and 4 was standardized with 60 – 92 per cent success during June – September.

7.2 Second phase of cashew research in Goa

From among the local germplasm collection of 42 accessions, the genotypes Balli-1 and Balli-2 showed most promising performance. Subsequently, an

evaluation trial of 11 local accessions including Ball-1 and 2 along with Vengurla -4 variety was initiated in 1994 for long term evaluation. Vengurla-4 was the most promising introduction for commercial cultivation in Goa , besides HB-1600, HB-1598 from Kerala, which recorded medium-smaller nut size.

For large scale multiplication of grafts, a scion bank of Vengurla-4 variety was established and further, top-working technique was also standardized for converting unthrifty trees with high yielding varieties.

7.3 Third phase of cashew research in Goa

- Local survey was further intensified under an ad-hoc project launched during 1996-2001, with the objective of collection and establishment of cashew germplasm bank. Ninety mother trees were identified based on three basic traits – nut yield, nut size and apple size, in different zones all over the state and the clonal germplasm bank of these accessions was established in Institute's Farm.
- "Metroglyph Analysis" based on average nut weight and nut yield per tree, scattered all the accessions in to 15 clusters (Fig.1). However, there was a negative trend line, in general, among the accessions for the above two characters. Two accessions namely Valpoi –5 (No 70) and Bardez – 9 (No. 6) were the solitary clusters to form extreme groups (Groups I and XV). These represented the distant genetic relationship in respect of mean weight of nuts and nut yield per tree. Other groups namely XII, XIII and XIV also consisted of only one accession each namely Tiswadi-3 (No.42), Tudal – 4 (No.21) and Valpoi – 4 (No.69) respectively, which were distinctly away from other clusters in terms of nut weight and nut yield per tree, but possessed higher total index scores in the range of 15 - 16. The other promising genotypes namely KN 2/98, Tiswadi-4 and 7, Valpoi-3 and 7 also emerged from this germplasm collection
- The accession Balli-2, identified from Balli village in Quepem zone, with promising performance of higher nut yield (8-9 kg/tree) coupled with bold nut size (7.8 g) and higher shelling percentage (29 –30 %) of exportable grade kernels (w 210- W240), bigger and juicy apples (70 g) was released in 1999 under the name **"Goa-1"** for commercial cultivation in the state of Goa.
- Evaluation results of local accessions revealed the potential of Tiswadi-3, Ganje-1 and 2, Balli-1, Karapur-1 and 2 as the promising genotypes. Further, "Nucleus scion bank" of Tiswadi-3 was established by *in situ* soft wood grafting. A core collection of 67 cashew germplasm was maintained

- Considering the nut yield performance (10.02 kg/tree) during the last 10 years and its nut (9.2 - 10.6 g) and apple (100.5 – 110 g) characteristics, a proposal for releasing the accession Tiswadi-3 as a commercial variety for cultivation in the state of Goa under the name **Goa-2** was approved in the in the AICRP Biennial workshop on cashew held at ICAR Research Complex for Goa during 22-24 November 2007. Bold nuts yield jumbo sized kernels with exportable grade of W180 – W210 counts.
- The traits, number of nuts per panicle, sex ratio, nut weight and number of flowering shoots per m^2 canopy showed higher genetic advance over mean of 59.53, 46.53, 41.87 and 38.35 per cent, respectively coupled with higher heritability, thereby indicating their importance in the selection. The selection based on these characters will bring about the enhancement in the genetic strength of the genotypes.
- The investigations on correlation studies in cashew genotypes of Goa revealed the importance of growth (tree height, canopy spread, number of leaves per twig and total leaf area per twig), flowering (number of flowering shoots per m^2 canopy and flowering intensity) and yield related characters (Nut weight and number of nuts per panicle) as selection criteria for improvement of nut yield in cashew genotypes.
- Principal component analysis (PCA) identified first 8 principal components which accounted for about 80.2 per cent of variability. Based on the loading of the eigene vectors for each character (variable) within each principal component, PC1 was identified as nut factor accountable for 20.62 per cent variability. Similarly, flowering factor (PC2), apple factor (PC3) and growth and yield factor (PC4) contributing 16.70, 10.50, and 8.25 per cent variability, respectively were identified.
- Further, the PCA grouped all cashew genotypes into six clusters. Tiswadi -3, Balli -1, Bandez-9, Agonda-1, KN -2/98 and Valpoi-7, were the conspicuously distinct genotypes compared to others. The clustering pattern of the genotypes probably reflected the genetic history of the genotypes. Thus, the distinct genotypes with potential genetic history for desired traits have been identified, which could be either useful in planning subsequent breeding programmes or could themselves be the evolved potential new varieties for cultivation on commercial scale.
- In hybridization programme, high yielding varieties as Balli-2, Vengurla-4 and Ganje – 2 were used for crossing with bold nut

accessions *viz.* Tiswadi –3, Valpoi - 7 and KN 2/98. Evaluation of F1 hybrids of these parental combinations is under progress.

- Molecular diversity studies constructed based on the RAPD data indicated two broad clusters among the 57 cashew genotypes. The Cluster 1, the broad group, comprised of 35 genotypes, while the cluster 2 had 22 genotypes, both of which in turn comprised of several sub-clusters.
- Grouping of genotypes into six morphometric clusters and two molecular based clusters substantiates the fact that morphometric variables are always under the influence of environment and thus often mislead in understanding the actual divergence and there lies, the significance of diversity at molecular level. In the present studies, the partial consensus between the morphometric and molecular data is very evident. This helps in selection of correct parental combinations in hybridization programmes depending on the breeding objectives.
- Overall influence on photosynthetic characteristics at varied levels under different soil moisture conservation measures appeared to have been reflected in nut yield. The studies showed the benefit of the *in situ* moisture conservation (CCT+VB / SCT+VB CST+VB) under lateritic soils of Goa and indicated that although, cashew has inherent drought tolerance and is thus considered a hardy species, its response to moisture availability during critical stages could be tremendous.
- Studies indicated that turmeric varieties such as Sudarshan, Prabha, Pratibha, Kedaram, Alleppey and RCT-1, and ginger variety- Varada can be successfully cultivated as intercrops in cashew plantations during gestation period, with rhizome yield of 18 – 24.5 tonnes per hectare with one protective irrigation during October or November in case of long duration varieties.

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