TROPICAL AGRICULTURE | 9 |

CASHEW AS AN AGROFORESTRY CROP

Prospects and Potentials

Rüdiger Behrens

Margraf Verlag

This study examines the world market situation for cashew nuts, cashew kernels and cashew nut shell liquid (CNSL).

The cashew nut production has diversified since the 1970s: India, Mozambique and Tanzania shared 95 % of the world market. In the 1990s Brazil and India are main producers, followed by Mozambique, Vietnam and Indonesia, as important newcomers as well as several other countries.

A long debate on pollination of cashew should be closed – it is clear from the literature reviewed in this study that cashew flowers are pollinated by insects.

The influence of soils and climate has been studied in detail. Cashew is suitable for erosion control and soil improvement. Major pests and diseases are shortly described – potential hazards to production should be considered when planning a cashew development program.

The author has 20 years working experience with cashew in several African countries. He started his career in Northern Cameroon. Thereafter he was chief technical adviser in a cashew nut project of the forest department in Senegal and extension adviser in the Tanzanian cashew and coconut tree crops project. During this period he visited cashew growing areas in other African and several Asian countries. He believes that cashew is an ideal crop for smallholder farmers in many developing countries with a good potential for the future.

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DEDICATION

DEDICATED TO MY LATE PARENTS

HANS and GERDA BEHRENS

WHO BROUGHT ME UP WITH LOVE

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ABSTRACT

The study examines the world market situation for cashew nuts, cashew kernels and cashew nut shell liquid (CNSL). The cashew nut production has diversified since the 1970s: India, Mozambique and Tanzania shared 95% of the world market. In the 1990s Brazil and India are main producers, followed by Mozambique and Vietnam and Indonesia, as important newcomers as well as several other countries. Due to drought and pest and disease incidence in major producing countries the production is highly erratic. Highest production was achieved in 1993 when 150 000 t kernels were produced. The market could absorb this amount, showing a big elasticity. CNSL is a natural phenol, currently low priced compared to technical phenols. Market perspectives are good. Cashew nut processing will probably be done in smaller units easy to manage and to supervise. Technology development might open new ways of cashew shelling, deep freezing is one possible way to avoid CNSL-contamination of the kernel during shelling. A long debate on pollination of cashew should be closed - it is clear from this study that cashew are pollinated by insects. This conclusion derives from the sticky nature of the pollen and trials conducted by a number of researchers cited in this study. The influence of soils and climate has been studied in details. Conditions with <800 mm rainfall and soils with <1,5 m depth do not allow to reach full yield potential. Spacing of cashew trees depends on farming system and planting material used. Young cashew trees must be protected from livestock and wild animals - the best means are cheap local devices. Planting in widely spaced hedges (minimum: 5 m x 20 m) is favoured to include additional uses as field delimitation and wind breaks. Cashew is suitable for erosion control and soil improvement. Major pests and diseases are shortly described - potential hazards to production should be considered when planning a cashew development program. Selection and breeding can raise productivity of cashew plantations as clonal propagation methods for cashew are now commonly used. A yield of about six tons of fresh nuts is considered to be the maximum achievable. Small farmers with family labour to collect the nuts are favoured as cashew growers, the field establishment should scope with the labour capacity of the farming family.

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Abbreviations used in this paper

ACP	Asian, Caribic and Pacific States having a special trade agreement with the European Community
C&F	Cost and freight
CGCA	Canopy ground cover area
CIF	Cost- Insurance- Freight (paid by supplier)
CIS	Commonwealth of Independent States
cm	centimetre
CNSL	cashew nut shell liquid
CO_2	carbondioxid
dbh	diameter at breast high
FAO	Food and Agricultural Organisation
FCFA	Franc Communaute Financiere Africaine
FOB	Free on Board
FRG	Federal Republic of Germany
g	gram
GA	gibelleric acid
GCA	General combining ability
GDR	German Democratic Republic
ha	hectare
IAA	indole acetic acid
IBA	indole butyric acid
ITC	International Trade Centre
kg	kilogram
l	litre
lb.	pound = 453,6 g
LW	Large whites (Brazilian cashew kernel specification)
m	metre
mm	millimetre
Mt.	metric ton
NAA	naphthalene acetic acid
NPV	Net Present Value
NRI	Natural Resources Institute
ODA	Overseas Development Agency
P	Pieces (cashew kernel specification)
PASA	Projet Anacardier Senegalo-Allemand
ppm	parts per millia, 1:1 000 000
S	Splits (cashew kernel specification)
s.d.	sine data
SCA	Specific combining ability
SLW	Special large whites (Brazilian cashew kernel specification)
sp.	species (singular)
spp.	species (plural)
t	metric ton
TPI	Tropical Products Institute
UAE	United Arab Emirates
UK	United Kingdom of Great Britain and Northern Ireland
USA	Unites States of America
W1, W2	Whites (Brazilian cashew kernel specification)

WW Whole whites (cashew kernel specification)
YB FAO Production Yearbook

Preface

I write this dissertation because I like the cashew tree, and I have sought answers to questions I found myself asking when I was managing the Senegalese-German Cashew Project in Sokone from 1979 to 1988. I was privileged to read Jan G. Ohler's "Cashew", some months before it was published by the Royal Tropical Institute in Amsterdam in 1979. This book remains the reference for cashew growers all over the world. However, since 1979, a lot of research has been carried out on cashew, e.g. on vegetative propagation, and the market has faced much turbulence. Nevertheless, production still cannot satisfy demand. Today the market is buoyant and demand is rising and making cashew a more profitable commodity. In the future if production finally does exceed demand, cashew nuts can be eaten by the producer as a valuable food, surplus production will not become mere waste, as with some other tropical crops such as coffee.

I hope my paper will be useful for policy makers, development project staff and farmers who want to consider cashew in their plans, but space prevents offering as wide a treatment as Ohler's.

1. Introduction

The cashew nut tree, *Anacardium occidentale* L. belongs to the family **Anacardiaceae** which contains a number of ornamental and fruit trees like sumach (*Rhus*), pistachio (*Pistacia*), mango (*Mangifera*) and African plum (*Sclerocarya birrea* (A.Rich.) Aubr.). *A. occidentale* is one of eight species of *Anacardium* - all indigenous to tropical America (Purseglove 1968; Mabberley 1986).

A. occidentale is a tree that can grow up to a height of 20 m with a diameter at breast height (dbh) of 1 m under good growing conditions. However, under poor conditions growth stagnates. Healthy trees have oval leaves 10 to 20 cm long and up to 10 cm wide, reddish or light green while young and dark green when mature. The bark is grey. If trees are not pruned or browsed, lateral branches touch the soil and may even root. Cashews grow in the tropics up to 1000 m, under a mean annual rainfall from 500-4000 mm the optimum being 800-1200 mm (Purseglove 1968; Ohler 1979; Maydell 1983). NOMISMA (1994) states that cashew trees grow at latitudes as high as 31°, mentioning some trees in Florida. However, this is a clear exception and does not lead to commercial production. The optimum rainfall regime is unimodal with a dry period of 6-9 months long. Flowering starts about 3 months after the rainy season ends- on the new branches. Fruits ripen 2-3 months later, normally at the end of the dry season.

The Tupi Indians of today's north east Brazil where the species originates (Schery 1954, Smith et al. 1992) called the tree "acajou" and the fruits were an important part of their diet. They did not need any other food during the harvesting period in December. Andre Thevet was the first European to describe cashew (in 1558) and its uses by the Indians. He stated that the fruit was hardly edible because of its “unripe” taste, but that a juice could be made from it and the nuts could be eaten if cooked. He also described the cashew nut shell liquid (CNSL) as oil of the nut shell that is extracted by the indigenes (Ohler 1979). Unfortunately there is no account of how the nuts were opened by the Indians. It can be assumed that they burnt them in fires as it is still done today.

Portuguese travellers took the cashew tree to colonies in India [first recorded in Cochin by 1578, in Goa by 1598, (Smith et al. 1992)] and Africa from where they spread more widely. Rosengarten (1984) states that Spanish sailors introduced cashew to Panama and Central America in the 16th century, though Carib natives had presumably taken it to the West Indies somewhat earlier. Cashew trees are easy to multiply by seeds that can germinate immediately after the harvest or even after 1 or 2 years, depending on storage. Harvesting and sowing are easy and direct seeding is feasible where the rainfall exceeds 800 mm during the 3 months following sowing. They can grow on poor sandy soils and withstand salty winds from the sea. Sometimes cashew trees are found on beaches beside mangroves. They were often used as a cheap means to fix dunes or to reafforest depleted forest reserves, for example in India and in Senegal. When the nuts became a commercial product, responsibility for the crop was disputed between forest departments and departments of agriculture/ horticulture which sometimes hindered the development of the cashew resources (Ndiaye, 1979). Differing perceptions of the cashew tree arose accordingly: in some tropical countries they were seen as forest trees and little effort was made by farmers to plant them. In India, Mozambique and Tanzania, however, the cashew nut was recognised as a very valuable product and farmers planted the trees as a crop. Intercropping practices are reported by many authors, but the deliberate integration of cashew trees and annual food crops on a piece of land seems to have been ignored by many researchers and there are few references to integration of cashews in farming systems. The main exception seems to be the home gardens of India and Sri Lanka. In Brazil, the apple was originally the main trade product. It was either sold fresh for consumption or processed into a beverage. In the mid-1980s, however, the nuts gained more importance. Cashew nut shell liquid as a cheap source of phenol was a strategic material during the Second World War and the USA then linked the import of nuts with a certain quantity of cashew nut shell liquid used for the war industry. Ohler (1979) describes cashew wood as termite resistant and useful for boat building, but argues against use as firewood because of sparking (caused by the CNSL content). He nevertheless confirms that it produces a good charcoal.

It is astonishing that the many uses of cashew are still not combined. The cashew tree can offer more than only fruits and nuts. It produces copious litter and could therefore be used to reduce soil erosion. It grows well in rows and is amenable to coppicing, making it ideal for windbreaks and hedges. Cashew trees provide shade and shelter for many species including humans. Wastelands with deep soils can be reclaimed with cashews, whose deep roots bring nutrients to the surface. Experience has shown that once farmers are aware of the economic value of the cashew crop, they plant more trees and participate in the efforts of reforestation. Their objective, however, is not always profit maximisation but is frequently risk reduction, as the cashews produce few fruits even in dry years or when other crops are damaged by locusts (Cisse 1990, H. Ohmstedt 1991).

This study examines, in the context of today’s land use pressures and trading practices, the economic value of the cashew tree and its by-products and the incentives leading farmers to plant them. It also attempts to provide information needed to decide about the promotion of cashew on national level and touches on the implications of different production levels for marketing and the use of by-products (cashew nut shell liquid, apples and wood).

Flowering, pollination and fruit setting have been studied intensively. As this is a crucial aspect of the tree’s biology, this information is later considered in more detail and the implications are examined.

Rapid progress has been achieved in the field of vegetative propagation within the last 15 years. It is now possible to produce clonal material for planting on-farm. Heterosis, strains and clonal material are discussed in relation to breeding and selection.

Husbandry practices are influenced by many factors, among others small farmer’s socio-economic situation, environment, available planting material and market requirements. This study shall indicate how cashew can be integrated in the farming system to achieve an optimal benefit for the farmer. Less attention is given to large scale commercial operations.

2. Cashew uses, trade and processing

This chapter is divided into three main parts. The first two, uses (2.1) and trade picture (2.2) are sudivided as appropriate. A shorter section (2.3 - processing methods) completes the chapter.

2.1 Uses of cashew nuts and by-products

2.1.1 Uses of cashew kernels

Most cashew kernels (Plate 1) are probably used in snacks, as roasted and salted nuts, alone or in mixture with other nuts. In Bangor, raw cashew kernels are sold in several shops, mostly packed, sometimes as brand “Indian cashew kernels”. No reference is made to grades, only broken kernels are sold as “splits”. Chinese restaurants sell a variety of meals with cooked cashew kernels. Broken kernels are used in confectionery and sometimes as substitute for almonds. Ground cashew kernels can replace peanut butter in exotic dishes. In Kenya cashew kernels are integrated in delicious chocolates. Most uses are, however, restricted by the relatively high price of cashew kernels, but a wide variety of local uses including soap making is reported from Mali (Traore 1988). Recipes for cashew uses are given in each number of the Indian Cashew Journal.

2.1.1.1 Nutritive value of cashew kernels

The composition of cashew kernels given in the literature varies greatly, probably due to varietal variation and differences in analyses as shown in Table 1 and Table 2. (Water and ashes make totals up to 100%). The protein content varies depending on the genotype. Values between 13-25% were found (Ohler 1979). In Table 1 the protein content is around 21%, - high compared with the value given in Table 2.

Plate 1: Cashew kernels, cashew apples with nuts attached and fruits of *Cordyla pinnata*

Table 1: Composition of cashew kernels

Author	Proteins (%)	Fat (%)	Carbohydrates (%)
Franke (1976)	21	47	24
Ohler (1979)	21	47	22
Ohler (1979)	21	44	29
NOMISMA (1994)	22	45	27

Table 2: Composition and calorific value of 5 major tree nuts (per 100) g

	Calories	Protein	Fat	Carbohydr.	Fibre
Almond	598	18.6	54.2	19.5	2.6
Amazonia nut	654	14.3	66.9	10.9	3.1
Cashew	561	17.2	45.7	29.3	1.4
Pistachio	594	19.3	53.7	19.0	1.9
Walnut	628	20.5	59.3	14.8	1.7

Source: Duke (1989)

There is no discrepancy in the fat content, cashew has 10-20% less fat than the other nuts and might therefore be preferable to other dessert nuts for the well nourished consumers. About 77% of the fatty acids are unsaturated and ideal for heart diets, according to the American school[1]. The protein content lies between 10% (maize, Franke 1976) and 38% (soybeans, Rehm et al. 1984) and could help to reduce malnutrition in cashew growing countries. In countries with bad cashew marketing channels the nuts are often eaten by children.

2.1.2 Cashew nut shell liquid (CNSL)

CNSL is contained in the mesocarp of the cashew nut shell, making about 15-30% of the nut weight. It is a viscous, oily or balsam like substance with a specific weight of 1.013 (g/cm³).It has a pale yellow to dark brown colour, a bitter taste and caustic properties. It also occurs in other parts of the cashew tree (Table 3).

Table 3: CNSL-levels in various parts of the cashew tree (ppm)

Roots	Wood	Bark	Leaves	Apples	Kernels
75	25	85	250	60	35

Source: Hammonds (1977).

CNSL is a by-product of commercial cashew nut processing. The most widely used method, the hot oil bath (see chapter 2.3), extracts about 50% of the CNSL (7-15% of nut weight) from the shell (Russell 1969, Ohler 1979, Gedam et al. 1986). Several special treatments before roasting can bring the rate up to 90-95%, and with solvents 100% can be achieved, but these methods are expensive and their use depends on the CNSL-price (Ohler 1966). Any sales add directly to the profit of the factory. If CNSL is not sold, it can be burnt or it has to be discarded thus creating additional costs.

[1] The ideal heart diet in America changes often with the marketing strategies of the Soy bean industry and it could be a marketing argument for cashew nuts.

Natural CNSL consists of anacardic acid, cardol, cardanol and 2-methylcardol in various compositions (Table 4).

Table 4: Composition of cashew nut shell liquid

Author	Anacardic acid (%)	Cardol (%)	Cardanol (%)	2-methyl cardol (%)
Cornelius (1966)	90	10		
Hammonds (1977)	82	13.8	1.6	2.6
Tyman et al. (1978	74.1-77.4	15.0-20.1	1.2-9.2	1.7-2.6
Ohler (1979)	90	10		
Tyman (1980)	80	15	small amount	small amount
Chemical Data (s.d., after 1986)	82	13.8	1.6	2.6

The chemical structure of the acids is shown in Figure 1 (Hammonds 1977). During the commercial extraction (hot oil bath) the liquid undergoes decarboxilation, the anacardic acid is converted into cardanol and polymer. Therefore commercial CNSL consists mainly of cardanol (60-65%), polymer (20-25%) cardol (10-12%) and a small amount of anacardic acid (Ramaiah 1976, Tyman 1980, Chemical Data s.d.).

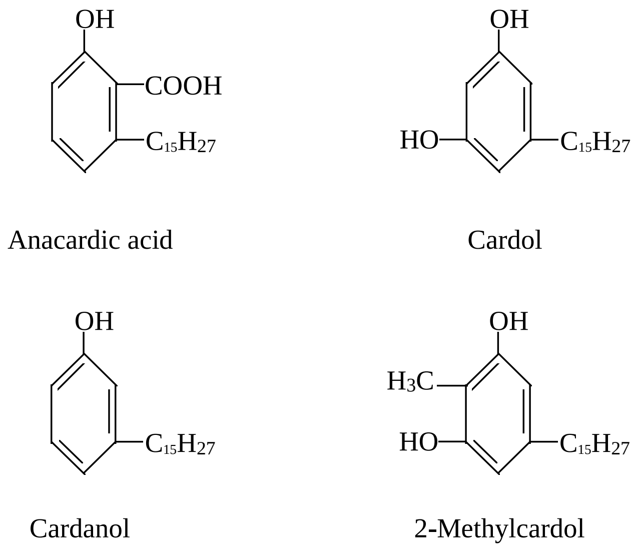

Figure 1: Structure of main acids in CNSL (Hammonds 1977, Wardowski et al. 1991)

2.1.2.1 CNSL Uses

About 90% of the CNSL imported by the USA, the UK and Japan was used as friction dust for drum-break linings and clutch facings in motor cars. It is expensive compared with asbestos but the superior friction modifying properties make it economic. Since disc brakes replaced break shoes in motor cars, the use of CNSL has decreased (Wilson 1975). Still then, a huge variety of other products can be made from CNSL (Table 5).

Table 5: Some uses of CNSL

Use	Authors
Wood protection against insects (raw CNSL)	Wolcott (1944)
Binders in particle boards	Dhamaney et al. (1979), Hughes (1995)
Special cements, resins for modification of rubbers, surface coatings, insulating varnishes and plasticisers	Evans (1955)
Germicides, fungicides, insecticides and photographic developers	Ramaiah (1976)
Lacquer	RUDECO (1989)
Medicines (including cancer treatment)	Duke (1989), Kubo[1] et al. (1993), Muroi[1] et al. (1993)

[1] These articles refer to compounds in the cashew apple

A breakdown of CNSL consumed by various industries in India in 1978 is given in Table 6 (Murthy et al. 1984).

Table 6: CNSL consumption by various industries in India (1978, in t)

Brake linings	1500
Cardanol	2280
Chemical resistant cement	160
Filter paper	150
Foundry core oil	1600
Oil tempered hardboards	100
Paints and varnishes	1000
Resins	50
Water proofing compound	32
Total	**6872**

The Indian Standards Institution has fixed specifications for untreated CNSL, treated CNSL and cold pressed CNSL, based on specific gravity at different degrees, viscosity, ash, moisture and acid values and others (Cashewnut Shell Liquid 1994).

It should be possible to produce CNSL for specific purposes, depending on the relations of producers and buyers, and on the price of the product. Currently the price of CNSL is about one third of the price for phenols from other sources, increased use could increase prices and therefore the profit of the cashew industry.

2.1.3 Cashew kernel testa

The testa (1-3% of nut weight) contains 25% tannin. A factory treating 1000 t of nuts/year would yield about 2 t of testa containing 400 kg tannin (Ohler 1979). Trials with cashew testa tannins as wood adhesives have been promising (Narayanamurti et al. 1969). Extraction depends on markets for the product.

2.1.4 Cashew apples

The cashew apple is the peduncle of the nut. The stages of its development are reported in chapter 3.3.4.2 (page 48). The colour of ripe apples is usually red or yellow, (Plate 2) but mixtures of both colours exist and greenish ripe apples are reported from Ghana (Amaning 1995). Many cashew apples have an astringent taste, probably due to CNSL traces and tannins (0.1-0.7%, Sastry et al. 1962). Ripe fruits can easily be removed from the tree and they are normally sweet and juicy. Both the apple and the nut are ripe at the same time. The apple represents about 89% (range 85-90%) of the complete fruit weight (Albuquerque et al. 1960). Cashew apples are juicy and rich in vitamin C. The composition of fresh fruits is shown in Table 7 and Table 8. Huge variations are typical. The high vitamin C content is outstanding, compared with other fruits which can be grown under the same conditions.

Table 7: Composition of cashew apples from selected varieties in Kerala*

Colour	Shape	Weight (g)	Juice recovery (%)	Total soluble solids (%)	Acidity (%)	Reducing Sugar (%)	Ascorbic acid mg/100g juice
Red	Cylindrical	54.3	63.8	14.13	0.42	11.80	290
Yellow	Cylindrical	50.3	59.6	12.88	0.38	10.83	282
Yellow	Pyriform	43.6	61.2	12.91	0.42	12.80	328
Red with-yellow shade	Oval	40.6	48.9	12.89	0.43	12.81	291
Yellow with red shade	Conical	39.1	49.6	13.18	0.32	13.28	322
Range (India)**		13-140	47-84		0.1-0.7	5.3-17.7	17-455

* Gopikumar et al. (s.d.)
** Sources: Nanjundaswamy et al. (1984), Subba Rao (1984), Chandran (1984), Wardowski et al. (1991),

Table 8: Composition of cashew apples compared with other tropical fruits (per 100 g fresh weight)

	Moisture (%)	Carbohydrates (g)	Calcium (mg)	Phosphorus (mg)	Iron (mg)	Ascorbic acid (mg)
Cashew*	88	12	10	10	0.2	262
Guava	80	13	15	27	1.0	200
Mango	87	11	14	10	0.4	30
Orange	86	10	40	24	0.3	55
Papaya	90	7	11	9	0.4	50
Tamarind**	20	71				

Sources: * Directorate of Cashewnut Development (1985), ** Purseglove (1968) refers to pulp (40% of pod), others: Rehm et al. (1984)

2.1.4.1 Apple storage

Fresh cashew apples cannot be stored for more than a day in ambient temperature. Microbial decay can be slowed down by various methods (Table 9).

Table 9: Shelf life of cashew apples under different treatments

Method	Shelf life	Author
dipping: 1% mustard oil	4-6 days	Chattopadhyay et al. (1993)
dipping: 0.25% citric acid and 500 ppm SO_2	3 weeks	Wardowski et al. (1991)
cooling: 0-1.5 °C, rel. humidity 85-90%	4-5 weeks	Abbott (1970)
deep freezing	4-5 month	McEvans (1980)

Deep freezing also reduces the astringency, frozen apples can be used for apple pies or ice cream (McEvans 1980).

Plate 2: Ripe cashew fruits (apple and nut).

2.1.4.2 Apple processing

Cashew apple processing is constrained by three biological features: the short production period (about 70 days per year), the low transportability and the natural astringency. In many cashew growing areas the industrial processing of cashew might not be possible because of missing infrastructure and no alternative uses of equipment for the rest of the year.

Steaming under pressure or cooking of the apples in a 2% salt solution are recommended to remove the astringency. Additions of gelatine, pectin or lime juice to the cashew juice clear it from remaining undesirable contents (Central Food 1963). Products that can be made from cashew apples are numerous and listed in Table 10. Most products are easily made. Preconditions are the availability of fresh water and a clean working environment.

Table 10: Products made from cashew apples

fresh fruits	clarified juice	jam	wine	chutney
dried fruits	cloudy juice		spirit	curried vegetable
candy	syrup			pickle
canned apple	carbonated juice			

Sources: Ohler (1979), Babu (1982), Directorate of Cashewnut Development (1985), Cisse (1988), RUDECO (1989).

Cashew wine is the most widespread use of the apple in non-Muslim countries. Cashew apple jam was in vogue in Europe during the 18th century (Rosengarten 1984). Dried fruits (15% of fresh fruit) are sweet and can be eaten like figs. In Senegal one kg of dried fruits was sold at 800 FCFA (appr. 3 US$) in 1989 (RUDECO 1989).

2.1.5 Cashew wood

Cashew wood is greyish-yellow, light with a specific gravity of 0.437 for stems and 0.485 for branches, slightly lighter than the rubberwood (0.543 and 0.494) (Bhat et al. 1990) that is now traded on the world market. The density decreases with increasing age (distance to pith) (Bhat et al. 1983). In Kerala the wood is used by small scale wood industries for packing cases, plywood and match manufacture (Florence 1989), for pulp (fibre length <900 æm, Bhat et al. 1989) and paper making (Gnanaharan et al. 1982). Ohler (1979) reports that cashew wood is termite resistant (because of its high resin content) and used as fence posts and in house and boat building. Cashew wood can be used as firewood but the resin provokes sparks, therefore it is not liked by cooks. It is good for charcoal (Eijnatten 1979, Maydell 1983), but it is not accepted by all users due to its light weight (75% of commercial charcoal).

2.2 World cashew trade

2.2.1 Overall market picture

2.2.1.1 Importance of cashew

Cashew nuts belong to the same market sector as groundnuts, almonds, pistachios, macadamia nuts and pecan nuts (all dessert nuts) and products used in confectionery as hazelnuts, walnuts, and Amazonia nuts[2]. Despite the fact that cashew trees have generally a low productivity and that serious research on the crop did not start until the 1970s, they accounted for 26% (marginally less than the main nut, almonds, 27%) of the world trade during the 1962-1966 period. The share increased to the same level as almonds (26.5%[3]) from 1971-1975 (Ohler 1979). The main competitors of cashew nuts are almonds and pistachios. Groundnuts are not in direct competition with cashew nuts because of a huge price difference. The present aggressive marketing policy of US producers could reduce the share of cashew nuts (RUDECO 1989), but alternatively India and Brazil as main exporters of cashew kernels might improve product promotion and marketing in the main markets in North America and Europe and maintain the market share.

Table 11 shows the quantity and the market share of traded tree nuts, separated for "5 major nuts" and "other nuts". Cashew had a share of 16% in 1979 to 1981 that fell to 13 % from 1989 to 1993 and ranks fourth after almonds, walnuts and hazelnuts. Compared to all traded nuts, the share fell from 6.8% in 1979-1981 to 5.8% from 1992-93 (YB92 figures). If the higher figures from YB93 are considered, the share increased to 7.1%. However, for a crop that is exclusively produced in developing countries, a share of 6% of all nuts is quite important and deserves the attention of policy makers and researchers.

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[2] The III World nut convention held in Manaus in 1992 the term "Brazil nut" was replaced by the term "Amazonia nut" (NOMISMA 1994).

[3] Ohler considered almonds, Amazonia nuts, cashew nuts, hazel nuts, pecans, pistachios and walnuts for computation.

Table 11: World production (Mt.) of edible tree nuts

	Cashew nuts	Almonds	Pistachios	Hazelnuts	Walnuts	Total 5 nuts	Other nuts[4]	Grand Total
1979-81*	440 038	988 790	91 546	472 662	788 097	2 781 133	3 648 000	6 429 133
%	16	36	3	17	28			
%	6,8	15,4	1,4	7,4	12,3		56,7	
1985	426 581	1 188 327	135 772	373 909	818 256	2 944 830	3 794 000	6 736 845
%	14	40	5	13	28			
%	6,3	17,6	2,0	5,6	12,1		56,3	
1986	437 873	999 618	152 918	480 701	828 905	2 902 001	3 728 000	6 628 015
%	15	34	5	17	29			
%	6,6	15,1	2,3	7,3	12,5		56,2	
1987	398 263	1 303 024	179 877	467 351	893 331	3 243 833	4 167 000	7 408 846
%	12	40	6	14	28			
%	5,4	17,6	2,4	6,3	12,1		56,2	
1988	434 038	1 135 051	207 584	596 278	780 946	3 155 885	4 217 000	7 370 897
%	14	36	7	19	25			
%	5,9	15,4	2,8	8,1	10,6		57,2	
1989	497 742	1 305 963	213 146	743 023	933 821	3 695 684	4 581 000	8 274 695
%	13	35	6	20	25			
%	6,0	15,8	2,6	9,0	11,3		55,4	
1990	450 097	1 293 321	250 550	553 256	906 039	3 455 253	4 316 000	7 769 263
%	13	37	7	16	26			
%	5,8	16,6	3,2	7,1	11,7		55,6	
1991	542 591	1 197 895	302 794	515 007	951 995	3 512 273	4 675 000	8 185 282
%	15	34	9	15	27			
%	6,6	14,6	3,7	6,3	11,6		57,1	
1992	486 670	1 284 302	287 777	700 085	918 180	3 679 006	4 924 000	8 601 014
%	13	35	8	19	25			
%	5,7	14,9	3,3	8,1	10,7		57,2	
1993	479 804	1 194 497	345 303	565 157	1 006 547	3 593 301	4 579 000	8 170 308
%	13	33	10	16	28			
%	5,9	14,6	4,2	6,9	12,3		56,0	

* Figures from FAO Production Yearbook 1992
Figures from FAO Production Yearbooks, 1987-1993
Percentages own calculations, shaded area refers to 5 major nuts, unshaded to total nut production

[4] The production of nuts relates to nuts in shells. FAO admits that these statistics are very scanty and refer only to crops for sale. Other nuts include nuts used as dessert and table nuts as for Amazonia nuts, pili nuts, sapucaia nuts and macadamia nuts, but not nuts used as spices or for oil extraction as cola, karité and coconuts. (Chestnuts were considered by FAO, but not in this context because of a different market sector).

2.2.1.2 Supplies of cashew

Ohler (1979) gave estimates of cashew production for the major producing countries Mozambique, Tanzania, India, Brazil, Kenya and Madagascar. World cashew nut production increases from 125 000 tons in 1955 to 470 000 tons in 1975 at a rate of about 6.9%/year were predicted. From 1975-2005 Ohler projected an average growth rate of 3.3%, bringing production to 1.25 million tons, excluding home consumption[5]. However, he expected a reduced harvest in 1978 from East Africa because of infrastructural problems and adverse climatic conditions, resulting in rising prices that would stimulate replanting programmes in several other countries. In fact, cashew output from East Africa dropped from 350 000 tons in 1975 to 140 000 tons in 1980 (Table 12, Table 13 and Table 14).

The figures in the shaded area of Table 12 show a scenario that could have happened if conditions had remained ideal in the five countries. Kenya and India nearly maintained the production level of the 1970s. From 1975 the civil war in Mozambique hampered nut collection, with a dramatic fall from 80 000 t (1982) to 20 000 t (1983). In Tanzania, the villagization program (ujamaa, started since 1974), drove farmers away from their fields (Shomari 1988) and, in addition, powdery mildew destroyed the cashew flowers which led to a dramatic drop in the cashew nut production. Brazil has increased its cashew production, but not to the estimated levels. Peak production in 1991 was followed by a drop of two thirds by 1993. Reasons for a decline in production may have been adverse weather conditions, pests

[5] Ohler mentioned growth rates of 14% for the period 1965 to 1975 and 6% from 1975 to 2005, but these percentages do not match the figures provided in the referring tables. The growth rates were reconsidered using the values from the tables.

and diseases, over-aged or badly maintained plantations or simply low producer prices combined with late payment to producers. In Ivory Coast, a price increase from 15 to 25 FCFA/kg (1975-1976) stimulated an increase in the harvest from 300 t to 560 t (Ohler 1979).

Table 12: **Cashew production (Mt.) for five major producing countries including home consumption (Ohler 1979)**

Country Year	Kenya	Mozambique	Tanzania	India	Brazil	World
1945	1 000	16 000	7 000	45 000	4 000	73 000
1950	1 000	75 000	11 000	55 000	5 000	147 000
1955	2 000	64 000	23 000	60 000	5 000	154 000
1960	5 000	78 000	42 000	65 000	5 500	195 500
1965	8 000	139 000	71 000	100 000	8 000	326 000
1970	13 000	140 000	120 000	125 000	37 000	435 000
1975	25 000	196 000	130 000	150 000	51 000	552 000
1980	30 000	180 000	142 000	177 000	93 000	622 000
1985	35 000	250 000	160 000	190 000	218 000	853 000
1990	40 000	275 000	252 000	200 000	245 000	1 012 000
1995	45 000	300 000	275 000	220 000	282 000	1 122 000
2000	50 000	350 000	290 000	250 000	317 000	1 257 000
2005		400 000	325 000	300 000	335 000	1 360 000

Data in shaded area are projections

Table 13 shows various production estimates. For the years 1970 and 1975 Ohler's figures match the other sources, assuming a home consumption of 10%. However, there is a difference of 20% between FAO/E&SD (1988) and the FAO/PY (1993), of 15% between NOMISMA (1994) and FAO/PY (1993) in 1980 and of more than 20% in the year 1985. The discrepancies might result from different countries and different sources considered by the authors. Initially, 5 countries produced 95% of the of the crop (Date 1965), nowadays many other countries produce considerable amounts of cashew nuts and it becomes more and more difficult to predict a future production. In the last ten years, world production ranged from 400 000 t in 1987 to 726 000 t in 1992 (Table 14, FAO/PY 1987-1993), with variations of more than 200 000 t from one year to another. Home consumption seems to have become more important in countries with a fast growing economy like India and Brazil. Home consumption itself can be divided into processed and traded products within a country and nuts consumed directly by the producers. Estimates of these values are even more difficult.

Table 13: Production estimates by different sources (in Mt.)

Year	Estimates Ohler 1979 (excl. home cons.)	NOMISMA 1994	FAO-Production yearbooks	FAO-Economic and Social development (1988)
1955	125 000			
1960	160 000			
1965	280 000			
1970	370 000	407 500		
1975	470 000			518 200
1980	*535 000	390 200	•446 000	367 800
1985	*750 000		••427 000	352 800
1990	*910 000	471 300	•••450 000	
1995	*1 000 000			
2000	*1 120 000			
2005	*1 260 000			

* estimated data

• FAO Production Yearbook 1993, •• FAO Production Yearbook 1987, ••• FAO Production Yearbook 1992

2.2.1.3 Prices

Within the last 15 years, the highest price obtained for cashew kernels of the grade WW 320 was about 7 US$/kg CIF (**c**ost - **i**nsurance - (sea)**f**reight paid by supplier) New York in 1981 and 1986 (NOMISMA 1994, FAO/E&SD 1988), equivalent to 1.60 US$/kg of raw nuts. The highest export prices from Tanzania, 1.385 US$/kg were also achieved in the same year (1981) leaving a margin of only 15% for the processing and transport. Such small margins may reflect government interventions in India that encourage exports (Kumar 1995), but they are not realistic in private trade.

Table 14: World cashew nut production (FAO Production Yearbooks, 1987-1993)

	YB93	YB87	YB88	YB89			YB90			YB91			YB92			YB93		
	79-81	1985	1986	1987	1988	1989	1988	1989	1990	1989	1990	1991	1990	1991	1992	1991	1992	1993
Angola	1 200	1 200	1 200	1 200			1 200			1 200			1 200	1 200	1 200	1 200	1 200	1 200
Bangladesh	15	60	64	70	76	84	50	80	80	80	80	86	80			50	50	50
Benin	1 087	1 200	1 200	1 200			1 200			1 200			1 200	1 200	1 200	4 000	1 500	1 200
Brazil	71 333	111 800	120 000	75 000	142 867	177 719	133 355	136 130	168 916	143 991	99 367	193 002	107 664	175 628	96 757	185 965	107 955	62 421
Burkina Faso	367												1 074	1 000	1 000	1 000	1 000	1 000
China	5 967															9 500	9 700	10 000
Dominican Rp.	870	910	920	920			920	926	931	930			930	930	930	930	930	933
El Salvador	2 208	2 162	2 208	1 895	1 872	1 900	1 858	1 900	1 900	2 024	1 900	2 000	2 098	2 000	2 000	2 000	2 000	2 000
Guadeloupe	3	4	4	4			4											
Guinea Bissau	3 833	8 500	9 000	10 000			10 000	10 000	10 000	17 000	20 000	20 000	30 000	30 000	30 000	20 824	30 000	30 000
Honduras							300			344			350	350	350	350	350	350
India	159 000	151 800	159 000	150 000	130 000	165 000	130 000	150 000		150 000			130 000	140 000	150 000	294 589	350 000	150 000
Indonesia	10 094	25 887	25 000	24 660		28 500	26 000			28 000	30 000	30 000	27 991	29 683	30 533	29 683	30 533	32 000
Ivory Coast	750	3 500	6 000	6 000			6 000			6 000			6 000	6 000	6 000	9 000	10 000	10 000
Kenya	15 763	10 000	10 790	10 000		10 000	12 000	10 000	12 000	12 400		15 000	7 000	15 000	15 000	15 000	15 000	15 000
Madagascar	3 400	4 000	4 100	4 200			4 300			4 400			4 500	4 600	4 700	4 600	4 700	4 800
Malaysia	4 267	335	290	290	300	324	9 860		14 400	13 546			10 000	11 000	12 000	11 000	12 000	12 000
Mali	248																	
Mozambique	69 400	25 000	30 000	35 000		40 000	40 000			45 000			49 000	40 000	40 000	31 000	54 000	54 000
Nigeria	25 000	37 000	37 000	37 000	37 000	37 000	3 000	3 000	3 000	25 000			25 000	25 000	25 000	25 000	25 000	25 000
Philippines	3 752	3 873	4 275	5 350			6 114			6 500			6 800	7 000	7 200	3 686	4 000	4 000
Senegal																3 000	500	500
Sri Lanka	8 400	950	1 222	9 184		10 000	10 892		10 400	9 771			10 000	10 000	10 500	10 000	10 500	11 000
Tanzania	54 181	32 400	19 200	18 490	22 470	22 000	24 285	19 275	20 000	20 000	28 000	33 000	17 060	29 850	40 150	29 850	40 150	37 000
Thailand	4 867	6 000	6 400	7 800	7 800	7 800	12 500	10 000	8 500	10 000			11 850	11 850	11 850	15 000	15 000	15 000
Togo					250	250	200			356			300	300	300	356	350	350
Total	446 005	426 581	437 873	398 263			434 038			497 742			450 097	542 591	486 670	707 583	726 418	479 804

Relevant are the first columns for each report, the other columns where left in to illustrate the changes in the estimations over the years and the progress of some countries

Table 15: Trend of imports and prices for cashew kernels

Year	t	US$/lb.[6]	US$/kg
1975	95 826	1.120	2.469
1976	94 893	1.220	2.690
1977	74 685	2.120	4.674
1978	60 584	1.850	4.079
1979	68 503	1.924	4.242
1980	69 676	2.650	5.842
1981	67 064	3.157	6.960
1982	70 596	2.378	5.243
1983	63 231	1.973	4.350
1984	55 498	2.365	5.214
1985	71 596	2.425	5.346
1986	67 192	3.178	7.006
1987	65 713	3.185	7.022
1988	62 594	2.975	6.559
1989	70 599	2.458	5.419
1990	90 523	2.387	5.262

Source: NOMISMA 1994

According to RUDECO (1989) the farm gate price for raw nuts in Senegal is about 30-40% of the FOB price (**f**ree **o**n **b**oard, supplier pays transport to the harbour and loading on the ship). In Tanzania, the price paid to producers was 25-73% of the export price (1972-1990) (NOMISMA 1994, Jaffee et al. 1995), whereas for producers in Mozambique the share was 65-85% of the price paid by the processors (1978-1989) (NOMISMA 1994).

The FOB price for raw-nuts is based on the kernel C&F (**c**ost and **f**reight) price in London or New York. Taking a kernel price of 7 US$/kg (1981, 1986) the FOB raw nuts price would be calculated as follows: 7 x 50% x 22.5%[7] = 0.788 US$/kg. If the kernel price is 4 US$/kg (1983), the FOB price would 0.450 US$/kg. Taking the Senegalese rates, the farmgate price would be 0.13-0.32 US$/kg, in Mozambique 0.26 US$/kg were paid in 1989, 0.25 US$/kg in 1990 and 0.42 US$/kg in 1991. Experience has shown that too low prices do not encourage farmers to collect their nuts; US$ 13/kg seems to be the lower limit.

[6] Cashew kernel are traded in lb. For better understanding figures in US$/kg were added by the author. Another source (FAO E&SD 1988) shows slightly lower figures.

2.2.1.4 Production trends

To get a more precise picture of the recent changes and prospects in cashew nut production world-wide, it is necessary to compare the production from different countries. The data may not be very accurate, as many of them are based on estimation by FAO or other sources, but the trend of a more diverse production is clearly shown (Figs 1 and 2): 6 countries produced 98% of all cashew nuts in 1970. Today (1989-1991) the biggest producers are India and Brazil with a share of 56% of the world market. Mozambique (7%) is still the third greatest producer of cashew nuts, accounting for 50% of the agricultural exports, followed by the newcomers Vietnam (6%) and Indonesia (5%). Tanzania, Nigeria and Guinea Bissau hold equal by the sixth position with 4% each, Kenya, Sri Lanka, Malaysia and Thailand follow with 2% each. All the other countries together have 6%. In Nigeria, the crop has been neglected during the oil boom. Prices were too low and there was no incentive to harvest. When oil money became scarce, people remembered other ways of generating income and cashew was rediscovered (Udofia 1995). Guinea Bissau gains 52.8% of its convertible currency earnings from exports of cashew nuts (Arnold 1994), the increase from 660 t (average from 1966-1968, Ohler 1979) to current levels was supported by a policy that encouraged farmers to barter cashew nuts against products they needed (NOMISMA 1994). In Figure 3 the most recent available production data from 1993 are shown. Imports Review (1994) mentions Equatorial Guinea, Ghana and Guinea as sources of raw nuts, as well as the Netherlands (100 t), Pakistan (1 760 t), Singapore (610 t) and Spain (146 t). The last 4 countries do not grow cashew nuts, they act as interim traders. Musaliar (1994) mentioned that

[7] This calculation is based on the assumption that the FOB raw-nut-price should be at least 50% of the kernel (end product) price and on a recovery rate of 22.5%.

Australia had produced 1 200 t of raw nuts in 1991, but profitability can only be reached if the yields are around 4-5 t/ha due to high labour costs (NOMISMA 1994).

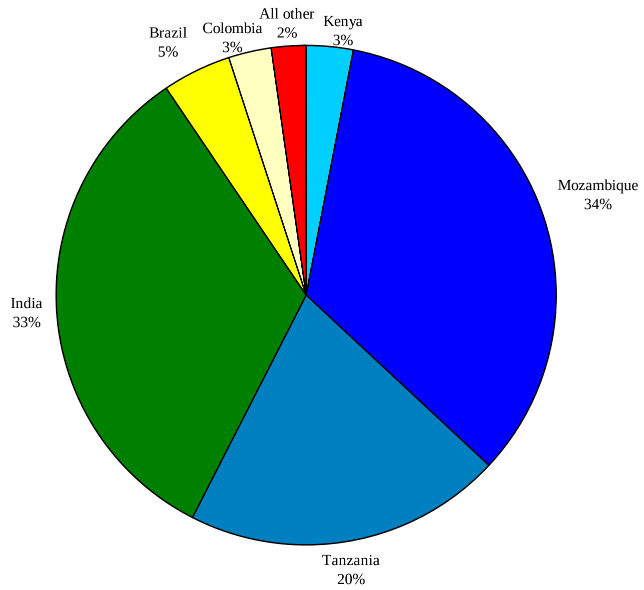


Figure 2: Production share of Cashew producing countries from 1969-1971

(Data from: Ohler 1979; Jaffee et al. 1995)

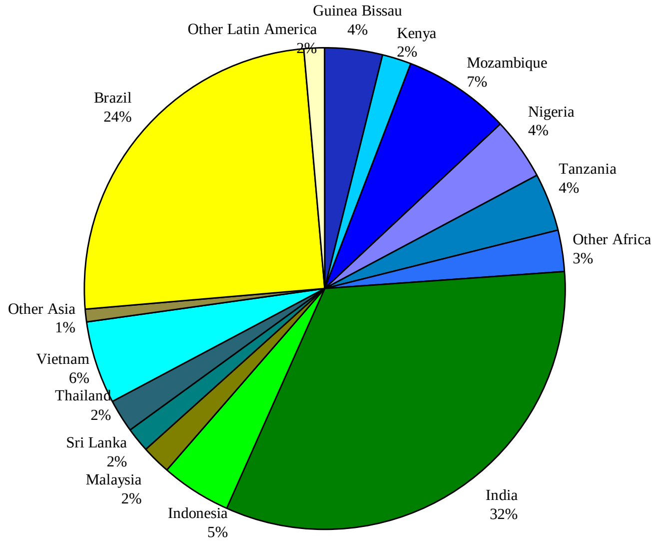
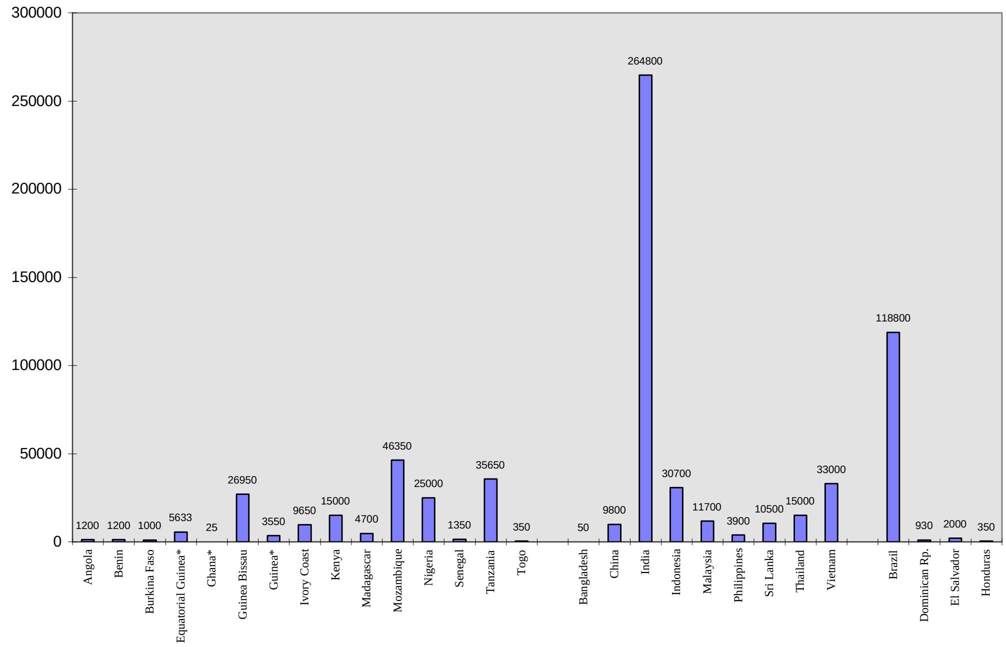


Figure 3: Production share of cashew producing countries from 1989-1991

(Data from: NOMISMA 1994; FAO PY 91-93)



Data from FAO PY 1993,
data with * from imports review 1994, only imports to India, January to March 1993 and 1994

Figure 4: Cashew nut world production in t per country. Average 1991-1993

The export price obtained for all grades depends very much on the processing quality. The Indian processors achieved an average price of 4 835 US$/t, Brazil 4 205 US$/t, Mozambique 3 577 US$/t, Tanzania 3 673 US$/t, China 3 568 US$/t, whereas Kenya got only 3 662 US$/t or 68% of the Indian price in the period from 1989-90. Wilson (1975) states a price differential of 88 US$/t between W210 and W320 and 67 US$/t between W320 and scorched whole, unfortunately without giving a price or a reference period. Examples of prices for different grades from Brazil are listed in Table 16. The difference of 35% between SLW1 compared to W1 (320) seems to encourage selection towards bigger nuts, but Wilson (1975) thinks that the market for the highest quality is narrow and prices will fall if the offer increases.

Table 16: Average prices by quality grades exported by Brazil, 1991.

Grade	Price in US$/t FOB Fortaleza
SLW1	6 967
LW1	5 798
W1 (240)	5 578
W1 (320)	5 159
W1 (450)	4 365
W2	4 916
S1	3 946
P1	2 557

2.2.2 Cashew products: The market view

2.2.2.1 Processing industry

Until the 1960s India had a quasi-monopoly on export of cashew kernels and the Indian specifications have become a norm on the world market (Date 1965). Mozambique was the first country to set up its own processing factories (in 1960), followed by Tanzania, where the TANITA factory in Dar es Salaam was set up in 1965 (Ohler 1979, NOMISMA 1994). Despite massive investments in processing factories in Africa with financial aid from the World Bank, Italy or Great Britain, these produced low quality products or have failed for several reasons:

⇒ the management was appointed from the government and was often unfamiliar with the industry,

⇒ supplies of raw nuts were inadequate because of too low prices (Senegal),

⇒ Ineffective staff training and poor running of the machinery,

⇒ bad nut-grading and neglect of sanitary measures.

Even when everything went well in the beginning, political interference sometimes hampered profit making. When plants needed repair, spare parts were often missing. The factory in Senegal only worked for 1 year, 2 of 12 factories in Tanzania did not even achieve test runs. From the remaining 10, 7 are currently not working and 3 operate only at low capacity (Jaffee et al. 1995). With this picture in mind, and the possible profits for the various national economies, Kumar (1995) suggests the installation of small scale Indian equipment in African producer countries. This equipment is cheap and its use labour intensive. He is also of the opinion that they should produce for the European market, mainly because of the ACP- trade agreements that could facilitate market access.

2.2.2.2 Trade in cashew kernels

Contrary to raw nuts, cashew kernels are traded in pounds (lb.), because of the traditional American market. Standard specifications for Indian cashew kernels have been laid down by the Indian government under the Export Act of 1963 (Commercial information 1994). Kernels are classified according to physical properties and weight. Whole white kernels are the best, followed by splits, bits and pieces. International price quotations are based on the most common Indian output, whole whites, 320 kernels per lb. (705/kg), referred to as WW320, W320 or count 320 (Wilson 1975). Formerly, the biggest whole nuts exported from India (250/lb., 550/kg) were called “jumbos” and the biggest nuts from Brazil (150/lb., 330/kg) “mammoths”[8]. The Indian standard and the Brazilian standard were combined in the ISO 6477 standard in 1988 to unify the classification for cashew kernels. The most important details are shown in Table 17. For more information NOMISMA (1994) should be consulted.

2.2.2.3 Consumption

The USA was the first country to import small quantities of cashew nuts from India in 1905 while real trade began in 1923 when 45 tons were shipped from India to the USA. The first load was infested by weevils when arriving in New York and no further shipments were made until 1928, when airtight containers filled with carbon dioxide gas were used to keep the nuts in good condition. Cashew kernel exports from India mainly to USA increased to 18 000 tons in 1941. Small quantities were shipped to the UK and the

[8] Parry (1970) refers to Brazilian cashew kernels as Jumbo and Extra Jumbo, Morton et al (1972) reports a “Jumbo” clone in Trinidad.

Netherlands. The war interrupted exports until 1943, when the USA linked the import of 1½ lb. (0.681 kg) kernels with the supply of 1 lb. (0.454 kg) CNSL to be used for break linings for war vehicles. Unrestricted cashew trade resumed in 1944 (Ohler 1979). The USA-need for CNSL also gave a fillip to commercial production and processing in North East Brazil (Parry 1970).

Table 17: Classification of cashew kernels (NOMISMA 1994)

1. General classification: Cashew kernels shall have been obtained by shelling and peeling cashew nuts (*Anacardium occidentale* L.),				
2. Special classification:	Indian/African grade	Brazilian grade	Number of kernels/lb.	Number of kernels/lb.**
A: W, white wholes: they must be kidney shaped, free from infestations, insect damage, mould, rancidness, testa residues extraneous material; white, pale ivory, or ash coloured; corrugated kernels are allowed if the kernel shape is not jeopardised. Up to 5% lower category is accepted.	 W 180 W 210 W 240 W 280 W 320 W 400 W 450 W 500	SLW1 LW1 W1 W1 W1 W1	160-180 180-210 180-200 200-210* 220-240* 260-280* 300-320* 350-400* 400-450* 450-500*	 120-180 190-210 220-320 400-450
B: SW: scorched wholes as above, pale or dark ivory, slightly burnt due to scorching	SW 180-SW 500	SL, W2, WW2, W2	as above	
C: Dessert cashew kernels				
scorched wholes seconds, as above, but scorching, small spots and fading are allowed	SST	W3		
dessert wholes, as above, but fading, scorching, black spots and corrugations are more evident	DWG	W4		
D: white pieces				
Butts: white kernels broken crosswise and cotyledons attached	B	B1		
Splits: white kernels split lengthwise	S	S1		
Large white pieces, kernels broken into more than 2 pieces that do not pass a ¼ inch mesh sieve.	LWP	P1		
Small white pieces as above, not passing through a 1/10 inch mesh sieve	SWP	SP1		
Baby bits plumules and broken kernels, not passing through a 1/14 inch mesh sieve	BB	G1		
E: Scorched pieces Several divisions	SB, SS, SP, SSP	B2, S2, P2, SP2		
F: Dessert pieces several divisions	SPS, DP, DSP	P3		

***** figures from Wilson (1975), **Codex Committee (1985)

From 1966-1971, an average of 72 800 t (ITC 1973) to 74 300 t (Mathew et al. 1983) was exported. In the 1970s, the USA (40 000 t) and the USSR (18 000 t) were the main importers of cashew kernels, the latter mainly because of bilateral trade agreements with India who paid industrial goods with cashew kernels (ITC 1973). Other major importers over the same period were Canada (3 100 t), United Kingdom (2 500 t), GDR (2 300 t), Australia (2 100 t), FRG (1 500 t), Japan (1 000 t), Belgium, New Zealand and Sweden (600 t total) (ITC 1973).

Since the 1970s, the world import of cashew kernels has changed as much as the nut production. The major importing countries and the quantities imported are shown in Table 18. The import level reached in 1990 was the highest for most countries (except USSR) since 1980. The latter had its highest imports (30 029 t) in 1975 and the lowest (108 t) in 1984 and is thus not a very reliable importer. The USA (49 257 t), Canada (6 583 t) and Japan (6 599 t) also reached peak imports in 1976 (NOMISMA 1994).

Table 18: Cashew kernels imports into major markets (Mt.)

	1988	1989	1990	Average 1989-91
Australia	2 014	2 720	2 808	2 930
Belgium	362	295	363	
Canada	3 299	4 377	4 730	4 309
France	1 176	1 065	1 202	
Germany	3 380	3 261	3 737	3 661
Japan	3 718	3 783	4 303	4 520
New Zealand	324	350	350	
Netherlands	2 883	3 058	3 873	3 669
Sweden	65	70	70	
UK	4 212	4 855	5 100	4 919
USA	38 010	41 338	54 600	48 372
USSR/CIS	3 151	5 849	9 807	3 328
Total	64 582	72 590	92 513	75 708

Source: columns 2, 3 and 4 NOMISMA (1994), column 5 Jaffee et al. (1995)

A more differentiated picture of cashew imports is shown by the Indian Cashew Journal (Increased Export, 1994). The Indian exports to USA increased from 6 785 t in 1990/91 to 24 487 t in 1992/93, the exports to CIS (USSR) decreased from 21 349 t to only 46 t during the same period. Compared with the figures from NOMISMA (1994), there was apparently an increase from 1990 to the period 1990/91 referred to by the Indian Cashew Journal. It is very probable that the CIS will come into the market again as their economy recovers. Other countries that imported an average of over 50 t in the period 1990/91 to 1992/93 cashew kernels from India are Lebanon (55 t), Italy (56 t), France (60 t), Spain (61 t), Korean Republic (86 t), Bahrain (121 t), Kuwait (132 t), Saudi Arabia (163 t), Israel (229 t), Taiwan (333 t), Canada (369 t), Poland (560 t), Czech Rep. (912 t), U.A.E. (1077 t), Hong Kong (1 234 t) and Singapore (1 547 t) and others (296 t), totalling 7 231 t or 14,4% of the Indian export (Increased Export 1994).

RUDECO (1989) predicted that an increased production could be taken up by the market if the price fell from 5 500 US$/t to about 5 250 US$/t, citing an unnamed leading nut processor. Currently, the prices are at 5 200 US$/t (Kumar 1995) and apparently the market could cope with the increased quantities in 1991 and 1992. As the economies of the so called “Tiger Nations” of South East Asia develop very fast, their demand will probably increase. The same can be predicted for China and Latin America. Home consumption in the producing countries might rise as well and countries with fast developing economies might abandon or decrease their cashew production. Therefore it seems still worthwhile to develop the cashew industries in countries that have appropriate growing conditions.

2.2.2.4 Trade in CNSL

Table 19 below shows the trend of CNSL exports and imports during the past 30 years. The quantities entering the market have risen steadily, but the price varies enormously, from year to year and from export country to export country. The highest earning for CNSL was 1 510 US$/t, achieved by Tanzania in 1979 (mean 1 367 US$/t). 1979 was also the year of peak export with a total of 36 350 t. The lowest price (10 US$/t) was paid to Mozambique in 1984 (mean 313 US$/t) (NOMISMA 1994). Higher prices stimulate the recovery of CNSL by the shelling factories, and the future of the market will depend on other uses than friction dust. Indian CNSL fetches higher prices (by 10-70%) than CNSL from other countries.

Table 19: CNSL export, import and mean price (in t)

	CNSL export					CNSL imports (major markets)			Price**
Year	India	Brazil	Mozam-bique	Tanza-nia	World	USA	UK	Japan	in US$
1962	7 400	800	1 400	0	9 600	5 393	2 559	1 128	350
1967	9 400	1 600	3 700	600	15 300	7 789	4 284	2 518	180
1972	5 000	7 300	12 200	400	24 900	12 232	4 984	5 279	175
1977	2 970	7 600	10 000	870	21 440	10 625	5 937	5 396	336
1982	5 800	6 700	7 100	2 000	21 600	6 518	4 559	7 137	205
1987	5 500	15 250	3 500	0	24 250	9 513	5 813	4 705	459
1990	4 400	26 300	1 700	0	32 400				298
*1994	3 482								287

Sources: Wilson (1975), NOMISMA (1994), RUDECO (1989),

** All time record (1995) - data only available for India.

* Mean fob price for (listed) CNSL entering the world market, prices per country differ

The main importing countries are USA, UK and Japan, but South Korea, The Netherlands, Spain and Mexico are other main importers of CNSL (RUDECO 1989, NOMISMA 1994). India used a total of 6 900 t on their own in 1978 and there is active research to increase the use of CNSL in the country (Murthy et al. 1984).

2.3 Cashew nut processing methods

The raw nuts should be sun dried for one to six days (Nair 1984) to reduce moisture content from about 25% to 9% or less for safe storage and to mature the seed through the infra red and ultra violet rays of the sun. Correctly dried nuts are pinkish in colour and when shaken together will make a sharp rattle. No impression can be made with a thumb nail into the exocarp (Russell 1969). They should only contain few impurities (0.25% Tanzania; 1% Mozambique) (Ohler 1979), and not more than 10% of the nuts should be damaged (RUDECO 1989). Dry raw nuts can be stored under dry conditions for at least 2 years (Morton et al. 1972) without losing their flavour, but they are generally processed within one year of harvesting. Kumar (1995) mentions that 3 year old stocks are of inferior quality for processing.

The decortication of cashew nuts is hampered by CNSL contained in the honeycomb structure of the mesocarp (Figure 4). CNSL blisters human skin unless precautions are taken and it will spoil kernels on contact.

In traditional artisanal cashew processing the nuts are put in an open pan over an open fire and stirred continuously to avoid scorching (Tropical Products Institute, 1961) until they start burning, then they are thrown on to sand to be extinguished and to remove the remaining liquid on the outer skin (Behrens 1993). In industrial processing the nuts are graded in different size classes and rehumidified to about 16% moisture by spreading water over them for about two days to make the kernel elastic and to fill the cells of the shells with water. Then they are “roasted” in a “hot oil bath”

(CNSL) that is heated to 192°C for about 90 seconds[9], depending on the size of the nuts. Ohler (1966) mentions other methods as steam processing at 270°C, quick roasting in rotary ovens at 300°C or cold methods that involve peeling of the outer shell, but these methods did not gain wider acceptance. Through the roasting process the cells of the mesocarp and the endocarp break and about 25% of the CNSL contained in these tissues flows into the bath. The remaining liquid on the outer shell is removed with sawdust. Both methods, the artisanal and the industrial, make the shells brittle so that they can be broken easily.

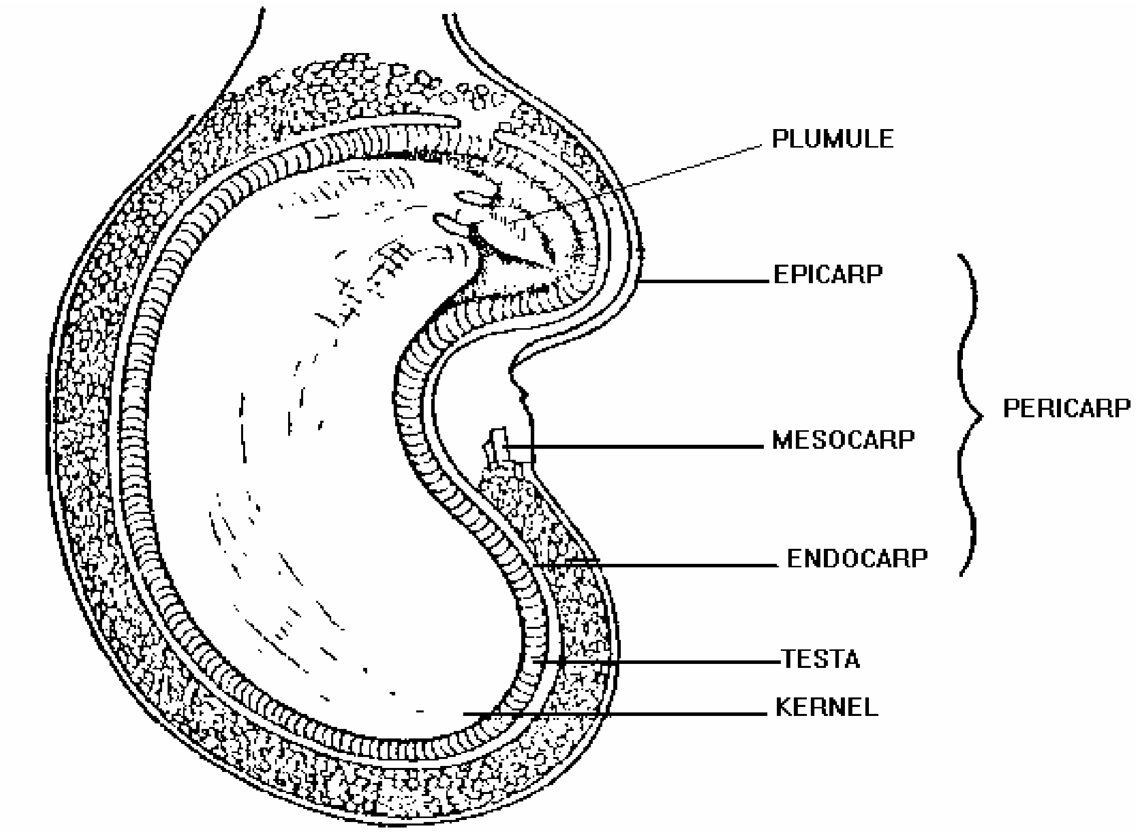


Figure 5: Section of a cashew nut
[modified from Russel (1969)]

[9] This roasting process before shelling is often confused with roasting (and salting) of kernels. In the described process the kernels are not affected, just the shell.

Another method to avoid contamination of the kernel with CNSL is to deepfreeze the nut and split the shell while frozen. This is a method suggested by R. Ramseier, a Swiss engineer, who developed a cashew shelling machine [Widmer & Ernst, later Bühler, currently Oltremare (Ohler 1995)] that cuts the shell by two specially designed horizontally mounted sawblades. The nuts are held by two rubber belts that hold and convey the nuts to the sawblades and consequently to two small wedges that separate the shell halves. The freezing method works and produces white kernels from which the testa can easily be removed. Disadvantages lie in the high cost of freezing and the fact that nuts and shells cannot be separated by air-blowing because they have the same specific weight. Nevertheless, with modern, laser operated separation equipment this might be a good method to produce very large white kernels for the luxury market. The quality of CNSL obtained through this type of processing is much more uniform than through hot-oil-processing (Ohler 1995).

There are different methods for manual cashew shelling. The most simple consists of placing the prepared nuts (page 30, paragraph 3) on a stone and using a hardwood stick to crack the shell. An average sheller can shell 10 nuts per minute or 21 kg/day yielding about 5 kg of kernels. Experienced shellers in India can shell twice as much with 90% whole kernels. Semi mechanised processes using a pair of knives shaped in the contour of half a nut were developed in Brazil and India. The equipment is simple and allows two persons to produce 15 kg of kernels/day (Ohler 1979).

The Italian Oltremare system and the Japanese Cashco systems used the knives in an industrial plant. The nuts are forwarded on a chain and automatically cut. In the first system the nuts are fed in by hand and the knives twist after coming together and separate shell from the nut. The latter process is fully automatic and uses pins for separation. Theoretically, 85-90% whole nuts are obtained by Oltremare and 75% by Cashco. The Swiss system combined with traditional roasting can also obtain 90% whole kernels. A British system developed by Fletcher and Stuart in cooperation with the Tropical Products Institute (TPI, now National Resources Institute, NRI) works with centrifuges to crack the shells. Shells and kernels are then separated in an air stream, heated shells are lighter and blow away. The method can, under perfect operation, obtain up to 75% whole kernels. The advantage of this system is its simplicity it was specially designed for local maintenance in developing countries.

After shelling, the nuts have to be dried to about 6% moisture content, thereafter the testa can be peeled off easily. They are then graded to the different categories described above (page 26), rehumidified to 8% and packed in 25 lb. (11.34 kg) tins (or other airtight containers), filled with CO_2 and sealed. The CO_2 inhibits infestation by insects and is slowly absorbed by the nuts thus producing a vacuum that prevents shaking and breaking of the nuts during transportation.

3. Cashew biology

This chapter is divided into three main parts - morphological characters of flowers (3.1), a short section on the chromosomal situation (3.2), and a larger part about the flowering process (3.3). The latter is subdivided into four divisions, including reproductive effectiveness (3.3.4) which has again three subdivisions.

3.1 Morphological characters

3.1.1 Inflorescenses

Reddy et al. (1986) give the number of panicles per tree as 100-400, but this depends more on the size of the tree than on genetic characters and is therefore not a valid selection criteria. More important is the relation of perfect to staminate flowers within inflorescences and this probably depends on the genotype. Reported relationships are listed in Table 20. The relationship can be an important criterion for pre- selection of cashew trees. The variation is huge between the different observations and if it is considered that all these values are averages from trees (lines or clones) that had been selected previously, total variation is underestimated. The most outstanding figures are given by Chattopadhyay et al. (1993), stating a ratio of 1 perfect flower to 0.7 male flowers.

The author observed trees with inflorescences without perfect flowers in Senegal and a tree bording a mangroves’ habitat that had only hermaphrodite flowers but which set no fruit. The number of hermaphrodite flowers varies significantly between trees and is highly correlated with fruit set and ripe fruit number. There is no year to year variation (Wunnachit et Sedgley 1992) thus indicating that the number of hermaphrodite flowers can be used as reliable criterion for selection of superior genotypes of cashew. A positive correlation between the percentage of hermaphrodite flowers and yield was also found by Parameswaran et al. (1984a).

Table 20: Number of flowers per panicle and relation between perfect and male flowers

Country	Flowers per panicle	Perfect flowers	Male flowers	Ratio perfect : male flowers	
				mean	range
Jamaica [1]		13-96	180-705	1:8	up to 1:28
Tanzania[1]				1:3.7	
				1:6.7	
India[2]	44-116				1:3.8 - 1:15.7
India[3]	200-650				1:3 - 26.7
India[4]	991 449	33 114	958 335	1:29 1:2.9	
India[5] (Selected clones)	162-382				1:0.7 - 1:1.9
Australia[6]	538-852				1.35 - 15.9

Sources: [1] Ohler (1979), [2] Patnaik et al. (1985), [3] Nawale et al. (1984), [4] Sapkal et al. (1994), [5] Chattopadhyay et al. (1993), [6] Wunnachit et Sedgley (1992)

3.1.2 Flower structure

Species of *Anacardium* possess a dimorphic androecium of one to four large stamens and a set of five to eleven smaller stamens or staminodes (Cundall 1995). In this thesis only the flower structure of *A. occidentale* is described below. Cashew is andromonoecious: each panicle produces perfect (hermaphrodite) and staminate (male) flowers (Ohler 1979, Wunnachit et al 1992b). According to Copeland (1961) the flowers are disposed in monochasial cymes and the apparent panicle is actually a thyrse (see **Error! Reference source not found.**). As inflorescences form, panicle branches develop from the first visible buds. The buds of individual flowers become apparent 5-6 weeks later.

Newly opened cashew flowers are small and white and scented. After a few days the colour turns pink (Ohler 1979). Reddy et al. (1986) have observed pink petals in most cases, but some selections had white or red petals. Morton (1961) states that the flowers are yellowish pink and about 8 mm large, born in 15 to 25 cm loose terminal panicles. The calyx usually consists of 5 narrowly lanceolate overlapping sepals, 3-5 mm long, each acute and externally bright green, but yellowish-green inside. There are 5 petals, each 10-12 mm long and 1-1.5 mm wide. Male flowers have 6 to 14 stamens (Wunnachit & Sedgley 1992) of which one or two are well developed (Ochse et al. 1961, Ohler 1979, NOMISMA 1994). Ohler (1979) reported variation in sepal number from 4 to 7 and petal number from 4 to 9. The stamens are arranged in an ellipse. The largest stamen is located at one end of the ellipse and is much stronger and longer than the others. On this large stamen, the anther, larger than the others, is exserted (Ohler 1979, Wunnachit et al. 1992a). Each flower has an ovary, vestigial in the case of male flowers. The pistil in perfect flowers, which are larger than male flowers, is usually longer than the largest stamen (Ohler 1979, Wunnachit et al. 1992b). The transmitting tissue is wide in the top and narrow in the lower region of the style. This might be an adaptation to bring the most vigorous pollen tube to the single ovule for fertilisation. (Wunnachit, Pattison et al. 1992). Functionally female flowers have been found in Brazil (Ohler 1979).

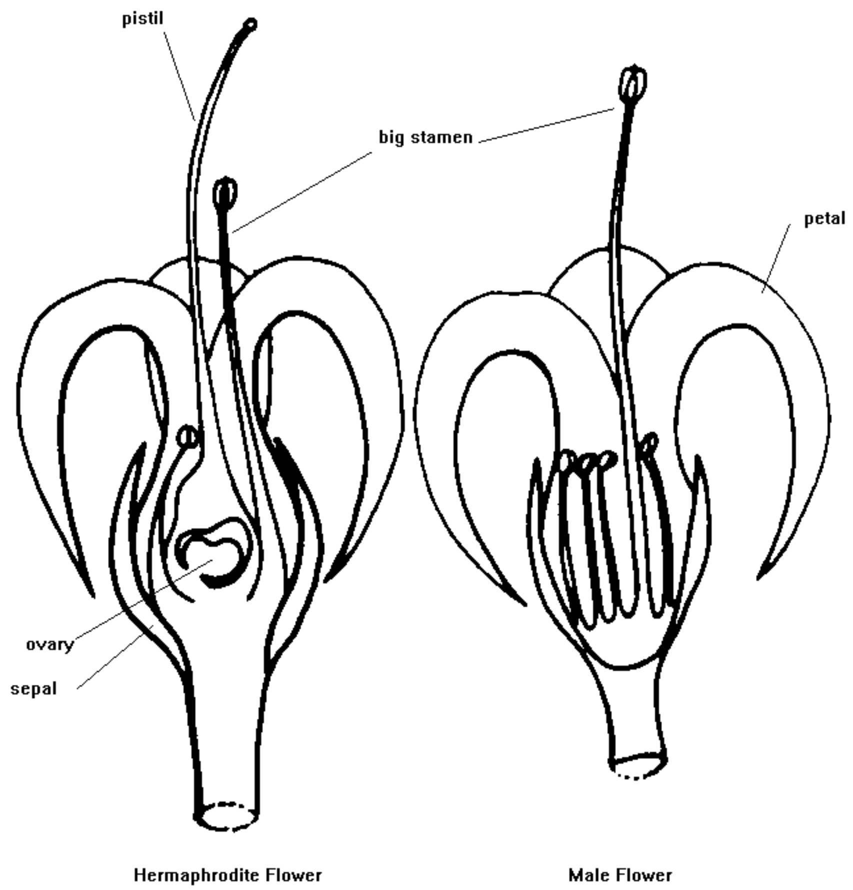


Figure 6: Longitudinal section of typical cashew flowers

3.1.3 Pollen

One anther yields 600 to 700 pollen grains (Reddi 1991). Pollen from different genotypes of *Anacardium occidentale* has been examined by several researchers. Pollen grains of *Anacardium* have a polar diameter of 40 μm and equatorial diameter of 35 μm (Mitchell et al. 1987). Monosulcate tricolpate grains predominate (Akinwale 1992). The pollen grains are sticky, only 1.75% of pollen sampled by Reddi (1991) were falling as singles on microscope slides when the dehisced anthers were touched. Pollen grains were not trapped by air samplers, thus showing that the role of wind in pollination must be minimal.

A comparison of pollen from large and small stamens and of hermaphrodite and male flowers did not reveal differences in grain number, structure, viability and vigour. Viability declined 48 h after anthesis. Pollen from large anthers in functionally male flowers had the highest capacity to germinate on the stigma, followed by pollen from small anthers in functionally male flowers. Pollen from the anthers of hermaphrodite flowers had the lowest capacity. Sugar was present in all pollen types, but at higher levels in hermaphrodite flowers. Pollen of the male flower is specialised in fruit set and pollen of the perfect (hermaphrodite) flower in attracting insects (Wunnachit et al. 1992b).

3.2 Chromosome numbers

Cashew is polymorphic and several chromosome numbers are reported. Darlington et al. (1955) indicate a complement of 2n = 42, whereas Cundall (1995) reports 2n = 24, 2n = 30, 2n = 40 and 2n = 42.

3.3 The flowering process

3.3.1 Flowering and fruiting in relation to climate

The age at which cashew starts to flower depends on growing conditions, on treatment (propagation) and on genetic factors. Under favourable conditions cashew trees may start to yield after 3 years and usually a few fruits and flowers are produced even in the second year (Ohler 1979). In exceptional cases, cashew trees start flowering after six months (Calzavara 1971). Similar behaviour was noted by the author in Senegal -on trees grown from seeds imported from Brazil, where Calzavara had worked. Usually, flowering follows the growth flush at the end of the rainy season. The inflorescences are produced at the distal ends of the newly developed shoots (**Error! Reference source not found.**). Under evenly distributed rainfall flowering can take place throughout the year (Tirimanna 1984, FAO 1988). Under bimodal rainfall conditions it takes place twice a year (Ohler 1979). The author observed trees flowering and producing throughout the year under conditions with only 4 months of rainfall and low relative humidity (<10% at midday) in Senegal. For a better understanding the climatic data for Kaolack are presented in Table 21 (see also Figure 2). Both the genotype as well as good soil conditions might be the reason for this flowering behaviour. The main fruiting period for these trees, however, corresponded with the normal fruiting period at the end of the dry season (April to June) in this area. In Australia the leaf flush occurred (beginning of June) one month after the hot rainy season when temperature, relative humidity, rainfall, daylength and radiation had declined. During the whole reproductive period from mid-June to September the relative humidity was below 40% while the temperatures rose from 22°C to about 30°C (Wunnachit et al. 1992a).

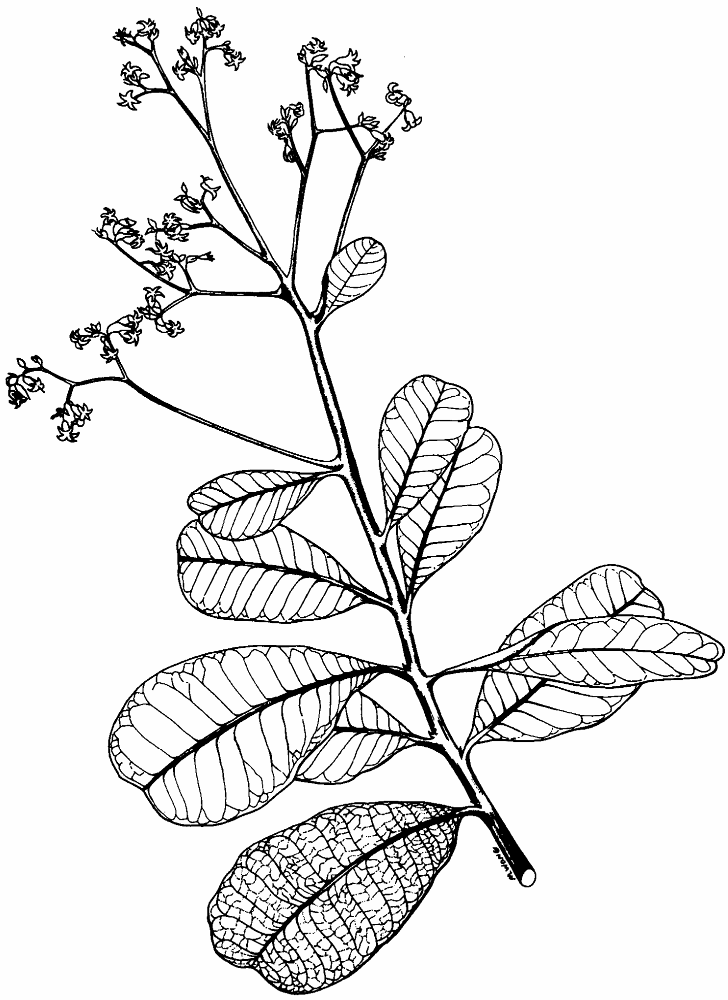


Figure 7: Young cashew shoot with (small) inflorescence

Table 21: Climatic data and flowering- yielding- period for cashew in (central) West Senegal

Kaolack	Jan	Feb.	Mar	Apr.	May	Jun.	Jul.	Aug.	Sep.	Cot	Nov.	Dec.	Year
Rainfall (in mm)	0	1	0	1	6	63	157	283	216	77	7	1	812
Mean temperature (in °C)	24,6	26,8	28,6	30,0	30,8	31,1	28,9	27,8	28,2	28,8	27,6	24,8	28,1
Rel. humidity at 05.00 (in %)	53	55	60	66	75	84	89	94	95	92	80	60	
Rel. humidity at 11.00 (in %)	24	23	22	26	36	52	67	75	72	61	37	27	
	Main flower. period			Main harvesting period						Vegetative growth flush		Flow. starts	

Flower and fruiting periods differ according to the climate and, to a certain extent, with altitude (Reddy et al. 1986). Lower temperatures delay flowering, but it is not influenced by day length (Ohler 1995). Other main flowering and fruiting periods are shown in higher yields (Parameswaran et al. 1984b). Heard et al. (1990) found

[10]. The mean annual temperature is in all cases between 25-30 °C, the average precipitation between 670 to 3 030 mm. Highest yields in India are reported from Kerala. The high rainfall in the area might be one reason for the higher production, despite the image of cashew to thrive under semi-arid conditions. The figures also prove the adaptability of the cashew tree to a range of climatic conditions.

3.3.2 Flowering at stand level

Cashew trees generally have three phases of flowering, a male phase, a mixed phase and a second male phase. Most of the perfect flowers open three to six weeks after the beginning of flowering (Northwood 1966, Ohler 1979). Parameswaran et al. (1984b) made a detailed study of flower opening in 20 trees of cashew. The patterns are shown in **Error! Reference source not found.** and are typical for cashew. Flowering extends over a period of 52-125 days, varying with individuals (Parameswaran et al. 1984b). Most trees showed the three distinct phases. Three trees had no male phase in the beginning, two of them no male phase at all. The group yielding above the median (11.6 kg/tree) had a shorter mean flowering period (84 days) compared with the group yielding below median (3.8 kg/tree and 103 days mean flowering period). The mean total male phase was 9.65 days (10.3%) for the former group and 26.8 days (26.1%) for the latter. The longer mixed phase might have increased chances for pollination

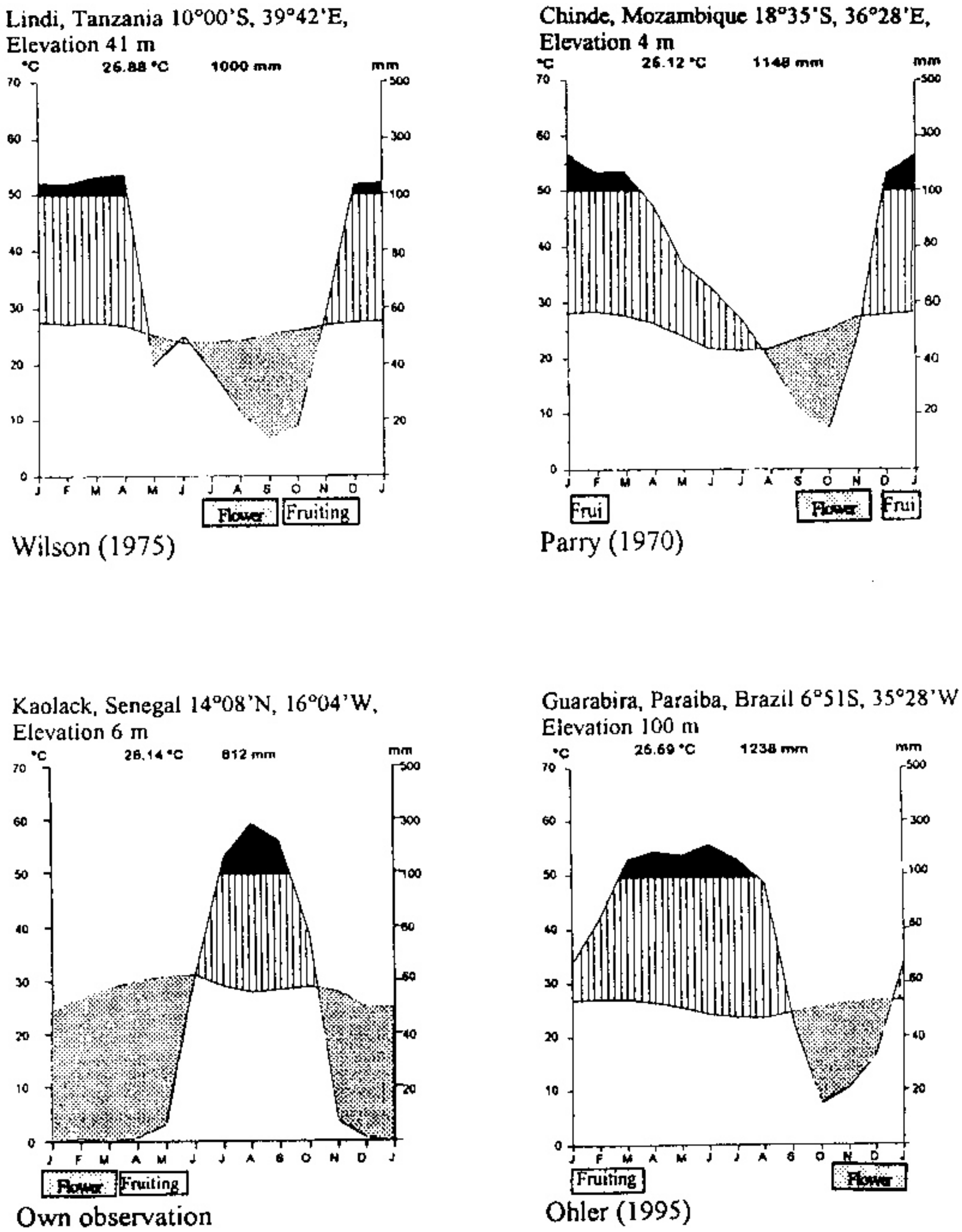
[10] The periods shown in the graphs only indicate the main flowering season, but they are not exact to either end. Late flowering and early fruiting can well occur at the same time on a tree. Times can be shorter or longer than shown, depending on genotype, soil conditions and climatic changes.

and thus being the basis for higher yields (Parameswaran et al. 1984b). Heard et al. (1990) found

Figure 8: Climate, flowering and fruiting of cashew in main producing countries

Sources: NOMISMA (1994) for cashew growing areas

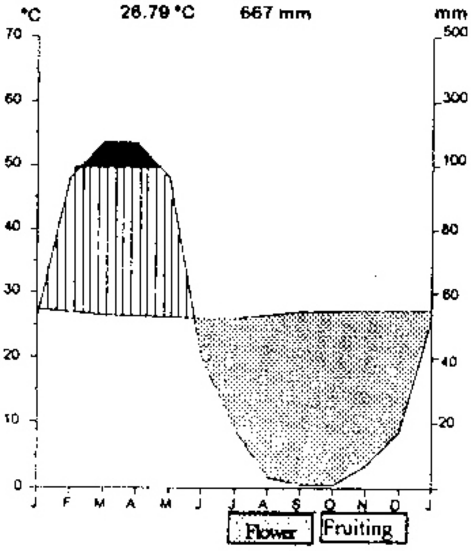
Meteorological Office (1983) for Africa; FAO (1985) for Brazil, FAO (1987) for Asia



higher yields (Parameswaran et al. 1984b). Heard et al. (1990) found

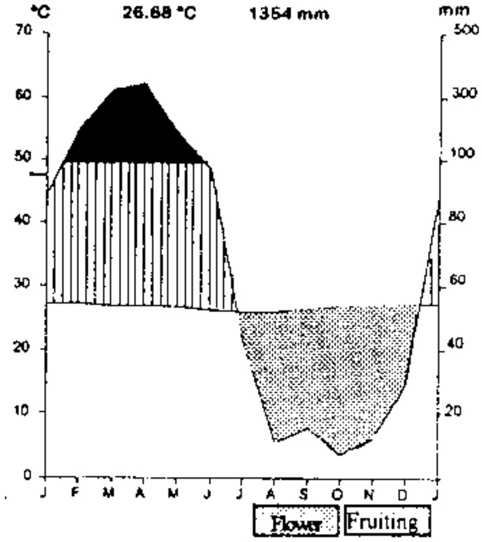
(cont.)

Guixada, Ceara Inland, Brazil, 4°57'S 39'W
Elevation 179 m



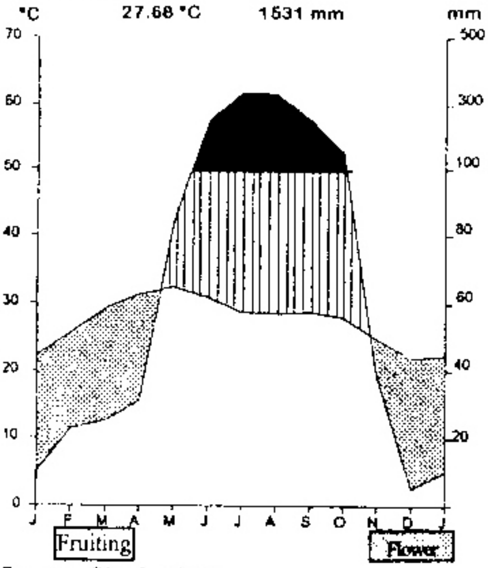
Ohler (1995)

Fortaleza, Ceara coast, Brazil, 3°44'S, 38°33'W,
Elevation 19 m



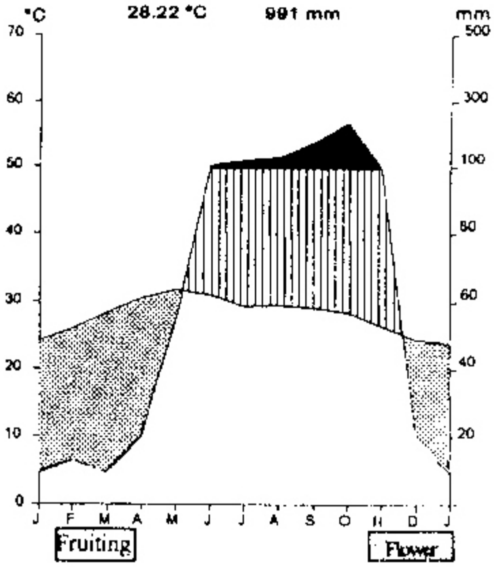
Ohler (1995)

Cuttack, Central Orissa, India 20°28'N, 85°56'E,
Elevation 27 m



Source: Singh 1995

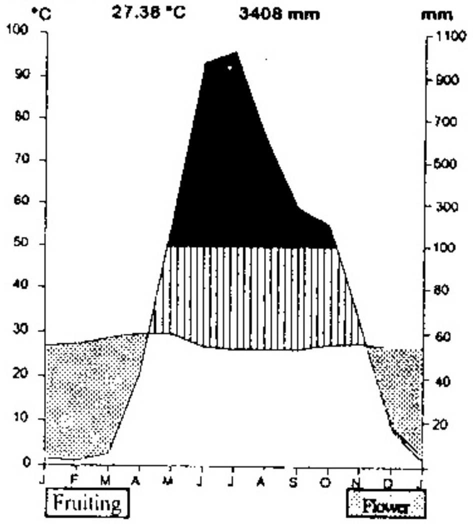
Vishakhapnam, Orissa- North, 17°43'N, 83°14'E,
Elevation 3 m



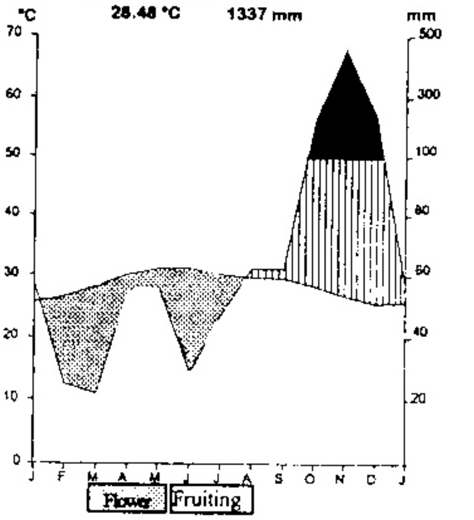
higher yields (Parameswaran et al. 1984b). Heard et al. (1990) found

(cont.)

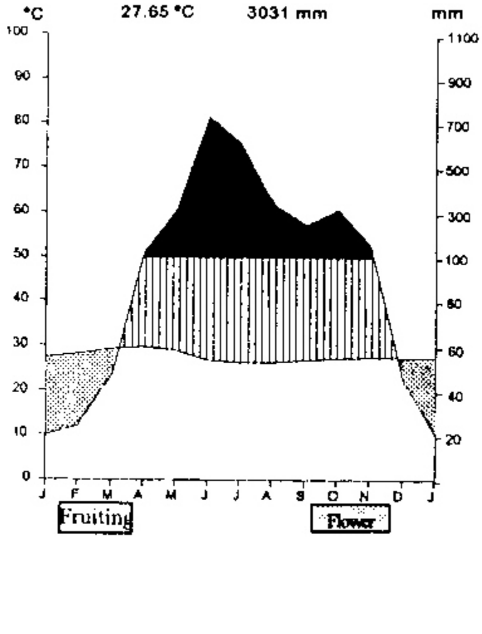
Mangalore, Karnataka, India 12°52'N, 74°51'E, Elevation 22 m



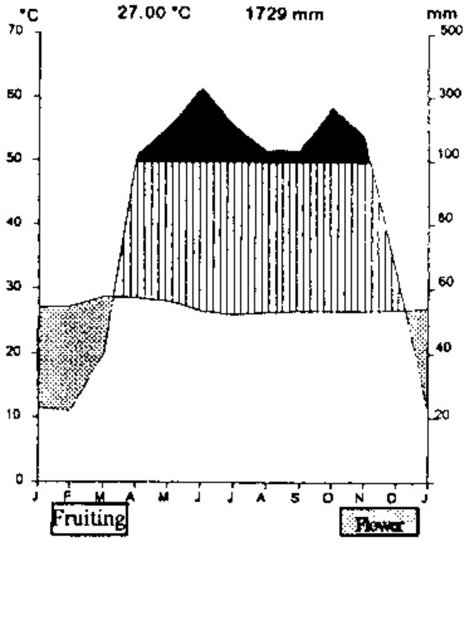
Naggappattinam, Tamil Nadu, India 10°46'N, 79°51'E, Elevation 9 m



Cochin, Kerala, India 9°58'N, 76°14'E, Elevation 3 m



Trivandrum, Kerala, India 8°28'N, 76°57'E, Elevation 64 m



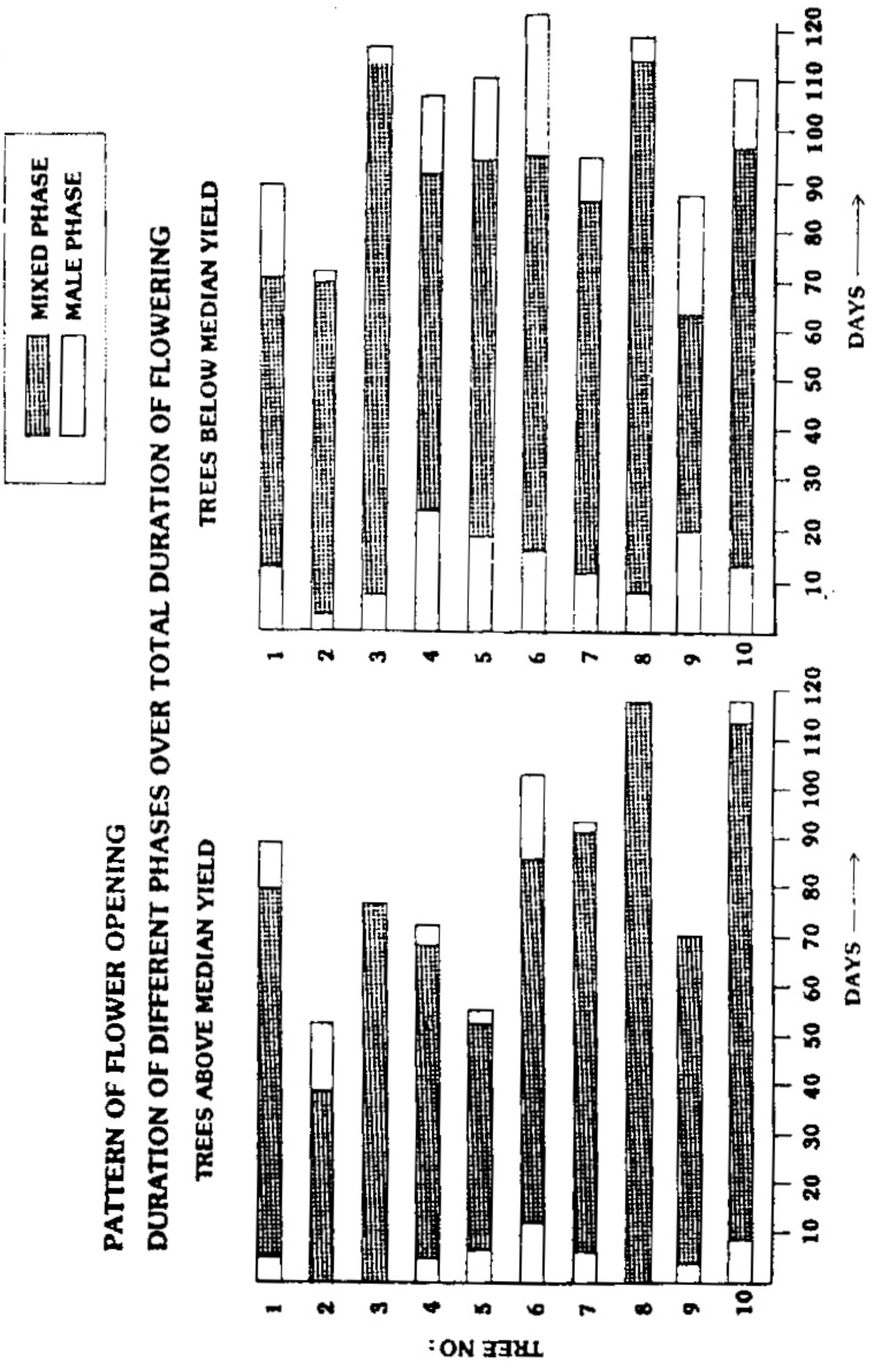
about one hermaphrodite flower opening every day in the first 30 to 40 days of panicle life, the male flower opening reached a peak of 18 opened flowers at day 32; at day 50 about 10 male flowers opened. Kumaran et al. (1984) found also a pure hermaphrodite phase after the first male phase, with a mean duration of 1.2 days.

3.3.3 Individual flower life: anthesis and pollen receptivity

Cashew flowers start opening at sunrise, more flowers open until the mid-afternoon. Different times for anthesis are given by different authors, with peak periods of flowers opening in the early morning (06.00 h - 07.00 h) and around midday (11.00 h - 13.00 h) (Ohler 1979, Mohan et al. 1982, Wunnachit et al. 1992a). Flower opening, stigma receptivity and anther dehiscence are also influenced by the climate and the processes are much shorter in the heat of the day than early in the morning (Ohler 1979). Damodaran (1966) had the impression that the gynoecium became receptive one day before anthesis and remained so for two days, with maximal receptivity soon after anthesis. Rao et al. (1957) found the stigma receptive throughout the day of opening but loosing the receptivity the next day.

Wunnachit, Pattison et al. (1992) found that the pistil supported maximum pollen germination and tube growth when pollinated within 3 h of anthesis and that the penetration of ovules by pollen was significantly reduced after that period. They also assessed specific combining ability (SCA) and general combining ability (GCA) amongst cashew genotypes. SGA was measured by pollen tube growth and both SGA and GCA by final fruit set. A difference in pollen germination between self and cross pollination was not found, but yield was reduced following self pollination (Sedgley et al 1992). Reduced yields indicate rising self-incompatibility of certain cashew lines mentioned by Ohler (1979). Wunnachit, Pattison et al. (1992) concluded that genotypes with high GCA should be interplanted in cashew orchards to minimise selfing.

Figure 9: Pattern of flower opening [from Parameswaran et al. (1984b)]



3.3.4 Reproductive effectiveness

3.3.4.1 Pollinators and pollination efficiency

Insufficient pollination may be a limiting factor for cashew production and therefore there has been active research to determine the pollinating agents, despite the fact that Morton (1961) has already mentioned that “cashew flowers produce an abundance of nectar and attract honeybees in great numbers”, thus confirming indirectly insect pollination. NOMISMA (1994) still states that wind is the main pollinating agent because self pollination is not possible due to the structure of the flower. One recent study (Elsy et al. 1986) confirms wind as major pollination agent, but the method used in his study (opening of the bags during main anthesis period) is rather unreliable. In the same study a mean of 2.16 airborne pollen grains per cm^2 on a sticky surface were also found. Heard et al. (1990) found 1 pollen grain/cm^2 over two days and states that the role of wind pollination is minor. Other studies do not confirm these results and airborne pollen were not found (Northwood 1966, Reddi 1991). Even medical researchers state that cashew is mostly entomophilous and pollen is not transported by air (Fernandes et al. 1995). Reddi (1991) clearly excludes wind pollination because of the sticky nature of the pollen. Reports on insects visiting cashew flowers are frequent (Table 22). It is indicated in this table that cashew flowers produce nectar. Wunnachit et al. (1992a) state that the primary function of the panicle and floral nectar is to attract insects for pollination. The extra floral nectar secretion is not associated with pollination and might serve to attract ants for the protection of leaves and fruits from predators. The number of insects visiting flowers varies with place, tree and season (Heard et al. 1990).

Table 22: Insects on cashew flowers and reported cashew nectar production

Morton (1961)	Nectar in abundance, flowers visited by many insects
Ohler (1979)	Ants, honeybees
Free et al. (1976)	Honeybees, ants, Diptera, hummingbirds
Moncur (1986)	Nectar only in few flowers, concentrations varied between selections, visited only by ants
Heard et al. (1990)	Honey bees (*Apis melifera*) collect nectar, and 40 other species, 10 coming regularly (butterflies, flies)
Reddi (1991)	20 insect species feeding on nectar of flowers
Wunnachit et al. (1992a)	Secretory tissues -in perfect and male flowers -at junctions of panicle branches -on the adaxial leaf surface -on developing fruit

In Kenya, high yielding trees had more stigmas with pollen than low yielding trees. This might be because the low yielding trees might be less attractive to foraging insects (Free et al. 1976). In Malaysia cashew is an important feeding plant for honey bees (Phoon 1983, Malaysia Beekeeping 1987). *Apis melifera* and *Ligyra* sp. were found to be good pollinators in Australia and an increase of insect populations from 1987 to 1988 increased pollination from 25% of perfect flowers to 96% (Heard et al. 1990). Free et al. (1976) expect honeybees to pollinate most cashew flowers in Kenya and Jamaica, but admit that ants and Diptera contribute. *Apis cerana*, *A. florea* and *A. dorsata*, other bees, ants, wasps, flies and butterflies were found to pollinate cashew flowers in India (Reddi 1991). The introduction of honeybee hives into cashew orchards did improve yield (Wunnachit et Sedgley 1992).

3.3.4.2 Fruit set and fruit development

About 10% of the hermaphrodite flowers produce mature fruits (Purseglove 1968). After fruit set a substantial fruit drop follows in most cases (Table 23). Sapkal et al. (1994) studied fruit set and fruit retention on 9 clones in 1985 (550 mm rainfall) and

1986 (595 mm) and found that only 0.7-4.1% of hermaphrodite flowers developed into ripe fruits. They attribute this to poor pollination (fruit set between 9-22%), but the dry weather might also be responsible for these low values. However, there are clonal differences and careful selection can easily increase yield.

Table 23: Fruit set and fruit drop

Fruit set (% of perfect flowers) and cause	Fruit drop (% of fruits set) and cause	Location	Author
40 low pollination	>77	Australia	Wunnachit & Sedgley (1992)
12-55	51-100	Orissa (India)	(Patnaik et al. 1985).
3-31 low insect populations	34-84 Physiological causes at the initial stage; insect or disease incidence for fruit drop in later stages	West coast of India	Nawale et al. (1984)

The time from fertilisation of the ovary to maturity of the fruit depends mainly on the temperature. Rao et al. (1962) found a range from 43 days in the later (warmer) season (April, 28 °C mean temperature) to 58 days in the early season (February, 24.4 °C mean temperature). In the early stage the nut grows faster than the apple and reaches its maximum size about 30 days after pollination. The peduncle (apple) remains smaller during this time and increases only after 35 days, while the nut shrinks by about 10% until maturity (Figure 10[11], Plates 3 and 4). Kumar et al. (1984) stated that optimum fruit development (ripening) occurred at 70 days after fruit set, without specifying the conditions. Renganayaki et al. (1993) found that early maturing nuts (40 days, 3.39 g/nut) were smaller than nuts that matured at 50 days (4.65 g/nut) or 60 days (5.38 g/nut). It seems, according to the method described, that the nuts harvested after 40 and after 50 days were not fully mature. This can be

[11] This drawing shows the stages of fruit development but not the true size of the fruit.

explained by too early harvesting which is a widespread practice on commonly owned trees.

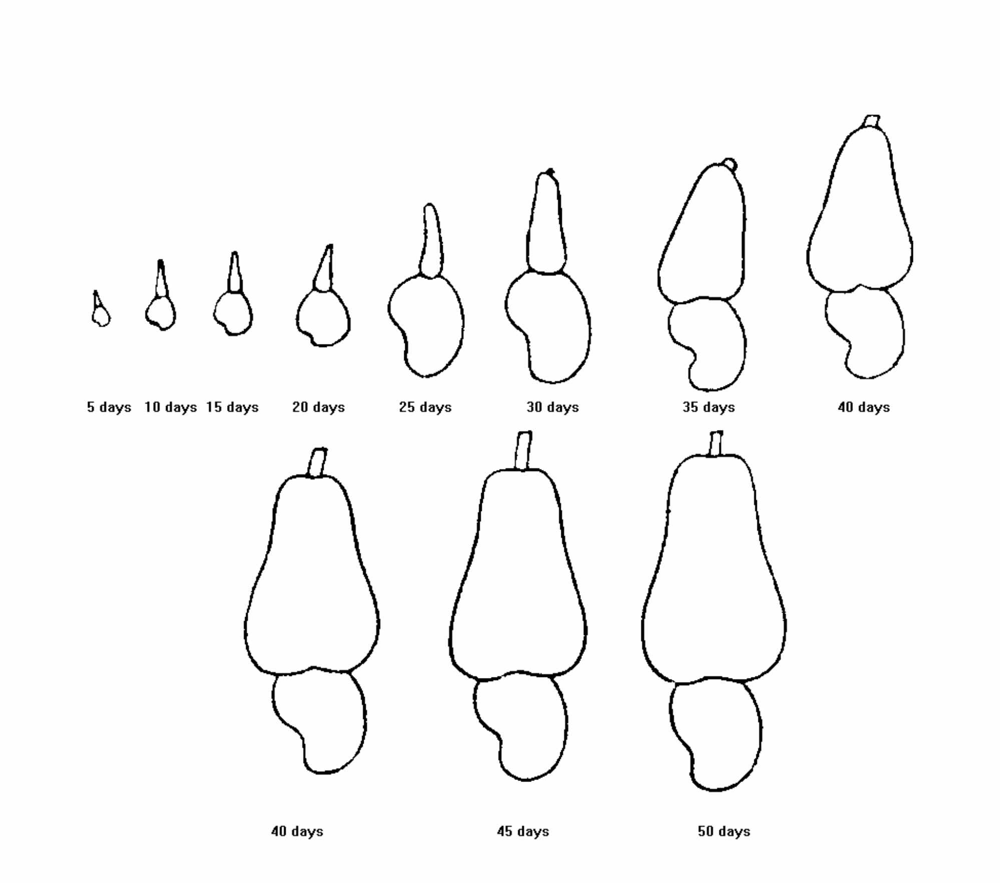


Figure 10: Stages of fruit development (from Rao 1962)

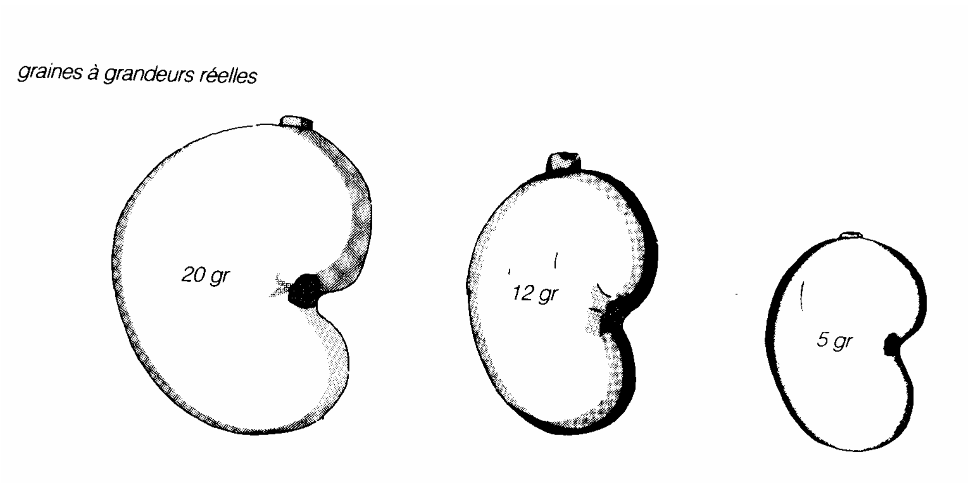


Figure 11: Original size (1:1) of 3 well formed cashew nuts [drawing by Vits from: Behrens (1988)]

Plate 3: Cluster of developing cashew nuts about 25 days after pollination

Plate 4: Cluster of developing cashew nuts about 30 days after pollination

3.3.4.3 Interventions to improve fruit production

Fruit set can be increased by using plant growth regulators. Babu (1982) sprayed whole trees at the time of fruit set and a fortnight later (Table 24). IAA at 50 ppm and IBA at 70 ppm produced the highest increase in fruit set. Konhar et al. (1988) conducted a study with 3 applications at 15 days intervals and confirmed positive influence of chemicals (Table 25). In his trial, fruit retention more than tripled over the control in all treatments. The highest percentage was obtained with Nutron. Chattopadhyay (1982) treated trees with GA, 2,4-D, 2,4,5-T and Noxa (beta naphtoxyacetic acid). There was increased fruit set and fruit retention over controls.

Table 24: Chemical treatment of cashew trees and fruit set

Treatment	Concentration	Fruit set (%)	Increase over Control (%)
Cycocel	500 ppm	10.0	13.6
	750 ppm	14.8	68.2
NAA	30 ppm	12.5	42.0
	50 ppm	16.6	88.6
IBA	50 ppm	13.6	54.5
	70 ppm	19.4	120.5
IAA	30 ppm	12.7	44.3
	50 ppm	32.2	265.9
Control		8.8	

From: Babu (1982)

Table 25: Chemical treatment of cashew trees and fruit retention

Treatment	Concentration	Fruit retention (%)	Increase over control (%)
Nutron (tricontanol	500 ppm	25.8	253.4
Ethrel (ethephon)	50 ppm	25.4	247.9
NAA	45 ppm	22.8	212.3
Control		7.3	

4. Cashew cultivation

This chapter covers five topics related to cashew in the field. These are: objectives of growing cashew (4.1), cashew agronomy (4.2) that is subdivided as appropriate and three shorter sections about socio economic considerations (4.3), selection (4.4) and vegetative propagation (4.5).

4.1 Objectives

The first cashew plantations in many countries were established by the forest departments as an easy way of afforestation. Cashew trees in India were planted for the protection of coastal dunes, sometimes in combination with *Casuarina equisitifolia* J. R. & G. Forst and *Cocos nucifera* L. (Patro et al. 1979) and for wasteland recovery (Chopra 1990, Chowdhury 1992), almost exclusively on poor soils unsuitable for other crops. In Brazil, plantations exist with more than 40 000 ha (Rudat 1995). In the countries south of the Sahel with 600-800 mm annual rainfall, cashew is important as a tree to counterbalance desertification. Plantations under forest department management reached sizes of more than 200 ha, but farmers

Table 26: Cropping system and yield of cashew in selected countries

Country	Plantation size (ha)	Spacing (m)	Objective	Inter-crops	Yield (kg)	Author
Mozambique	plantation: 77 farmers 0.3	12 x 12	fruits	 y	100-150	Ohler (1979) NOMISMA (1994)
Senegal	forest >50 " " 1 ha farmers	3 x 3, contour 1 m in rows 3 x 3 12 x 12, 5 x 20	 wind breaks, village woods fruits	n y n y	100-150 < 2000 100- 150 400-500	Behrens (1988) Ohler (1979) RUDECO (1989)
Tanzania	farmers <1	12 x 12, 14 x 14	fruits	y	400-500	Lamboll et al. (1993)
India Kera Karnataka Tamil Nadu Tripura Other	farmers	7x7, 9 x 9, 7.5x7.5, 10 x 10	- fruits - waste land recovery - erosion control	y*	348 1058 336 126 100 221	Ohler (1979) Mathew (1982) Sarkar et al. (1989)

* Intercropping is advised in the first two years after establishment

individually have only about 1-2 ha under cashew. Main objective for farmers is additional income from cashew (H. Ohmstedt 1991, Musaliar 1994). Table 26 shows cropping systems in different countries. Typical systems are shown in Plates 5 and 6. Yields are very low, except for Kerala where >1 000 kg/ha are achieved because of good soils and enough water. Reasons for low yields lie no genetical improvement, use of unselected planting material, poor management, poor soils and unstable climatic conditions.

4.2 Agronomy

4.2.1 Soils and climate

Cashew suffers from its image of thriving on the poorest soils were no other crops can give an economic return. As a result, the worst soils are chosen for cashew. The yield potential has never been evaluated on good soils. In typical poor cashew sites (Plate 7), yields are low, even with good genetic material (Ohler 1979). The interdependence of soil conditions and water availability has been confirmed by several authors. Venugopal et al. (1991) stated that temperature, humidity and sunshine hours prevailing in different cashew growing regions in India do not appear to influence the yield of cashew as compared to rainfall distribution. The criteria listed in

Table 27 represent only the most suitable conditions. Cashew can grow beyond these and even on lateritic soils - provided there are no crusts - this crop does well. Because of this Mathew (1984) suggests blasting lateritic crusts with explosives to make them permeable for cashew plantings. It also tolerates shallow soils (Plate 8) and altitudes up to 1000 m. However, it will not tolerate stagnant water or arid conditions (mean annual rainfall <600 mm) without supplementary water supply (Ohler 1979).

Plate 5: 20 years old cashew plantation (12 m x 12 m) in Tanzania, unproductive trees cleared and spaces intercropped with groundnuts.

Plate 6: 2 years old cashew trees in an agroforestry system (5 m x 20 m) in Senegal during dry season.

Plate 7: 5 years old cashew trees (6 m x 6 m) in Senegal on shallow sandy soil with a clay layer at 80 cm depth, after 2 years with only 600 mm rainfall, showing nutrient deficiency symptoms.

Plate 8: Well growing 25 years old cashew tree in a compound in East Ghana on lateritic soil. Note lateral roots on soils surface.

Table 27: Criteria for land suitability classification for cashew

	Characteristics	Suitable conditions
Soil	Soil texture (surface)	fine sand - sandy loam - silt loam
	Soil texture (subsoil)	fine loamy - coarse loamy
	Coarse fragments in the soil	< 20%
	Soil depth	> 90 cm
	Salinity	< 1 mmhos/cm
	Soil reaction	pH 5.6-7.3
	Water holding capacity to 1.80 m	> 14 cm
Topography	Slope	< 5%
	Rockiness	< 10% of rock exposed surface
	Stoniness	< 3%
	Altitude	< 600 m*
Drainage	Water table dry season	2-6 m
	Water table rainy season	1.5-4 m
	Depth of impermeable substratum	> 5 m
	Soil drainage	well to moderate

*from Rao et al. (1994)
[only most suitable and very suitable, after Devanadam (1983) and Mishra (1984)]

Detailed land classifications were made by Mishra (1985a&b) for Orissa (India) and by Zech et al. (1992) for Senegal. Five site classes were determined, depending on soil and rainfall. Table 28 shows the example of Senegal where 13 principally suitable soil classes in different regions were assessed. Unsuitable soils (not mentioned in the table) are all soils with low depth (<90 cm), stagnant water during the rainy season, lateritic crusts that reduce the potential rooting volume and soils with >42% clay and high bulk density (> 1.95 g/cm^3)

Field studies in Senegal (Krebs 1991) confirmed that available water was the limiting factor for cashew growth, despite low soil fertility. The annual precipitation and the potential root depth are significantly related to growth and Krebs concluded that soil depth should be 220 cm under precipitation of 600 mm/year to a minimal depth of 90 cm under 1400 mm/year (Table 28). Acute deficiencies in mineral nutrition were not found in the cashew trees, although the above mentioned soil types are not regarded as particularly fertile.

Table 28: Evaluation of potential cashew sites in 4 climatic zones in Senegal

Climatic zone ⇒	1	2	3	4
Soil ⇓	< 600 mm	600- 800 mm	800- 1000 mm	> 1000 mm
A) Ferrogenous tropical soils slightly lessivated				
1. Quartz rich sands	II[1]- III	III		
1. Clay sands		III		
1. Clay sands, shifted		III		
B) Ferrogenous lessivated tropical soils Ba) Soils without or with few rusty patches				
4. Lessivated clay sands		III - IV		
4. Lessivated quartz rich deep soils		II		
4. Alluvial lessivated soils, gley in lower horizon, (salty)		III		
Bb) Soils with rusty patches and Fe/Mn concretions				
7. Lessivated clay sands rich in Fe/Mn concretions		III - IV	II - IV	
7. Lessivated sands or clay sands rich in Fe/Mn concretions		III - IV	II- IV	
7. Lessivated clay sands rich in Fe/Mn concretions from granite				II - IV
Bc) Lessivated soils with Fe/Mn concretions and crusts				
10. Lessivated clay sands with Fe/Mn concretions and crusts			III - IV	II - IV
C) Slightly ferralitic soils				
11. Slightly ferralitic clay sands		II	II	I
11. Slightly ferralitic colluvial sands			II	I
D) Raw mineral sediment soils				
13. Deep quartz sands (dunes)	II[1] , V			

I	=	very good	II	=	good
III	=	suited	IV	=	suited with limitations
II1	=	good if groundwater can be reached by roots in 2-3 m depth	V	=	unsuited

4.2.2 Field establishment

4.2.2.1 Direct sowing

Direct sowing in the field is possible if the annual rainfall is above 800 mm/year. Planting holes (30 x 30 x 30 cm) can be dug before the rainy season to allow water to be held while it infiltrates. Top soil mixed with manure [if termites are not attracted by organic matter (Ohmstedt 1991b)] should be filled in the hole. In fertile sandy loam soils this is not necessary. Usually 3 seeds are sown per site in upright positions, the 2 smaller seedlings are removed after a certain period, depending on the growing conditions, but at the latest before the next rainy season.

4.2.2.2 Planting

Successful transplanting of cashew is possible, even if they were not sown in containers. The success rate of transplanting bare rooted seedlings varies with the age when it is done. The best results were obtained 11 month after sowing with shoots that had been cut back to half or to a third of their original length (Hassan et al. 1957, Table 29). Today, cashew are sown mainly in plastic containers or tubes with a diameter of 6-8 cm and length of 20-30 cm (Plates 9 and 10). Transplanting is done after 2-3 months, except for grafted seedlings which are transplanted after 4 months, without major setbacks. The water supply should not be interrupted during the 2 weeks immediately following transplanting.

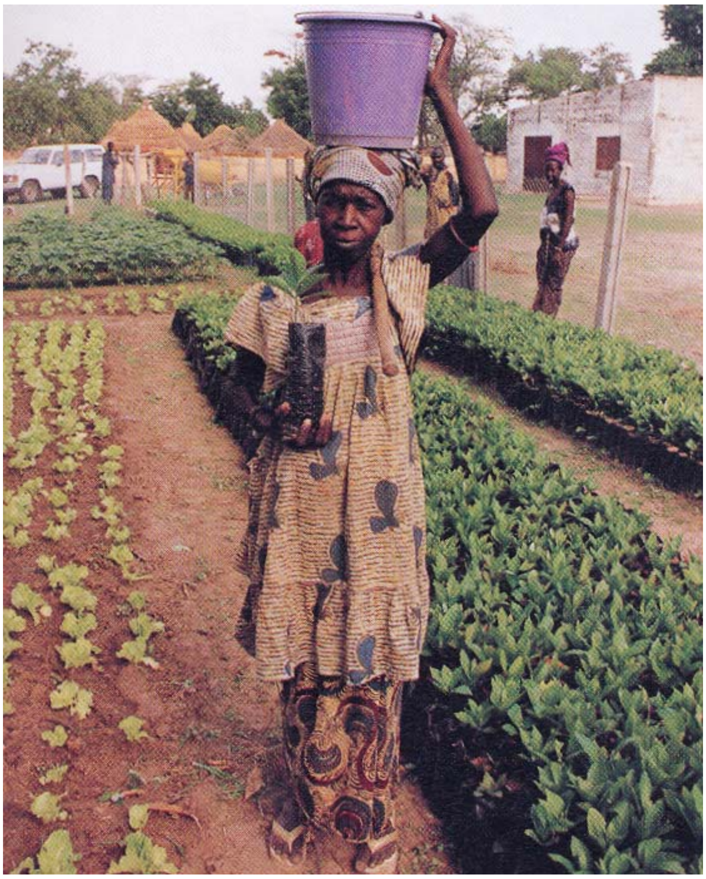


Plate 9: Cashew nursery run by a women's group in a vegetable garden in Senegal

Plate 10: Cashew nursery in Senegal in a farmers field, visited by school children

Table 29: Mean percentage of survival 2 month after transplanting

Age of seedling (month)	No. of batches transplanted	Percentage of survival	
		Range	Mean
one	12	60-100	95
two	11	20-100	66
three	10	0-60	34
four	9	0-100	33
five	8	0-80	28
six	7	0-20	10
seven	6	0-40	14
eight	5	20-80	60
nine	4	60-100	84
ten	3	80-100	94
eleven	2	100-100	100
twelve	1	80	80

Source: Hassan et al. (1957)

4.2.2.3 Spacing

Spacing of cashew for fruit production should consider root growth and canopy growth and not be too densely planted depending on the site. On good sites roots grow 4-6m from the stem in 2½ years, extending outwards about twice as far as the canopy itself (Ohler 1979, Satpathy et al. 1986). The number of trees/ha varies with the objective and conditions and range from 42 to 2500. Mathew (1982) favours high initial densities (1000 trees/ha) for early high yields/unit area, followed by selective thinning from the seventh to the twelfth year with a final density of 200 trees/ha. Ohler (1979) supports this. This method might be good for plantations, but farmers do not cut productive fruit trees. Therefore the current recommendation on farmers fields in Tanzania is a spacing of 14 m x 14 m combined with intercropping (ODA 1995). In Senegal farmers use distances of 5 m x 20 m with intercropping (Behrens 1988).

4.2.3 Interventions

4.2.3.1 Protecting cashew plantations

Young cashew trees are very vulnerable to damage by animals. In areas with a pronounced dry season they are often the only green plants in the field and therefore an easy target for wild and domestic animals. The Senegalese-German Cashew Project (PASA) used barbed wire fences to protect the fields, with a cost of 70 000 FCFA/ha (appr. 240 US$) for a 4 ha plantation. The high cost finally stopped this way of protection and farmers were urged to use fences made from local material (Table 30). Vegetal fences from different plant species (thorns or palms, Plate 11) are also recommended as cheap and efficient protection of cashew plantations in India, to be preferred to barbed wire or trenches (Satpathy 1986).

Another problem is the protection of cashew from wind damage of trees (Satpathy 1987) and/or flowers (Krebs 1991). Windbreaks with species like *Azadirachta indica* Juss. and *Senna siamea* (Lam.) Irvin & Barley are proposed to reduce such damage (Satpathy 1987).

Plate 11: Fence made with dead branches and thorny trees (2 years old)

Table 30: Protection of young cashew trees with local material

Method	Comments*
Individual protection	
Gabions made from branches, 70-90 cm high, 40-45 cm diameter	Too dense, no air circulation, seedlings suffering, termites
Gabions made from palm leaves 120-135 cm high, 60-65 cm diameter	Good if woven with wide spaces, resist 3 years, best plant development
Thorny branches around the seedling fixed like a tent	Cheapest method, good prot.
Thorny branches around the seedling fixed on supporting sticks	Better than above, because fixed in the soil
Circle planted with 10-15 *Jatropha curcas* L.	Not very efficient (60%)
Circle planted with 10-15 *Euphorbia balsamifera* Ait.	90% cashew survival
Life hedges around the field, immediate protection	
Euphorbia balsamifera cuttings planted in one row , 15 cm between plants, with support	98% recovery, 80-120 cm high, 70-125 cm deep
Euphorbia balsamifera cuttings, one row, *Agave sisalana* one row	Combination improves protection
Jatropha curcas one row	99% recovery on light soils, good protection after 1 year
Jatropha curcas one row, , *Agave sisalana* one row	Combination improves protection
Life hedges around the field, protection after 2-3 years	
Agave sisalana one row	95% recovery, 35-70 cm high, 30-85 cm deep
Agave sisalana one row, *Parkinsonia aculeata* L. one row	Combination improves protection
Parkinsonia aculeata in one row	88% survival, 40-100 cm high, 60-120 cm deep
Ziziphus mauritiana Lam. in one row	preferred by farmers, low recovery (42%) 20 cm high

* Source: Ohmstedt (1991b)
** The recovery and growth rates were taken 9 month after plantation in the middle of the dry season.

4.2.3.2 Fertilisation

Cashew responds well to fertilisers (Ghosh et al. 1986) if the ecological conditions are adequate. In a fertiliser trial in Senegal on 20 year old trees with 600 mm rainfall no reaction could be found to several doses of NPK applied at the beginning of the rainy season. On trees growing on poor soils fertiliser certainly has a positive effect (Table 31). The findings from Ghosh (1989) that the nut quality was improved, are interesting for processors as it could increase their margin. The dosages depend on the site conditions and have to be determined for each locality. Mathew (1982) suggests applying recommended fertiliser dosage on intercrops and adding the quantity needed for cashew, as farmers rarely fertilise the cashew trees alone.

Table 31: Fertiliser recommendations for cashew trees

Author	Fertiliser dosage (g/tree/year) and application*	Effect
Mahanthesh et al. (1994)	500 N, 100 P, 250 K, 1 application	produced highest yield of cashew apples,
Mathew (1982)	250 N, 125 P, 125 K, 1 application	raised nut yield level from 5 kg to 8 kg/tree
Khader (1986)	500 N, 125 P, 125 K 2 applications in 2 m radius from stem	early and higher yields
Radhakrishna et al. (1993)	500 N, 125 P, 125 K applied in circular trench, 25 cm deep at 1.5 m from trunk	significantly higher yield compared to other methods of application
Badrinath et al. (1988)	500 N, 250 P, 250 K, 2000 Ca, 50 Zn (foliar spray)	raised yield from 5.3 kg (250 N, 250 P, 250 K) to 8 kg/tree
Ghosh (1989)	500 N, 200 P, 200 K	flowering period increased, number of nuts increased, nut yield (weight) increased kernel percentage increased

* P = P_2O_5, K = K_2O

4.2.3.3 Weeding

Weeding (circles about 2 m in diameter around the tree) of cashew until taller than the weed community of the area is absolutely necessary to facilitate initial growth. If the tree grows vigorously, weed growth under the crown will be suppressed after 3-5 years and weeding is only important to facilitate nut collection and to prevent fire damage.

4.2.3.4 Pests and diseases

Ohler (1979) describes 21 diseases and nearly 100 pests on cashew nuts. Some are of local importance, others are widespread. Powdery mildew (*Oidium anacardii*) affects cashew flowers in vast areas in Tanzania, reducing yield by 80% (Tsakiris 1990). Selected diseases are listed in Table 32. The tea mosquito (*Helopeltis antonii* Mill.) and its close relatives *H. shoutedeni* Reut and *H. anacardii* Mill. belong to the most important insect pests in India and Africa. They have a number of host plants and this complicates the control. Cotton is the main host for H. shoutedeni and should therefore not be interplanted with cashew (Ohler 1979). A typical Helopeltis damage is shown in Plates 12 and 13. Selected pests are listed in Table 33.

It is useful to screen pests and diseases when embarking on a large planting program to minimise later damage.

Table 32: Selected major cashew diseases (1980- 1994)

Disease	Damage caused	Treatment and comments	Country	Author
Anthracnosis *Glomerella cingulata* (Stonem.) Spauld. et Schrenk (syn *Colletotrichum gloeosporioides* Penz.)	Most common pathogen, attacks shoots, reddish brown shiny lesion, can kill trees	fungicides and foliar fertiliser, copper hydroxide	Tanzania, Malaysia	Intini et al. (1983); Lim et al. (1984);
Powdery mildew *Oidium anacardii* Noack	Attacks inflorescences, causes losses of 50-70%	Varietal differences observed. Treatment with sulphur powder at offset of flowering and twice more, removal of mildew harbouring tissues (water shoots)	Tanzania	Intini et al. (1983); Sijaona et al. (1987); Tsakiris (1990); Waller et al. (1992); Nathaniels et al. (1993)
Blossom blight *Glomerella cingulata*	Petals turn black, floral shoot dies starting from tip	Fungicides	Malaysia	Lim et al. (1984)
Die-back *Phomopsis anacardii*	Young vegetative shoots die from tip downwards	Fungicides	Malaysia, Tanzania	Lim et al. (1984); Intini (1987)
Bacterial wilt *Pseudomonas solancearum* (E. F Smith) E. F Smith	Root rot and leaf fall, death of tree		Indonesia	Shiomi et al. (1991)

Plate 12: ***Helopeltis* damage -** black lesions on a developing cashew twig.

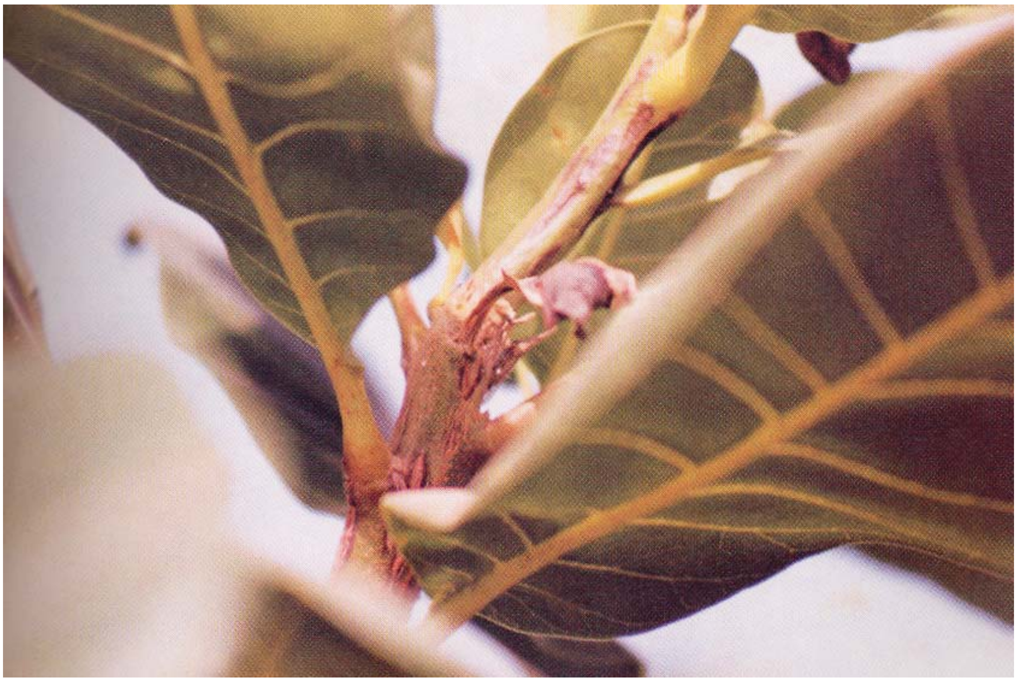


Plate 13: ***Helopeltis* damage -** lesions and damage on a mature cashew twig.

Table 33: Selected major cashew pests (1980- 1994)

Pest	Damage caused	Treatment and comments	Country	Author
Tea mosquito *Helopeltis antonii* Signoret	Sucks on new shoots and nuts, causes black lesions and die-back Wound pathogens enter through lesions, dieback caused by *Botryodiplodia theobromae* Pat.	Varietal differences in attack observed, seasonal differences, various insecticides, single and in combination, application includes aerial spraying, egg parasitoids and ants feeding on nymphs were found	India, , Goa Karnataka Kerala Maharashtra Tamil Nadu, West Bengal, Sri Lanka, China Hainan	Nair et al. (1982, 83, 84); Ambika et al. (1983); Babu et al. (1983); Rajapakse et al. (1983); Sathiamma et al. (1983); Pan et al. (1990); Sundararaju (1992); Chatterjee (1989); Godase et al. (1992)
H. anacardii	As above, occurs on newly formed shoots	Increased where water is available	Brazil, Bahia Senegal	Adis et al. (1979); Behrens (1988)
Tree borer *Plocaederus ferrugineus* L	Eggs laid in bark up to 1 m from the ground, larvae feed on bark and wood, interrupt sap flow, branches or trees can die	Up to 25% of trees affected (SL), chemical soil treatment, manual killing of larvae, severely attacked trees to be destroyed	Sri Lanka, Andhra Pradesh, Karnataka Kerala, Tamil Nadu,	Gerini (1976); Devi et al. (1983); Rai (1983); Misra et al. (1985); Rao et al. (1984)
Selonothrips rubrocinctus Giard	Attacks seedlings, young leaves, older leaves, shoots, inflorescenses, flowers	Threshold for treatment: 240 adults on 6 weeks old seedling	Nigeria Trinidad	Igboekwe (1991) Ananthakrishnan (1985)
Scirtothrips dorsalis Hood	Cause premature shedding of flowers	Feeds also on *Prosopis*, *Acacia*	Goa	Raju et al. (1983); Sundararaju (1984)
Lamida moncusalis Wlk.,	Webs leaves and flowers together		Tamil Nadu Goa	Babu et al. (1983) Muthu et al. (1983) Raju et al. (1983); Sundararaju (1984)
Hypatima haligramma (Meyr.) syn. *Chelaria h.* Meyr.	Pupation inside folded leaves, caterpillar feeds on unfolded leaves *	Insecticides	Goa	Raju et al. (1983); Sundararaju (1984)
Cashew whitefly *Aleurodicus cocois* Curt.	Live on underside of leaves, larvae produce wax, leaves fall *	Biological control, organosynthetic insecticides	Brazil, Ceara	Gondim et al. (1981); Sales et al. (1981)
Leave miner *Acrocercops syngramma* Meyr.	Larvae mine tender leaves, 26-80% trees infested *	Insecticides	India Tamil Nadu Goa	Babu et al. (1983); Muthu et al. (1983); Raju et al. (1983); Sundararaju (1984)
Nephopteryx spp.	Larvae move to joint of apple and nut, spoil both	Insecticides	India, Hainan	Babu et al. (1983); Pan et al. (1990)
Carpenter moth *Salagenea sp.*	Larvae feeds on bark and bores galeries in wood	Removal of larvae, pruning, insecticides	Zambia	Latis (1990)

* Ohler (1979)

4.3 Selection and breeding

The priority in cashew selection is to find germplasm having the capacity to yield as many nuts as possible of an acceptable size and above average kernel content under local conditions. This implies that a tree (clone, line, variety) that does well under specific conditions may not be as good under other conditions. Therefore it is important to select within the environment where the cashew trees will be grown - from healthy high yielding trees.

Table 34: Parameters for the selection of mother trees

Parameter (Manoj et al. 1993)	Indicators or minimum requirement
Growth	height, girth, canopy spread, compactness, (leaf area)
Flowering	Duration (short or long), period (early or late), panicles/canopy area, flowers/panicle, % perfect flowers, "high" fruit set
Nut production per tree	depends on size of tree, (see table 2) number of nuts/panicle better: yield per CGCA* >250 g/m² **
Nut size	>5 g, better 6 g or more
Nut shape ***	regular, flat, no hollows
Kernel content	>25%, better >30%
Protein content	18-40%, not essential
Disease resistance	Powdery mildew, Anthracnosis
Pest tolerance	*Helopeltis* spp.
Apple qualities	Weight, colour, shape, juice content, sugar content, taste

* CGCA = **C**anopy **G**round **C**over **A**rea (see page 70)
** Method was developed by Prof. Langner, Bundesforschungsanstalt für Holz- und Forstwirtschaft, Großhansdorf, Germany, cited by Behrens (1988).
*** Ohler (1979)

The simplest selection method is to throw the nuts in water and to select only those that sink. Auckland (1961) found that nuts with a density of >1.025 g/cm³ (sinking in a solution obtained by dissolving 71 g sugar per l water) germinated faster, had a higher survival rate and produced more vigorous plants and more flowers in the first season than nuts below this density. Nuts that float in water should be discarded.

Table 35: Characteristics of selected cashew varieties

Location	Origin	Age (years)	Mean Yield/tree (kg)	Nut weight (g)	Kernel content (%)	Yield/ha (kg)	Kernels/lb.	Comments
Anakkayam [1]	Hybrid	15-25	12.43	8.8	-	-	-	Hybrids for big nut size
Kerala	Hybrid	15-25	11.72	10.8	-	-	-	Hybrids for big nut size
	Hybrid	15-25	0.74	9.5	-	-	-	Hybrids for big nut size
Bapatla [2]	Selection	33-48	57.82	4.6	28	11 560	365	Yield/ha extrapolated from 1 tree
Andhra Pradesh [2]	Selection	33-48	13.57	5.0	27	2 710	335	Yield/ha extrapolated from 1 tree
Andhra Pradesh [3]	Hybrid	25	19.00	4.0	26	-	435	Released varieties
Maharashtra [3]	-	28	23.00	6.0	31	-	245	Released varieties
Tamil Nadu [3]	-	17	7.40	5.0	20	-	454	Released varieties
Karnataka [3]	Selection	25	19.00	7.0	31	-	210	Released varieties
Kerala [3]	Selection	7-14	17.14	7.3	26	-	240	Released varieties
Karnataka [3]	Selection	-	6.69	4.5	33	-	305	Selection for high kernel content
Anakkayam [4]	Selection	-	3.29	3.6	46 (39)	-	(280) 330	Selection without CNSL in kernel (calculation based on provided figures)
Ullal [5]	Selection	11-20	14.68	7.0	30	-	215	New selection from released variety (used as example in Table 36)
Senegal [6]	Seedling	29-32	36.48	6.9	-	-	-.	Trees from farmers fields
	Seedling	15-19	25.24	5.8	-	-	-	Trees from farmers fields
	Seedling	7-11	17.04	5.6	-	-	-	Trees from farmers fields
	Seedling	59-64	164.16	5.7	25	3 860	318	Single tree covering 425 m² including 1 m space around tree [7]

Sources: [1] Nalini et al. (1994a), [2] Reddy et al. (1983), [3] Bhaskara Rao (1989), [4] Nalini et al. (1994b), [5] Kumar et al. (1994), [6] Ohmstedt (1991c), [7] Behrens (1986).

A better selection can be made if good trees are observed and selected. Table 35 shows, for selected material in different countries, nut yield parameters to give an orientation on the yield potential. Unfortunately not all parameters are given by the authors, and there are gaps in this table. For the comparing trees, the canopy ground cover area (CGCA) gives a better indication of performance than the nut yield/tree than current descriptions (Table 36).

The following points from Table 35 are noteworthy:

⇒ a released variety with only 20% kernel content is featured - this cannot be accepted by the processing industry. Nuts below 5 g in weight are uneconomic to harvest for farmers.

⇒ the yield of 11 560 kg of nuts per ha is suspiciously high (see page 83, discussion).

⇒ trees older than 15 or 20 years can still give high yields

⇒ most released varieties have relatively small kernels and this is an obvious scope for improvement.

⇒ cashew researchers do not use a standardised system to describe germplasm. Seedlings, hybrids and selections are mixed up and it is not clear whether varieties are based on the transfer of characteristics from parent material in seed gardens or whether clones are used. A standard would be helpful for comparison of germplasm for different purposes or sites.

⇒ Special lines without CNSL could be interesting for homestead growing, but attract rodents that can destroy the total yield.

Breeders responsible for the selection of cashew material should be aware that the economics of cashew cultivation and processing depend to a great extent on the planting material supplied to farmers. As a cashew tree produces for more than 20 years, the effects of selection will last long and care should be taken to supply only the most suitable germplasm for any extension program.

Table 36: Description of a cashew clone with suggestions for improvement

Description of the new cashew variety "Ullal 3" (Kumar et al. 1994)		Comments
1. Plant height	3-4 m	
2. Branching	intensive	CGCA* after 3, 5, 10 and 15 years would be useful to compare with other trees and to plan intercropping
3. Canopy	highly spreading	
4. Leaf length	17 cm	
5. Leaf breadth	10 cm	
6. No of laterals/leader	4-5	Very important to assess compactness
7. Flowering time	Nov. 1st wk.-Jan. 4th wk.	Useful for plant protection measures
8. Flowering duration	60-70 days	Climatic data should be added, as well as suitable sites
9. Harvesting time	January - March	Allows to plan length of harvesting season
10. Panicle shape	conical	Of botanical interest only
11. Panicle length	31 cm	
12. Panicle breadth	27 cm (at base)	
13. Av. No of perfect flow./pan.	152	Allows pre screening of selections
14. Av. No. of flowers/panicle	1005	
15. Male: perfect flowers	6.61:1	
16. No of fruits/panicle	8-10	
17. Coherence of nut to apple	Medium attachment	Important for harvesting
18. Cumulative yield for last 10 years	146.83 kg/tree	Shows yield development,
19. Mean yield/year	14.68 kg/tree	
20. Annual mean yield for last 5 years	21.98 kg/tree	
21. Highest yield recorded	34.52 kg/tree/year	
22. Nut size	6.99 g (medium)	
23. Number of nuts/kg	143	Linked to nut size, not essential
24. Shelling percentage	30%	
25. Kernel count/pound	W 210 (52%) W 240 (36%)	
26. Apple colour	pink red	Taste, juice content, sugars could be added
27. Apple shape	conical	
28. Apple size	medium (60 g)	
29. Tea mosquito tolerance	not tolerant	Disease tolerance were important

* Canopy ground cover area

4.3.1 Breeding

Trees differ for their quality as parents. Some transfer characters to progeny, differently with pollen than with ovules or if selfed. The best way to assess compatibility and heritability is through hand-pollinated crosses between selected germplasm in efforts to find optimal combining ability and consequently good breeding material (Harries 1993, Nalini et al. 1994b). This is only of valuable use if a long term breeding program can be assured. If financial or manpower resources are restricted, efforts should be concentrated on selection of available material and import of grafted plants from other cashew research centres for screening .

4.4 Vegetative Propagation

Vegetative propagation is the fastest method for producing high yielding plants. Progress has been rapid in the past 20 years. Today, vegetative propagated material should be used for mass multiplication for farmers' fields wherever possible. Clonal seed gardens are an alternative but there is need to screen mother trees for compatibility. A period of 3-5 years would be necessary before good material is available from selections.

4.4.1 Propagation by division

4.4.1.1 Air layering (marcotage)

Air layering (Plate 14) was the first successful method of vegetative multiplication in cashew (Argles 1976). With air layers, rooting rates between 40% and 100% are reported during the rainy season, but less or even none during the rest of the year. Sawdust (Rao, -SN 1985) and sphagnum moss (Shetty et al. 1990) and peat (Ohmstedt, 1991a) were used as rooting media. Hormones like IAA (indole acetic acid) at 250 ppm, IBA (indole butyric acid) at 250, 300 and 2000 ppm and NAA

Plate 14: Air layering

(naphthalene acetic acid) at 500 ppm) improved rooting. Callus formation started after 10 days and root initiation after 25 days during the best season (Rao, -SN 1985). Rooting was found to take 60 to 80 days and was related to shoot growth cycles. Non-flowering shoots gave higher rooting than flowering shoots (Damodaran 1985; Palaniswami et al. 1985; Valsalakumari et al. 1985; Suryanarayana et al. 1989; Rao et al. 1989a; Shetty et al. 1990). Acclimatisation under mist increased survival rates. Damodaran (1985) confirms van Eijnatten's (1980) view that air layers developed better root and shoot systems than seedlings.

4.4.1.2 Stooling

Nagabhushanam (1985b) covered shoots three months after stooling and allowed 40 days further growth, then the shoots where cinctured at the base, treated with IBA and again covered with sand. Six months after stooling, rooting success varied between 44% and 64%, depending on the season. Suryanarayana et al. (1989) found a significant difference in rooting depending on the age of shoots. Rooting rate and root characters decreased with increasing age from 100% at 4 months to 77.5% at 6 months old shoots which had been girdled at 3½ months.

4.4.1.3 Cuttings

Cuttings are cheap and easy to produce if the species has the potential to develop roots. Muhs (1992) made cuttings from young seedlings (10 to 20 cm high) and cut just above the cotyledons. He cut the leaves in half to reduce transpiration and put the stems into a mixture of 50% peat and 50% sand (without growth regulators). They were covered with a transparent plastic sheet and watered regularly. Rooting was 90-95% after 8 weeks. The decapitated seedlings developed 2 new shoots that were used again for cuttings. Rootability after the third cycle declined to 40-60%. Rao et al. (1989b) achieved 78% rooting of cuttings when dipped in 1% IBA and grown in a vermiculite medium kept under 7 hours mist per day. The phenolic compounds in the vegetative material did not influence rooting capacity (Shetty et al. 1990). Ohmstedt (1991a) found that the rootability of semi-lignified cuttings varied within the time of the year. Best results were obtained during the dry season (during flowering period) with 15 -20 cm long cuttings from juvenile shoots. Best rooting media was a 1:1 mixture of vermiculite and peat. Rooting under a plastic cover was 35% (plants that could be transplanted). Non juvenile-material did not root or survive. Other rooting media were not suitable, hormones had no effect.

Pre-treated cuttings

Semi-hardwood cuttings of cashew, taken from ringed and etiolated shoots, produced adventitious roots in 30% of the cases. The rooting rate was increased to 80% by soaking cuttings in 10 ppm calcium carbide for 24 hours followed by a 5-second dip into NAA + IAA, each at 5 000 ppm (Sen et al., 1991). Rao et al. (1989b) used cuttings (ringed 90 days before harvesting) of 4-, 8- and 16-year-old trees. They were examined for auxin activity and phenol content before putting into vermiculite medium under mist. Total phenol content declined from 3.45% in cuttings of 4 year old trees to 3.0% and 2.7% in cuttings of the 8 and 16 year old trees; the corresponding rooting percentages were 52.5, 22.5 and 0.0 respectively.

4.4.2 Grafting and budding

Grafting is a widespread and well known technique. When rootstocks and scions are of the same diameter, whip grafting is the easiest grafting method (Garner 1958). It does not require any capital investment other than a sharp knife and strips to fix and protect the scion on the rootstock. Sawke et al. (1986) and Ohmstedt (1991d) reported a strong seasonal effect (over a period of 3 years) with the highest grafting success obtained in August (84%), attributed to matured budsticks coupled with low temperatures and high humidity. Grafting success was lowest in December (22%) due to temperature changes between day and night which retarded the formation of new cambial cells. The availability of scion wood seems to be the limiting factor for successful grafting, coupled with such unfavourable climatic conditions as extreme low humidity and temperature changes between day and night (Nagabhushanam 1985a).

4.4.3 Micropropagation

Plantlet formation from embryos, cotyledonary explants, apical cuttings and axillary buds from seedlings, is reported by several authors with differing media and hormones used to initiate callus formation and root differentiation. Most tissue sources were either seeds or seedlings (Philip 1984; Falcone 1987; Sy et al. 1991; D'Silva et al. 1992; Hegde et al. 1990). D'Silva and Lievens et al. (1989) obtained plantlets with roots under in-vitro conditions which were true to type and transferred successfully to the soil. Falcone (1987) concluded that tissue culture could be a useful alternative to conventional propagation of cashew.

Table 37: Grafting methods and success rates obtained

Grafting method	Time and success rate	Place /Author
Cleft Grafting used for top work on old trees	54% in August (rainy season) 58% in September	Karnataka (India), Nagabhushanam (1985a)
"	90%	Tanzania, Shoo (1994).
Patch Budding	41% (rainy season, shaded)	Andhra Pradesh, S.N. Rao (1985)
"	71% in July (Rainy season), sprouting after 25 days	Palaniswami et al. (1985)
"	61% on seedlings, (dry season) 62% (rainy season)	Dhandar (1985)
"	23% on 1 year seedlings in situ	Nagabhushanam (1985a)
Side Grafting	25% in situ (rainy season)	Nagabhushanam (1985a)
"	53%-58% (March, dry season) 54-56% (July/August, rainy season)	Orissa, Sahani et al. (1985)
"	60-80%	Das et al. (1985)
Whip Grafting, on seedlings in polybags	September 40% August 44% (mid rainy season)	Karnataka, Nagabhushanam (1985a).
"	>50% in the nursery	Tanzania, Shoo (1994).
Wedge Grafting under mist, 8-month old seedlings	March. 75% (dry season)	Valsalakumari et al. (1985)
Modified "Epicotyl" Grafting, two bottom leaves of rootstock left intact after removing the top. The stem was cut longitudinally so that each half had a leaf	45% (6% with all leaves removed)	Seshadri et al. (1985).
Veneer Grafting	96% in July (rainy season)	Andra Pradesh (India) V.N.M. Rao (1985)
leaves were removed from the scions a week prior to grafting	92%, (rainy season)	(Dhandar, 1985).
Inarch Grafting	52%-96% (graft union defective)	Rao, -V.N.M. (1985)
	80-100% (both seasons, but very cumbersome)	Damadoran (1985)

4.5 Socio economic considerations

In most countries cashew is a typical smallholder crop (Table 26). In India vast areas are planted in the frame of soil conservation by the department of agriculture and as a source of income in social forestry and waste land recovery programs (Satpathy 1987, Chopra 1990, Chowdhury 1992). As these programs aim to plant vast areas in a short period of time, seed quality cannot be assured. Nevertheless, in the Arabari social forestry project (West Bengal) the collection of cashew nuts carried out by men, women and children was by far the most remunerative of all forestry operations and thus important for the success of the project (Chopra 1990).

Large private plantations are rare, high harvesting costs reduce the profit to nothing where the cashew apple is not the main product. Morton et al. (1972) reports about a frustrated Brazilian cashew manager who was disillusioned about cashew as a paying proposition, advising people to grow anything else than cashew.

The greatest limitation to cashew production is the large amount of manual labour to harvest the nuts. An experienced worker can collect about 525 nuts/hour (Morton et al. 1972), equal to 2.6 kg for nuts weighing 5 g each. With an average wage of 150 FCFA/hour (in Senegal) and a farm gate price of 100 FCFA/kg (RUDECO 1989), harvesting costs take nearly 60% of the revenue (nuts weighing 8 g each = 4.2 kg/hour = 28%). This figures underline the importance of careful selection of planting material, bigger nuts reduce harvesting costs.

This limitation offers a chance for smallholder farmers whose aim is not profit-maximisation per area of land or per man hour but to raise overall family income. The cashew harvest usually starts during the last 2 months of the dry season, when fresh food becomes rare and money from cash crops dwindles. This indicates an ideal period for additional income! Children and old people can collect apples for direct consumption and nuts for sale without creating harvesting costs.

Economic analyses of farmers' cashew plantations are often very positive, despite the fact that they all deal with different inputs and yields. Economic results are generally shown by such parameters as net present value (NPV), benefit cost ratio and internal rate of return, but the figures reflect the local situation and are therefore not directly comparable. Examples of economic evaluations of cashew plantations are summarised in Table 38. Despite the application of different methods, the cashew crop was found to be interesting for the farmer, whether the apples are used too or not. However, better planting material and increased use of apples improve the economics of cashew growing for smallholder farmers considerably.

Table 38: Economic analysis of cashew cultivation in selected countries

Basic conditions	Considered costs and revenues	Results	Author
Planting in rows 5 m x 20 m Final density: 63 trees/ha Yield: 6.25/kg/tree, 400 kg/ha/year Yield apple 10% of potential = 320 kg/ha/year	Investment cost incl. barbed wire fence, 2.5 man-days planting/replanting, 2.4 man-days maintenance 28 man days harvesting soil cover considered, opportunity costs soil: gross margin/ha, annual crops opportunity cost labour: gross margin/man day	Gross margin/man day higher than from traditional crops. Gross margin/ha reaches 196% (of traditional. crops) with full yield. Rate of return responds strongly to apple utilisation. Demands labour when family is underemployed. Provides financial liquidity when needed. Interesting crop for diversification, income increase in medium term, improvement of food situation of family. No substitution of traditional crops found. Intercropping highly appreciated by farmers.	RUDECO (1989), Senegal
Life span: 25 years Intercrops: year 1-3 (groundnut, pearl millet) Trees/ha: 175 Yield: 200- 250 kg Rainfed conditions	Cost incurred: establishment incl. watering in 1st year, maintenance, harvest, cashew yield from year 4. Calculation based on 15 years, mean nut yield of 300 kg and includes wood value but apparently no felling costs	Positive net income each year. More profitable than other rainfed crops.	Sekar et al. (1994), Tamil Nadu, India
Compared seedlings and grafts Seedlings: age 35 years 1,17 ha/farm, 121 trees 103 trees/ha, yield/ha: 391 kg Grafts age 6 years 0.83 ha/farm, 181 trees 219 trees/ha yield/ha 785 kg	Yields of nuts and apples (100% use) considered, Value of all apples 1/3 of nut value	Cashew orchards planted with grafts of high yielding varieties are more profitable for farmers than seedling material.	Dalvi et al. (1991), Maharashtra, India
Pre bearing period: 5-7 or more years. High yielding trees (20-28 kg/year) Yield/ha: 2000 kg, Production increases up to 15-20 years, stable production up to 40 years, thereafter decline	Considered cost of land, field preparation, marking, digging of pits, filling, planting, shading, watering, fertiliser, plant protection, planting material, capital costs.	Cashew is most remunerative crop in the Konkan area, improves income of rural people , employment through cashew factories, more remunerative than other crops, all economic parameters positive.	Naik et al. (1992), Maharashtra, India

5. Discussion

Much uncertainty affects prediction of the development of the world market for cashew. Extensive planting programs are going on in India and massif increases in areas planted with cashew are reported from other countries (Table 39).

Table 39: Area under cashew in major growing countries

Country	Area under cashew (ha)	Year
Brazil	650 000	1991
India	532 000	1991
Indonesia	(138 500)	1981
"	207 300	1985
Thailand	56 400	1988
Vietnam	104 500	1991
Kenya	51 000	1991
Mozambique	500 000	1970
Tanzania	400 000	1991
Total (approximate)	2 500 000	1990

Sources: Eijnatten (1991), NOMISMA (1994).

Eight countries already have a total of 2.5 million ha under cashew, very often mixed with other crops. Rapid expansion of cashew nut areas using improved planting material is not yet possible. It can therefore be assumed that the average nut yield at least until 2015 will be around 400 kg/ha. This would give a total of about 1 million tons, as predicted by Ohler for 1990 (Table 13, p. 21), but from different countries. FAO/PY (1993) (Table 15) simply mentions a record production of 726 000 t in 1992 but it fell to only 480 000 t in 1993, due to climatic hazards in India and Brazil. The important point is that the market was able to absorb the kernels (181 000 t) produced in 1992. Mathew et al. (1983) had predicted a total growth rate (demand) of 4.9% (based on the rate from 1950-1979 and 98 500 t in 1980) per year and just for the USA, Japan, Netherlands, Germany, Australia and Canada a kernel demand of

330 000 t by the year 2000. This demand could not be met by the current cashew production potential in the 8 countries of Table 39 even if a growth rate of 5%/year is considered (Table 40). The economic development in China and the “Tiger Nations” in South East Asia (not considered in this calculation) is rapidly expanding the market for cashew products. This is because cashew nuts are part of the diet, not merely dessert nuts. In China, the local price is higher than the world market price. Growth in income in these countries will further increase demand.

Table 40: Potential cashew kernel production and exports *

Year	Potential cashew kernel production (growth rate 3%)	Potential kernel export (home consumption 20%)	Potential cashew kernel production (growth rate 5%)	Potential kernel export (home consumption 20%)
1990	250 000	200 000	250 000	200 000
1995	289 819	231 855	319 070	255 256
2000	335 979	268 783	407 224	325 779
2005	389 492	311 593	519 732	415 786
2010	451 528	361 222	663 324	530 660
2015	523 444	418 756	846 589	677 271

* based on the potential production in 1990

Minor producing countries should therefore be able to sell their cashew nuts on the world market, provided the quality is adequate. The ACP countries have the advantage of close trade relations to the European Community which represents a potential market for cashew kernels. Adequate (small scale) processing facilities in the producing countries could create employment and additional foreign currency earnings (Kumar 1995).

The price of CNSL in 1995 is about 320 US$/t - synthetic phenol is traded at 960-1600 US$/t (Bolton 1995). Nobody can foresee the price of petroleum which is the source of synthetic phenol, but it is sure that the price will rise within the next 15-20 years and thus influence the price for substitutes such as CNSL. The value of

CNSL might not reach the value of the kernel, but it is likely to get a bigger share of the profitability of cashew shelling operations.

At present cashew apples do not have a market. Due to the problems described in Chapter 2.1.4 (pages 10-13) it might be difficult to create processing facilities exclusively for cashew apples in areas where production is scattered. However, the example of Goa shows that a large part of the apple supply can be used and thus increase the profit of the farmer. In Senegal farmers make higher profit from only 10% of the apples than from the nuts. The nutritional value of the cashew apples is much appreciated by people and influences farmers in their decision to plant cashew. Development projects must promote the use of this valuable product for local needs as well as for the market. Alcohol, dried fruits, juice or jam have a market under all circumstances. The combination of small scale nut processing and apple processing can be a solution to overcome the problems related to short production periods .

Since the beginning of the cashew kernel trade, cheap labour of women in India compensated for the complicated process of cashew nut shelling and made it a profitable business. Attempts for large scale hand shelling in Africa have failed. Semi-mechanised processing is favoured by Kumar (1995), and doubtless represents the future. The deep freezing method could be used to produce high quality grades of kernels if the technology would become cheaper possibly due to new developments.

Cashew nuts have become one of the most important tree nuts without any serious attempts to improve husbandry practices. A concern for treatments arises only if diseases or pests hamper yield (Tanzania, India) and it is only during the last 20 years that serious research has been done to select varieties and to promote clonal propagation. High yielding varieties with big nuts and high kernel contents (tolerant to major pests and diseases) increase the economic return in all levels of the cashew industry, from the grower to the roaster/packer. Joint ventures between importers, processors and growers to improve selection and cultivation suit all concerned. However, the yield potential of cashew trees is limited - as for all other crops. Anybody promoting cashew should use realistic yield estimations. The yield potential (fresh weight) of cashew and selected crops is shown in Table 41. Banana is the only crop yielding more than 100 t/ha, but normal yields are around 60 t/ha. Intensively cultivated selected mango produced 22 t/ha. A cashew fruit production of 22 t/ha is equivalent to 2.4 t/ha of nuts. If the European apple (*Malus* spp.) with a mean yield of about 60 t/ha is taken as a reference, the potential nut yield would be 6.6 t/ha. A nut yield of 15 t/ha is equivalent to a total fruit yield of 136 t/ha, thus more than banana under most sophisticated management. I conclude from these figures that a realistic achievable nut yield is about 6-7 t/ha (or about 60 t/ha of apples and nuts together) under good site conditions (Chapter 4.3, page 67).

Table 41: Maximal annual yields of selected crops

Crop	Highest yield (t/ha fresh weight)	Conditions	Author
Cashew nuts (India)	15	extrapolated	Mathew (1982)
Cashew nuts (Brazil)	8-10	Long term yield target	Ascenso (1986)
Cashew nuts (India)	12	extrapolated from 1 tree	Reddy et al. (1983)
Mango (Karnataka, India)	22 (5th year)	1600 dwarfs/ha farmyard manure, NPK fertiliser, irrigation	Majumder et al. (1989)
Banana (India)	128.56	Black polyethylene mulch, irrigation, fertiliser	Bhattacharyya et al. (1989)
Wase satsuma mandarin (Japan)	60	Ploughing, fertiliser	Tachibana et al. (1990)
Apple (Germany and Netherlands)	19-92	Intensive orchards	Thiele et al. (1991)
Cassava tubers (Trinidad and Tobago)	63 7	Rainfed with NPK fertiliser; (no fertiliser)	Wilson et al. (1994)

Two other important selection parameters are nut size and the kernel content. Abreu (1995) reports of new Brazilian cultivars with a kernel component of 85%. This figure was probably confused with the percentage of whole nuts after shelling and therefore misleading as a result. The highest realistic kernel content reported is about 46% in nuts without CNSL (Nalini et al. 1994a). For normal nuts a range from 23-38% is reported from breeding material by Manoj et al. (1993). Hybrid H-419, apparently the best identified, is reported to have a mean nut weight of 9.6%, a kernel content of 31.6% and a nut yield of 21.5 kg/tree/year (Manoj et al. 1993). The yield per canopy ground cover area (CGCA) was not indicated.

Countries embarking on cashew growing should try to obtain clonal material from elsewhere (India or Brazil) for screening. Locally selected material should have minimum requirements indicated in Table 42. Yield could best be expressed as kernels per m² CGCA. For the moment there is no need to look on CNSL properties, but this might become more important in the future. Trees with CNSL-free nuts should only be grown if tree climbing rodents can be excluded.

Table 42: Requirements for selected planting material

	Minimum - short term	Medium to long term
Tree	healthy, compact, adapted to environment, tolerant to diseases and pests	different clones for special purpose, e.g. dwarfs for home gardens, big trees for hedgerows
Nut yield	>150 g/m² CGCA	400-500 g/m² CGCA
Nut size	>6 g	8-10 g
Kernel content	>26%	≥30%
Apple	sweet and juicy	good taste, juice, vitamin rich

Vegetative propagation of cashew is now standard practice in India and other countries (Tanzania, Senegal). In Brazil special clones for apple or nut production are recommended according to the choice of the farmer (Parente 1991). Grafted mangoes and citrus are quite common, even for smallholder farmers in the same areas where cashew is grown, so that there is no reason for not using this technique for cashew field establishment. Topworking (cutting of the old crown and grafting with good clones for improvement of existing stands is also recommended (Rao, -V.N.M. 1985; ODA 1995). Various propagation methods produce high success rates (Table 43).

Table 43: Success rates for vegetative propagation

Method	Success rate
air layering	up to 100%
stooling	up to 100%
cuttings from seedlings	up to 95%
cuttings from watershoots under field conditions	up to 35%
pre-treated cuttings	4 years old trees: 52.5% 8 years old trees: 22.5%
veneer grafting	92%
cleft grafting	90%
side grafting	80%
patch budding	71%
Whip grafting	under mist: 75% nursery: >50%

From Chapter 4.4

The grafting routine probably increases success. Local grafting skills should be considered when choosing a multiplication method. Most of the propagation methods are strongly influenced by the season. The best time and method for each locality therefore have to be determined before mass propagation can start. Micropropagation of cashew is possible and independent of season. More research is, however, needed to develop a method that allows the use of material from **adult** (elite) trees at low costs. The vegetative propagation of high yielding, disease-resistant material for plantation establishment should allow at least a five-fold increase in nut production compared to propagation by seedlings.

As biotechnology develops very fast. I assume that it will influence the improvement of cashew within the next 20 years. As a comparison, pathogen resistance against the potato disease *Phytophthora infestans* (Mont) de By has been achieved in several transgenetic lines (Knogge et al. 1992). Resistance against powdery mildew through biotechnology in cashew should be feasible and might depend mainly on financing.

It is often stated that most cashew fields are not monocultural but intercropped in various ways (Ohler 1979, NOMISMA 1994). Some authors see cashew only as a crop and propose interplanting with other trees such as *Melia azedarach* L., *Leucaena leucocephala* (Lam) de Wit., *Dipterocarpus alatus* Roxb., *Casuarina junquiana* Miq. and *Eucalyptus* spp. (Watanabe 1988). Results are usually not satisfactory. When *Eucalyptus teretecornis* was interplanted with cashew, the incidence of *Helopeltis antonii* Sign. rose from 20% to 80% and the nut yield was reduced by 75% (Ghosh 1993). Jacob (1989) suggests interplanting of 2 rows of *Eucalyptus* (and other species) in (10 m) interrows of cashew as possible agroforestry system. This practice cannot be recommended for smallholder farmers, cashew as treecrop should be intercropped with annual plant species.

In Orissa, an area with frequent hurricanes, 20 rows of *Casuarina equisetifolia* Forst. were planted to form a shelterbelt and to provide fuel. These were followed by 20 rows of cashew on the lee side as a soil binder and for the nut crop and combined successfully. Coconut palms were also interplanted and irrigation and fertilisers were applied. Economic returns from the cashew trees were obtained from the 5th year (Patro et al. 1979, Reddy 1979, Kumar 1981).

In areas where hurricanes are rare cashew trees alone can serve as windbreak, even if they are planted around farmers fields. Much has been published about the benefits of wind breaks, mainly in temperate climates. The grain yield in fields protected by hedgerows in northern Germany is 10% higher than in unprotected areas. This includes the space taken by the hedgerow (Eigner 1975). Wind protection is given about 5 times the height before the hedgerow and 15-20 times the height on the leeward side. Cotton yield increased by 4-10% in northern India (Puri et al. 1992) and by 10 % in south Yemen (Raussen 1990) due to the effect of windbreaks (lowering evapotranspiration). Even higher yield increases where obtained in protected fields in the Majjia Valley in Niger where yields were 23% higher during a year with above average rainfall and still 16% higher in a year with rainfall 46% below average (Rocheleau et al. 1988). Steiner (1984) stated that advantages of intercropping are greater in a climate with high insolation (semi arid tropics) where wind brakes change the microclimate considerably. He also mentions that mere 15 trees/ha provide sufficient shade and wind protection to improve the yield of field crops. At first glance cashew trees might not be ideal for windbreaks because they grow very dense, but they can be pruned if necessary. Some strains of cashew grow to 12 m high. Assuming a protection by a cashew hedge, a belt of 12.5 x tree height (12m) wide (150 m) would be protected by one row. If the crop yield increases by 5% due to the wind protection over a unit area of land the total crop yield should remain stable compared to a non protected area. This includes the space taken by the cashew hedgerow (800-1000 m²) and adverse effects on crops by shade and lateral cashew roots. The yield realised from cashew would represent additional cash income.

Eijnatten (1991) argues for growing cashew in hedgerows. He states that hedgerows (2-3 m spacing within the row) at 12-15 m intervals double the canopy surface area per ha and result in doubled yield over the first 10 years.

Experience in Senegal has shown that farmers do not substitute their traditional crops with cashew (RUDECO 1989). They prefer planting systems that allow permanent intercropping. Therefore they should be encouraged to plant cashew in widely spaced rows against the main wind direction to protect their fields.

Asare (1995) reports that farmers in northern Ghana practise a 20 years fallow period that has been reduced due to population pressure. In such systems, cashew takes the role of a forest tree, planted in strips, with some natural vegetation left between the rows. This vegetation can be cleared in year 16 to crop and plant new cashew trees. The first rotation of cashew should be felled at an age of 21 years and the land made available opened for cropping. Aweto et al. (1994) found that soil under 20 year old cashew plantations was similar to soil under logged rain forest. The same findings were made by Kögel et al. (1985) in Senegal who concluded that cashew had no adverse effects on the soil despite popular belief to the contrary. A rotation system can, however, only work if the farmers agree and if livestock is excluded from the area while there are cashew trees younger than 5 years.

Some natural vegetation left in the cashew field might be suitable for deleterious insects. Predatory ant species can protect cashew trees from *Helopeltis* damage: the best known are red weaver ants (*Oecophylla longinoda* Latr.) that provide efficient protection against the coconut bug *Pseudotheraptus wayi* Brown on coconut palms in Tanzania (Varela 1991). The role of ants in pollination is unclear: it is unlikely that they act as regular pollinators.

Honey bees (*Apis melifera, Apis* spp.) are accepted pollinators of cashew. In north east Brazil a colony placed in an cashew orchard could yield 12-60 kg of honey per season that starts from the first flower opening until the last fruits ripen (the first honey is light red and turns black with time because the bees forage the apple juice at the end). Bee keepers in Brazil have to pay a fee to the plantation owner despite improved pollination (Freitas 1994). Nevertheless it is useful for cashew farmers to place bee hives in their cashew field to enhance the overall output.

We have found that most cashew trees are grown by smallholder farmers who have generally inadequate resources for making large investments. On wastelands with free ranging livestock, protection of young trees is a major problem. Fencing of large areas is not feasible under smallholder conditions and it is too expensive to fence small areas. Therefore, farmers should not plant cashew in one go, but according to their ability to protect and care for the young plants (including watering if there is a dry spell during the rainy season after planting). It is better to plant 20 healthy trees of good genetic material with 80-100% success rather than 200 trees of bad material with 10% success.

High density planting in the beginning is often favoured to suppress weed growth and to realise high and early yields. There is, however, the danger that farmers will not fell trees as required if they grow and if canopies close yield reduces. It would be better to plant 100 trees/ha at 5 m x 20 m spacing, intercrop and get a final density of 40-60 trees/ha (normal mortality included).

It would be profitable if private nurseries could be established to produce and sell improved (grafted) planting material to farmers. This would garantee quicker and more controlled improvement of the crop.

In areas with more than 800 mm mean annual rainfall direct sowing of cashew can be done, followed by grafting during the next season.

The tree planting tradition of farmers should be considered in the extension approach. Field layout should be as flexible as possible. It depends largely on site conditions (slope, soil, main wind direction) and farmers own perception. With normally growing planting material a density of 40-100 trees/ha is adequate. Planting should be in rows to allow future mechanisation, should it become feasible and desirable. The rotation periods of cashew might be longer than 20 years as 40 years old trees have shown good performance. Bad yielders should be removed from the field as soon as their yielding behaviour is confirmed. A final density of less than 40 trees/ha is not in itself a problem as the remaining trees produce and the interspace can be used for other crops or grazing. Densities over 100 trees/ha are also possible if dwarf material is used and labour and site conditions allow intensive cashew farming. It has to be borne in mind that high yielding crops remove nutrients from the site, - that have to be replaced if to maintain high outputs over a long period of time. Fertilisation will then become a necessity.

In India cashew is grown very often in schemes for "wasteland" (rangeland) recovery, with fruit production as the second objective. Positive effects of cashew growing on sandy areas in Brazil have been confirmed by Ohler (1995). In the marginal cashew growing areas (600- 800 mm rainfall) a government might be interested to stop the desertification process. Fruit trees are preferred by farmers and cashew is a low demanding fruit tree perfectly adapted to long dry periods. The promotion of cashew growing in these areas makes sense if farmers are accepted as responsible partners who invest their own resources and knowledge into their plantations. The role of donors and governments is to provide the best possible advice and planting material as well as economic conditions that allow the farmer to reach their own targets from their cashew intervention.

6. Conclusions and recommendations

This study shows that demand for cashew kernels is higher than the current nut production and prospects for an increasing demand in the traditional import countries and the opening of new markets in East Asia are bright. Progress in selection and vegetative multiplication make it possible to use high yielding planting material on farmers fields. Cashews can grow under low rainfall conditions (600-800 mm/year) on poor sandy soils, but fruit production is then low. In such cases the ecological effects of cashew planting should then be considered through economic evaluations, including added values as windbreaks and positive fertility influences due to litter and shade. Higher yields are obtained under higher rainfall regimes (800-3000 mm/year) and on deep (>1.5 m), fertile, sandy loamy soils. Increases in nut yields from currently 0.4 t/ha to 2-3 t/ha should be achievable within the next 10-15 years. Potential maximum nut yield will not be more than 6-7 t/ha until at least 2020. The integrated use of all parts of the cashew tree including apples, CNSL and wood can increase the overall economic benefits from cashew. Adapted planting systems are preconditions for sustainable production. Smaller family managed units using agroforestry techniques are favoured against large plantations for fruit production. If cashew is used in large scale forestry programmes the seeds should be selected from high yielding stands or clonal seed gardens to assure rapid spread of improved material. Improved and reliable marketing channels and fair prices are necessary to sustain farmers' interest in the cashew crop.

In order to be able to use the given potential as indicated in the preceding paragraphs, the following recommendations can be made:

1. Cashew production per unit area of land should be increased by:
   - ⇒ use of improved planting material
   - ⇒ adoption of improved husbandry practices
   - ⇒ placing of bee hives in orchards/plantations or creating good conditions for other potential pollinating insects by leaving natural vegetation
   - ⇒ integration of adapted plant protection measures

2. The rentability of cashew for farmers (and processors) can be increased by:

- ⇒ planting material that has larger nuts and a higher kernel content
- ⇒ enhanced use of the apple.
- ⇒ enhanced use of CNSL
- ⇒ enhanced use of wood

3. Cashew planting promotion must not aim at large areas/unit of time but on sustainable husbandry - with farmers as responsible partners both for investment and decision making. The role of development agencies should be limited to ensure that optimal planting material is provided for farmers and adequate knowledge is available to the farmer to allow an informed decision by her/him on which material to use and how to plant it. This can best be done through adequate nursery development.

To make use of the positive attitudes of farmers towards the integration of cashew with annual crops, programs of research should be adopted and more emphasis given to it. Mechanisms of communication between farmers and extension should be introduced and where existing, improved.

7. References

Abbott, -JC (1970) Marketing fruit and vegetables. *FAO Marketing Guide No. 2.* Rome; Italy.

Adis, -J; Kerr, -WE (1979) A thrips as a pest of 'piquia'. *Acta Amazonica*. 9: 4; p 790.

Akinwale, -SA (1992) Implications of pollen characters to the systematic delimitation of cashew (Anacardium occidentale L.). *Plant-Cell-Incompatibility-Newsletter*. No. 24; pp 1-6.

Albuquerque, -SDS; Hassan, -MV; Shetty, -KR (1960) Studies of the apple characters of cashew (*Anacardium occidentale* L.). *Mysore Agricultural Journal* 35: 1; pp 2-8

All time record in cashew export (1995) *Indian Cashew Journal*; Vol 22 No.1; pp 2-5.

Amaning, -E (1995) *Personal Communication.*

Ambika, -B; Abraham, -CC; Vidyadharan, -KK; Venkata-Ram, -CS (1983) Relative susceptibility of cashew types to infestation by *Helopeltis antonii* Sign. (Hemiptera: Miridae). Plant protection PLACROSYM II 1979 [edited by Venkata Ram; C.S.]; ; Kasaragod; Kerala; India pp 513-516.

Ananthakrishnan, -TN (1985) Host relationship and damage potential of thrips infesting cashew. In: Rao, -EVVB; Khan, -HH (1984) *Cashew research and development.* Indian Society for Plantation Crops. Kasaragod; Kerala; India.

Argles,-GK (1976) *Anacardium occidentale*- Cashew in *The propagation of tropical fruit trees* 184-222Horticultural Review No.4 Commonwealth Agricultural Bureau, Farnham Royal.

Arnold, -G (1994) *The third world handbook*; London 1994.

Asare, -AB (1995) *A socio-economic study of cashew plantations in the semi arid zone of Ghana*. Draft paper for MSc Thesis, Bangor.

Ascenso,-JC (1986) Potential of the cashew crop. *Agriculture-International*. 38: 11, pp 324-326.

Auckland, -AK (1961) The influence of seed quality on the early growth of cashew. *Tropical Agriculture (Trinidad)* 38: 1; pp 57-67.

Aweto,-AO; Ishola,-MA (1994) The impact of cashew (Anacardium occidentale) on forest soil. *Experimental-Agriculture*. 30: 3, pp 337-341.

Babu, -RSH; Rath, -S; Rajput, -CBS (1983) Insect pests of cashew in India and their control. *Pesticides*; 17: 4; pp 8-16;.

Babu, -VKS (1982) Prcessing of casew apple. *Cashew Causerie.* 1: 82; p 5.

Badrinath; Krishnappa, -AM; Khan, -MM; Rao, -KB (1988) Effect of lime and nutrients on the yield of cashew. *Cashew*; 1: 88; p 14.

Behrens, -R (1986) *L'anacardier.* Draft paper.

Behrens, -R (1988) *Initiation a la culture de l'anacardier*. Projet Anacardier; Sokone; Senegal.

Behrens, -R (1993) *Report of a Mission to ASA Farm, Agricultural Station Atebubu, Ghana.* Institut für Projektplanung Stuttgart, Germany

Bhaskara Rao, -EVV (1989) Released cashew varieties. *Cashew.* 1: 89, pp 16-18

Bhat, -KM; Bhat, -KV; Dhamodaran, -TK (1989) Fibre length variation in stem and branches of eleven tropical hardwoods. *IAWA-Bulletin*. 10: 1; 63-70.

Bhat, -KM; Bhat, -KV; Dhamodaran, -TK (1990) Wood specific gravity in stem and branches of eleven timbers from Kerala. *Indian Forester.* 116: 7 pp 541-546.

Bhat, -KM; Bhat, -KV; Rugmini, -P (1983) Variation in wood and bark properties of cashew. *Journal of the Indian Academy of Wood Science* 14: 1; pp 12-17

Bhattacharyya, -RK; Rao, -VNM (1989) Relative efficacy of some soil covers used in Robusta banana grown under different soil moisture regimes. *Indian Journal of Horticulture*., 46: 3, 333-338.

Bolton, -J (1995) *Personal Communication.*

Calzavara, -BBG (1971) O cajueiro (*Anacardium occidentale* L.) e suas possibilidades culturais no litoral Paraense. *Boletim, Escola de Agronomia da Amazonia.* No. 2, Brazil.

Cashewnut Shell Liquid: The raw material of the future (1994) *Indian Cashew Journal*; 21; 2; pp 7-9.

Central Food Technology Research Institute Mysore (1963) Utilisation of cashew apples; *Indian Cashew Journal*; 7: 10; pp 4-6.

Chatterjee, -ML (1989) Comparative efficacy of some insecticides against the tea-mosquito bug (*Helopeltis antonii*) on cashew. *Pestology*; 13: 7; pp 26-29.

Chattopadhyay, -N; Ghosh, -SN (1993) Studies on the floral biology of some cashew types under Jhargram conditions. *Cashew*. 1993; 7: 2; pp 5-7.

Chattopadhyay, -PK (1982) Cashew fruit set and retention as influenced by chemical spraying. *Udyanika*. 1982; 5: 1/2; pp 45-47.

Chemical Data and Safety Sheet; (s.d.) Cashew nut Shell Liquid (CNSL)

Chopra, -S (1990) Integrating conservation and development: A case study of the socio-economic forestry complex t Arabari; West Bengal. *The International Tree Crops Journal*; 6; pp 193-204.

Chowdhury, -MK (1992) Kendbona eco-development project, - a novel approach to wasteland reclamation. *Indian Forester;* December 1992; pp 879-885.

Cisse; M (1990) *Personal Communication.*

Codex Committee on processed fruits and vegetable (1985) *Proposed draft standard for cashew kernels*. Codex alimentarius Commission; FAO and WHO; Geneva 1985.

Commercial information (1994) Exports of cashew kernels from India. *Indian Cashew Journal*; 21; 3

Copeland, -HF (1961) Observations on the reproductive structures of *Anacardium occidentale*. Phytomorpology (India) 11: 4 pp 314-325.

Cornelius, -JA (1966) Cashew nut shell liquid and related materials. *Tropical Science 8;* pp 79-84.

Cundall, -EP (1995) Cashew. In Smart, -J and Simmonds, -NW (eds) (1995) *Evolution of Crop Plants.* 2nd edition; pp 11-13.

D'Silva,-I; D'Souza,-L (1992) In vitro propagation of *Anacardium occidentale* L. *Plant-Cell,-Tissue-and-Organ-Culture.* 29: 1, pp 1-6.

Dalvi, -VD; Thakare, -GG; Borude, -SG (1991) Economics of production of cashewnut in Sinhudurg District (M. S.). *Cashew*; 3: 91; pp15-17.

Damodaran, -VK (1966) The morphology and the biolgy of the cashew flower *Anacardium occidentale* L. II. Anthesis, dehiscence receptivity of stigma pollination, fruit set and fruit development. *Agriculture Research Journal of Kerala*. 4: 2, pp 78-84.

Damodaran,-VK (1985) Vegetative propagation of cashew - review of work done in Kerala. *Acta-Horticulturae.* No. 108, 51-56.

Darlington, -CD; Wylie, -AP (1955) *Chromosome Atlas of Flowering Plants;* George Allen & Unwin LTD; London; UK.

Das, -RC; Mishra, -SN (1985) Vegetative propagation in cashew. *Acta-Horticulturae.* No. 108, 285.

Date, -A (1965) *The market for cashew nut kernels and cashew nut shell liquid; TPI report* No. G11.

Devanandam, -M (1983) Soils for cashew. *Cashew Causerie* 1: 83; pp 6-9.

Devi, -MR; Murthy, -PRK (1983) Protection of cashew from tree-borer pest. *Pesticides*; 17: 9; p 37.

Dhamaney, -CP; Singh, -KR (1979) Cashew nut shell liquid for Indian particle boards. *Paintindia;* June 1979; p 40.

Dhandar,-DG (1985) Increase cashew production adopting vegetative propagation.

Acta-Horticulturae. No. 108, 285-286.

Directorate of Cashewnut Development (1985) Cashew apple preparations. *Cashew Causerie;* 2: 85; pp 12-16.

Duke, -JA (1989) *Handbook of nuts.* CRC Press Inc.; Bota Raton; Florida.

Eigner, -J (1975) Unsere Knicks im Natur- und Landeshaushalt. *Schleswig Holstein* 7: 1975, Kiel, Germany.

Eijnatten, -CLMvan (1979) *Charcoal from coconut palms and cashew trees*. Communication;-Coast-Agricultural-Research-Station;-Kenya. No. 6.

Eijnatten, -CLMvan (1991) *Anacardium occidentale* L. In: Verheij, -EWM; Coronel, -RE; *Plant resources of South-East Asia, No 2, Edible fruits and nuts.* Wageningen, The Netherlands.

Eijnatten, -CLMvan (1980) *Personal communication.*

Elsy, -CR; Namboodiri, -KMN; Vidyadharan, -KK; Oommen, -A (1986) Role of pollen and pollinating agents in cashew yield. *Cashew Causerie*; October-December 1986; pp 3-4.

Evans, -EM (1955) The application of cashew nut shell liquid resins. *Rubber and Plastics Age*; Vol 36; No. 5

Falcone,-AM; Leva,-AR (1987) Preliminary tests on the morphogenesis of the cashew in culture. *Rivista-di-Agricoltura-Subtropicale-e-Tropicale.* 81: 1-2, 117-125.

FAO (1985) *Agroclimatical data for Latin America and the Caribbean*; Rome; Italy.

FAO (1987) *Agroclimatical data for Asia;* Vol. 1; Rome; Italy.

FAO (1988) *Traditional food plants*. Bulletin 42; Rome; Italy.

FAO Economic and Social Development Paper 76 (1988) *The world market for tropical horticultural products;* Rome; Italy.

FAO *Production Yearbook 1987-1993*; Vol. 41-47.

Fernandes, -L; Mesquita, -AM (1995) *Anacardium occidentale* (cashew) pollen allergy in patients with allergic bronchial asthma. *Journal of Allergy and Clinical Immunology*. Vol 95 No 2 pp 501-504.

Florence, -EJM (1989) Sapstain microorganisms associated with some commercially important timbers of Kerala. *Evergreen Trichur*. No. 22; 6-7.

Franke, -G (1976) *Nutzpflanzen der Tropen und Subtropen*; Band II. S. Hirzel Verlag; Leipzig; pp 289-300.

Free, -JB; Williams, -IH (1976) Insect pollination of *Anacardium occidentale* L.; *Mangifera indica* L.; *Blighia sapida* Koenig and *Persea americana* Mill.

Tropical Agriculture (Trinidad) Vol. 53; No 2 pp 125-139.

Freitas, -BM (1994) Beekeeping and cashew in north-eastern brazil - the balance of honey and nut production. *Bee world* 75: 4, pp 160-168.

Garner,-RJ (1958) *The grafters Handbook* Faber, London, 2nd Ed.

Gedam, -PH; Sampathkumaran, -PS (1986) Cashew nut shell liquid: extraction chemistry and applications. *Progress in Organic Coatings*; 14; pp 115-157

Gerini, -V (1976) The Coleoptera present on cashew; with particular reference to *Plocaederus ferrugineus* (L.) in Sri Lanka. *Rivista di Agricoltura Subtropicale e Tropicale*; 70: 7/12; pp 185-190.

Ghosh, -SN (1989) Effect of nitrogen; phosphorous and potassium on flowering duration; yield and shelling percentage of cashew (*Anacardium occidentale* L.) *Indian Cashew Journal* 19: 1; pp 19-23.

Ghosh, -SN (1993) Effect of eucalyptus (*Eucalyptus teretecornia*) plants as intercrop in the cashew plantation - a case study in West Bengal. *Cashew*. 7: 2, pp 17-19.

Ghosh, -SN; Bose, -TK (1986) Effect of nutrition on NPK content in leaf and shoot of cashew (*Anacardium occidentale* L.). *Cashew Causerie* 2: 86; pp 9-10.

Gnanaharan, -R; Nair, -KSS; Sudheendrakumar, -VV (1982) Protection of fibrous raw material in storage against deterioration by biological organisms. *KFRI-Research-Report*; No. 12.

Godase, -SK; Dumbre, -RB; Kharat, -SB (1992) Evaluation of some insecticides for the control of tea mosquito on cashew. *Journal of Maharashtra Agricultural Universities*; 17: 2; pp 219-220.

Gondim, -MTP; Sales, -FJM (1981) Life cycle of the cashew whitefly. Preliminary note. *Fitossanidade*.; 5: 1; p 38.

Gopikumar, -K; Aravindakshan, -M; (s.d.) Studies on some qualitative aspects of cashew apple. *Indian-Cashew-Journal.*

Hammonds, -TW (1977) The distribution of cashew nut shell liquid type compounds in the cashew plant. *Tropical Science* 19: 3; pp 155-159.

Harries, -HC (1993) *Pre assignment report.* ODA Cashew Research Project, Breeding Programm. Mtwara,Tanzania.

Hassan, -MV; Rao, -VNM (1957) Studies on the transplantation of seedlings of cashew (*Anacardium occidentale* L.). Indian Journal of Agricultural Science. 27: 2; pp 177-184.

Heard, -TA; Vithanage, -V; Chacko, -EK (1990) Pollination biology of cashew in the Northern Territory of Australia. *Australian-Journal-of-Agricultural-Research*.; 41; pp 1101-1114.

Hegde, -M; Kulasekaran, -M; Shanmughavelu, -KG; Jayasankar, -S (1990) In vitro culture of cashew seedlings and multiple plantlets from mature cotyledons. *Indian-Cashew-Journal*. 20: 2, 19-24.

Hughes, -S (1995) *Personal Communication*.

Igboekwe, -AD (1991) Injury to young cashew plants; *Anacardium occidentale* L; by the red-banded thrips *Selenothrips rubrocinctus* Giard (Thysanoptera: Thripidae). Agriculture Ecosystems and Environment. 1985; 13: 1; pp 25-32.

Imports Review (1994) Imports of raw cashewnuts into India during January to March 1993 and January to March 1994. *The Cashew*; 3/94; p 36.

Increased export of Indian cashew kernels in 1992/93 (1994) *Indian Cashew Journal* 21: 3, pp 25-31.

Intini, -M (1987) Phytopathological aspects of cashew (*Anacardium occidentale* L.) in Tanzania. *International Journal of Tropical Plant Diseases*; 5: 2; pp 115-130.

Intini, -M; Sijaona, -MER (1983) Calendar of disease control with reference to phenological phases of cashew (*Anacardium occidentale* L.) in Tanzania. *Revista di Agricoltura Subtropicale e Tropicale*. 77: 3; pp 419-422.

ITC International Trade Centre UNCTAD/GATT (1973) *Major markets for edible tree nuts & dried fruits*. Geneva, Switzerland.

Jacob -VJ. (1989) Role of cashew in agroforestry in Kalahari sands. In: Kamara, -CS; Gossage -SJ; Kwesiga, -F (1995) *Agroforestry in Zambia.*, Proceedings of the First Zambia National Agroforestry Workshop, April 1989. Draft

Jaffee, -S (1995) *Private trader response to market liberalization in Tanzania's cashew nut industry*. Policy Research Working Papers. World-Bank., No. WPS1277, Washington, D.C., USA.

Khader, -KBA (1986) Management of cashew orchards. *Cashew* 1: 86; pp 13+15.

Knogge, -W; Scheel, -D, (1992) Resistenz von Pflanzen gegenüber pathogenen Pilzen. In: *Pflanzenproduktion und Biotechnologie*. Max-Planck-Institut für Züchtungsforschung.

Kögel, -I; Zech, -W (1985) The phenolic acid content of cashew leaves (*Anacardium occidentale* L.) and of the associated humus layer, Senegal. *Geoderma*. 35 pp 119-125.

Konhar, -T; Mech, -A (1988) Effect of growth regulators on flowering; fruit set and fruit retention in cashew (*Anacardium occidentale* L.). *Indian Cashew Journal*. 18: 4; pp 17-19

Krebs, -M (1991) *Standortkundliche Voraussetzungen für den Anbau von Cashew (*Anacardium occidentale *L.) im Senegal*. Diplomarbeit; Universität Bayreuth.

Kubo, -I; Ochi, -M; Vieira, -PC; Komatsu, -S (1993) Antitumor agents from the cashew (*Anacardium occidentale*) apple juice. *Journal of Agriculture Food Chemistry*. 41: 7; pp 1112-1115.

Kumar, -DP; Hedge, -M (1994) "Ullal-3"-- A new cashew variety for Karnataka. *The Cashew*. 1, 94; pp 11-14.

Kumar, -GNM; Narayanaswamy, -P; Mokashi,-AN; Mohan-Kumar, -GN (1984) Fruit growth and development in cashew (*Anacardium occidentale* L.). *Journal-of-Plantation-Crops*. 12: 1, pp 81-84.

Kumar, -PH (1981) Problems and prospects of establishing a plantation forestry with Casuarina, cashew and coconut in the coastal belt of India. *Rivista di Agricoltura Subtropicale e Tropicale*. 75: 4, pp 317-323.

Kumar, -R (1995) The cashewnut sector- Potential profits lost to Africa. *Marches Tropicaux et Mediterraneens*; February 1995.

Kumaran, -PM; Nayar, -NM; Murthy, -KN; Vimala, -B (1984) A study of variation in flowering characters of cashew germplasm. In: Rao, -EVVB; Khan, -HH (1984) *Cashew research and development.* Indian Society for Plantation Crops. Kasaragod, Kerala, India.

Lamboll, -R; Temu, -H; Gongwe, -A; Katinila, -N; Mtambuki, -A (1993) *Annual cashew research report; socio economics; FSR Section 1992-93.* ODA Cashew Research Project; Mtwara; Tanzania.

Latis, -T (1990) A note on the carpenter moth *Salagena* sp; a new pest of cashew in Zambia. *Tropical Pest Management*; 36: 3; pp 276-278.

Lievens,-C; Pylyser,-M; Boxus,-P (1989) First results about micropropagation of *Anacardium occidentale* by tissue culture. *Fruits-Paris.* 44: 10, 553-557.

Lim, -TK; Singh, -G (1984) Disease and pest problems of cashew in Malaysia. In: Rao, -EVVB; Khan, -HH (1984) *Cashew research and development.* Indian Society for Plantation Crops. Kasaragod; Kerala; India.

Mabberley, -DJ (1986) *The plant book.* Cambridge University Press.

Mahanthesh, -B; Melanta, -KR (1994) Effect of Nitrogen; Phosphorus and Potassium on the yield of cashew apple (*Anacardium occidentale* L.). *Cashew*. 4: 94 pp 14-18.

Majumder, -PK; Sharma, -DK (1989) A new concept of orcharding in mango. *Acta Horticulturae*., No. 231, pp 335-338.

Malaysia Beekeeping Research and Development Team (1987) *Beekeeping: Malaysia Research and Development*. Summary report1983-1986.

Manoj, -PS; George, -TE; Krishnan, -S (1993) Evaluation of F1 hybrids of cashew (*Anacardium occidentale* L.). *Cashew*. 7: 2, pp 3-4.

Mathew, -MT; Manuel, -K; Krishnaswami, -L (1983) Cashew 2000 A.D. *Cashew Causerie*; 3: 83; pp 3-11.

Mathew, -T (1982) Manuring of cashew. *Cashew Causerie* 4: 82; p 23.

Mathew, -TJ (1984) Reclamation of laterite areas of North Kerala and Karnataka for cashew cultivation. *Cashew Causerie* 4: 84; pp 21-22

Maydell, -HJv (1983) *Abres et arbustes du Sahel*; Schriftenreihe der GTZ No. 147; Eschborn, Germany.

McEvans (1980) *Personal Communication*.

Meteorological Office (1983) *Tables of temperature;relative humidity; precipitation and sunshine for the world; Part IV Africa; the Atlantik Ocean South and the Indian Ocean;* Her Majesty's Stationery Office; London.

Mishra, -DP (1984) Land suitability for cashew I. The criteria. *Cashew Causerie* 4: 84; pp 12-20.

Mishra, -DP (1985a) Land suitability for cashew II. The procedure. *Cashew Causerie* 1: 85; pp 7-19.

Mishra, -DP (1985b) Land suitability for cashew III. A case study. *Cashew Causerie* 2: 85; pp 12-15.

Misra, -MP; Basuchoudhuri, -JC (1985) Control of *Plocaederus ferrugineus* (L.) (Coleoptera: Cerambycidae) through field hygiene. *Indian Journal of Agricultural Sciences*; 5: 4; pp 290-293.

Mitchell, -JD; Mori, -SA (1987) *The cashew and its relatives* Anacardium*: Anacardiaceae.* Memoirs of the New York Botanical Garden Volume 42.

Mohan, -KVJ; Kumaran, -PM; Murthy, -KN; Nayar, -NM (1982) Anthesis and anther dehiscence of cashew flower. In: Vishveshwara, -S *Genetics, plant breeding and horticulture*. Proceedings of the fourth annual symposium on plantation crops (Placrosym IV), Mysore 3-5 December 1981 pp 360-367.

Moncur, -MW; Wait, -AJ (1986) Tabular descriptions of crops grown in the tropics 15. Cashew (*Anacardium occidentale* L.). *Technical Memorandum, Institute of Biological Resources*, CSIRO.

Morton, -JF (1961) The cashew's brighter future. *Economic Botany*; Vol 15; pp 57-78.

Morton, -JF; Venning;, -FD (1972) Avoid Failures and Losses in the Cultivation of the Cashew. *Econmic Botany*; pp 245-252.

Muhs, -HJ (1992) Macro- and microvegetative propagation as a tool in tree breeding as demonstrated by case studies of aspen and cashew and regulations for marketing clonal material. *Rapid propagation of fast-growing woody species.* 71-85; CASAFA Report Series No. 3. Wallingford, UK; CAB

International.

Murthy, -BGK; Sivasmaban, -MA (1984) Recent trends in CNSL utilisation. In: Rao, -EVVB; Khan, -HH (1984) *Cashew research and development.* Indian Society for Plantation Crops. Kasaragod; Kerala; India.

Musaliar, -TKSH (1994) Global cooperation in cashew promotion; need of the hour. *Indian Cashew Journal*; 21: 2; pp 11-12.

Muthu, -M; Baskaran, -P; Venkata-Ram, -CS (1983) Performance of quinalphos against the insect pests of cashew (*Anacardium occidentale* L.). Proceedings of the Second Annual Symposium on Plantation Crops. Plant protection PLACROSYM II 1979 [edited by Venkata Ram; C.S.].; pp 474-483.

Nagabhushanam,-S (1985a) Vegetative propagation in cashew - review of work done at Vittal. *Acta-Horticulturae.* No. 108, 57-63.

Nagabhushanam,-S (1985b) Preliminary studies on propagation of cashew by stooling and layering. *Acta-Horticulturae.* No. 108, 286-287.

Naik, - VG; Wakar, -SS; Talathi, -JM (1992) Economic evaluation of investments in cashew orchard in the Konkan region. *Cashew* 4: 92, pp 11-13.

Nair, -GM; Abraham, -CC (1982) Relative efficiency of some foliar insecticidal treatments for the control of *Helopeltis antonii* Signoret infesting cashew trees. *Agricultural Research Journal of Kerala*; 20: 2; pp 41-48.

Nair, -GM; Abraham, -CC (1983) Control of *Helopeltis antonii* Signoret infesting cashew using dusting powder formulations of some common insecticides. Agricultural Research Journal of Kerala; 21: 1; pp 21-26.

Nair, -GM; Abraham, -CC (1984; Relative efficiency of some of the common insecticides and their joint formulations with carbaryl against the tea mosquito bug (*Helopeltis antonii* Signoret) infesting cashew trees. *Agricultural Research Journal of Kerala*; 22: 2; pp 118-123.

Nair, -KV (1984) Harvesting; collection and storage of cashewnut. *Cashew Causerie*; 2: 84; pp 17-19.

Nalini,-PV; Pushpalatha,-PB; Chandy,-KC (1994a) A special type of cashew nut sans shell liquid. *Cashew*. 8: 1, 15-16.

Nalini,-PV; Pushpalatha,-PB; Chandy,-KC (1994b) Hybrids for nut size. *Cashew*. 8: 4, 23-25.

Nanjundaswamy, -AM; Setty, -GR; Patwardhan, -MV (1984) Utilization of cashew apples for the development of processed prodcuts. In: Rao, -EVVB; Khan, -HH (1984) *Cashew research and development.* Indian Society for Plantation Crops. Kasaragod; Kerala; India.

Narayanamurti, -D; Rangaraju, -TS (1969) Further experiments with Cashew kernel testa tannin. *Paintindia*; 20-1.

Nathaniels, -NQR; Shomari, -SH; Sijaona, -MER (1993) *Annual Cashew Research Report; Plant Pathology Section (1992/93).* Mtwara; Tanzania.

Nawale, -RN; Salvi, -MJ; Limaye, -VP (1984) Studies on the fruit set and fruit drop in cashew (*Anacardium occidentale* L.) *Cashew Causerie* 1: 84; pp 5-7.

Ndiaye, -A (1979) *Project preparation report to the Governor of Sine Saloum*; Kaolack; Senegal.

NOMISMA (1994) *The world cashew economy*. Bologna; Italy.

Northwood, P.J. (1966). Some observations in flowering and fruit-setting in the cashew *Anarcadium occidentale* L. *Tropical Agriculture* **43**: 35-42

Ochse, -JJ; Soule, -MJJr.; Dijkman, -MJ; Welburg, -C (1961) *Tropical and Subtropical Agriculture*; Vol.1. The Macmillan Company; New York; pp 523-525.

ODA Cashew Research Project (1995) *Annual cashew research report.* Mtwara; Tanzania.

Ohler, -JG (1966) Cashew nut processing. *Tropical Abstracts* Vol. 21; pp 549-554

Ohler, -JG (1979) *Cashew*. Communication 71; Koninklijk Instituut voor de Tropen; Amsterdam.

Ohler- JG (1995) *Personal Communication.*

Ohmstedt, -H (1991) *Motive der Pflanzung von Anacardium occidentale und ihre sozialen und ökonomischen Auswirkungen auf das bäuerliche Leben*. GTZ Project Report; Sokone; Senegal

Ohmstedt, -U (1991a) *Versuche zur vegetativen Vermehrung von* Anacardium occidentale *durch Stecklinge.* Project Report PASA; Sokone; Senegal.

Ohmstedt, -U (1991b) *Protection des champs d'anacardier par les moyens naturels; regenerable et disponible au niveau local*. Project Report PASA; Sokone; Senegal.

Ohmstedt, -U (1991c) *Les parcelles d'essais et les arbre plus*. Project Report PASA; Sokone; Senegal

Ohmstedt, -U (1991d) *Vegetative Vermehrung von* Anacardium occidentale *durch Veredlung.* Project Report PASA; Sokone; Senegal.

Palaniswami,-V; Hameed,-AS; Vijayakumar,-M (1985) Vegetative propagation in cashew - work done at Vridhachalam. *Acta-Horticulturae.* No. 108, 67-70.

Pan, -XL; Geest, -LPSvd (1990) Insect pests of cashew in Hainan; China; and their control. *Journal of Applied Entomology*; 110: 4; pp 370-377.

Parameswaran, -NK; Damodaran, -VK; Prabhakaran, -PV 1984a) Factors influencing yield in cashew (*Anacardium occidentale* L.). *Indian-Cashew-Journal*.; 16: 3; pp 9-15.

Parameswaran, -NK; Damodaran, -VK; Prabhakaran;-PV (1984b) Relationship between yield and duration of different phases in flower opening in cashew (*Anacardium occidentale* L.). *Indian Cashew Journal*; 16: 4; pp 15-19.

Parente, -JIG (1991) *Recomendacoes tecnicas para o cultivo do cajueriro anao precoce.* Comunicado Tecnico, EMBRAPA, Brazil.

Parry, -CE (1970) *Marketing of cashew nuts, factors promoting growth and change.* ILMA, Bogota, Colombia

Patnaik, -HP; Das, -MS; Panda, -JM (1985) Studies on the fruit set and fruit drop in cashew (*Anacardium occidentale* L.) under Orissa conditions. *Cashew Causerie* October-December 1985; pp 7-8.

Patro, -C; Behera, -RN (1979) Cashew helps to fix sand dunes in Orissa. *Indian-Farming.* 28: 12; pp 31-32.

Philip,-VJ (1984) In vitro organogenesis and plantlet formation in cashew (*Anacardium occidentale* L.) *Annals-of-Botany*. 54: 1, 149-152.

Phoon, -ACG (1983) Beekeeping in Malaysia. *Pertanika;* 6

Puri, -S; Singh, -S; Khara, -A (1992) Effect of windbreak on the yield of cotton crop in semiarid regions of Haryana. *Agroforestry Systems.* 1992, pp 183-195

Purseglove, -JW ;1968) *Tropical crops; Dicotyledons*. Longman; London

Radhakrishna, -Y; Naranyanamma, -M; Ramadevi- M (1993) Effect of various methods of fertilizer application on the yield of cashew. *Cashew* 2: 93; pp 15-16.

Rai, -PS; (1983) Bionomics factor of cashew stem and root borer. *Journal of Maharashtra Agricultural Universities*; 8: 3; pp 247-249.

Rajapakse, -RRS; Jeevaratnam, -K (1983) Seasonal population changes of *Helopeltis antonii* (Heteroptera: Miridae) in cashew. *Agricultural Research Journal of Kerala*; 21: 2; pp 38-42.

Raju, -DS; Venkata-Ram, -CS (1983) A note on major pest problems of cashew; coconut and arecanut and their control in Goa. PLACROSYM II 1979 [edited by Venkata Ram; C.S.]. pp 523-529

Ramaiah, -MS (1976) Progress of research in cashew industry. *Fette Seifen Anstrichmittel* 78 Nr 12 pp 472-477.

Rao, -BHK; Ayyanna, -R; Narayana, -KL (1984) Integrated control of cashew stem and root borer Plocaederus ferrugineus L. In: Rao, -EVVB; Khan, -HH (1984) *Cashew research and development.* Indian Society for Plantation Crops. Kasaragod; Kerala; India.

Rao, -CB; Dasradhi, -TB; Rao, -YY (1962)) Studies on fruit development in cashew. *South Indian Horticulture*. 10; pp 18-21

Rao, -GSLVP; Gopakumar, -CS (1994) Climate and cashew. *Cashew Causerie* 4: 94; pp 3-9.

Rao, -MBN; Satyanarayana,-G; Kumari,-NG; Padmanabham,-V (1989a) Effect of method of potting and hardening on field establishment of rooted cuttings of cashew (*Anacardium occidental*e L.) *Indian-Cashew-Journal, 19: 2, 15-17.*

Rao, -MBN; Satyanarayana,-G; Rameswar,-A; Shivraj,-A; Padmanabham,-V (1989b) Bio-chemical basis for root-regeneration in ringed shoot cuttings of cashew (*Anacardium occidentale* L.) plants of different ages. Cofactor activity and total phenol content. *Journal-of-Plantation-Crops.* 17: 1, 65-68.

Rao, -SN (1985) Vegetative propagation of cashew - review of work done at Baptla. *Acta-Horticulturae.* No. 108, 64-66.

Rao, -VNM (1985) Top-working in cashew -commercial feasibility. *Cashew Causerie* 4: 85, pp 5-7.

Rao, -VNM; Hassan, -MV (1957) Preliminary studies on the floral biology of cashew (*Anacardium occidentale* L.) Indian Journal of Agriculture Science; 27; 3; pp 277-288.

Raussen, -T (1990) Planung von Windschutzstreifen in ariden und semiariden Gebieten. *Der Tropenlandwirt* Beiheft Nr 43, Witzenhausen, Germany.

Reddi; -EUB (1991) Pollinating agent of cashew, - wind or insects? *Indian-Cashew-Journal*. 20: 4; 13-18) 16 ref.; 1 col. pl.

Reddy, -CVK (1979) Shelter belts against storms and cyclones on the coast. *Indian Forester*. 105: 10, pp 720-726.

Reddy, -KS; Rao, -RR; Raju, -MR; Rao, -NHP; Rao -AM (1983) Promissing cashew clones from Cashew Research Station, Bapatla, A.P. *Cashew Causerie* 4: 83, pp 2-4.

Reddy, -MAN; Shivanandam, -VN; Gowda, -MC; Siddaraju, -M; Shankaranarayana; -V (1986) Morphological and yield characteristics of cashew (*Anacardium occidentale* L.) selections under Chintamani conditions. *Cashew* 2: 86; pp 3-5

Rehm, -S; Espig, -G (1984) *Die Kulturpflanzen der Tropen und Suptropen*. Eugen Ulmer; Stuttgart.

Renganayaki, -PR; Karivaratharaju, -TV (1993) Influence of physiological maturity on seed quality in cashew (*Anacardium occidentale* L.) *Cashew*; 4: 93; pp 10-13.

Rocheleau, -D; Weber, -F; Field-Juma, -A (1988) *Agroforestry in dryland Africa.* ICRAF Nairobi, Kenya

Rosengarten, -FJr. (1984) *The book of Edible nuts.* Walker Publishing Company; USA.

Rudat, -H (1995) *Personal communication*.

RUDECO (1989) *Potentialanalyse und Vermarktungsstudie für Cashewüsse*. Unpublished Report; GTZ; Eschborn.

Russell, -DC (1969) *Cashew nut processing.* Agricultural Services Bulletin 6; FAO; Rome.

Sahani, -JN; Patro, -C (1985) Vegetative propagation of cashew - through side grafting in-situ. *Acta-Horticulturae.* No. 108, 71-74.

Sales, -FJM; Oliveira, -LQ-de; Alves, -VPO (1981) Effectiveness of organosynthetic insecticides for the control of the cashew whitefly. *Fitossanidade*; 5: 1; 7-14; Brazil.

Sapkal; -BB; Hulamani, -NC; Nalwadi, -UG (1994) Flowering and sex-ratio in some cashew (*Anacardium occidentale* L.) selections. *Cashew*; 1: 94; pp 7-10

Sarkar, -BB; Nath, -SC; Debnath, -S (1989) Problem and prospect of cashew (*Anacardium occidentale* L.) in Tripura. *Cashew* 4: 89; pp 9-21.

Sastry, -LVL; Setty, -L; Satyavathi, -VK; Pruthi, -JS; Siddappa, -GS (1962) Polyphenol constitutents in cashew apple juice as influenced by region; strain and selection. *Indian Journal for Applied Chemistry*. Vol. 25; pp 4-7.

Sathiamma, -B; Venkata-Ram, -CS (1983) Varietal reaction of cashew to tea mosquito; *Helopeltis antonii* S. (Hemiptera: Miridae) a major pest of cashew. *Plant protection PLACROSYM II* 1979 [edited by Venkata Ram; C.S.]; pp 530-534.

Satpathy, -B (1986) Protecting cashew plantations by vegetal fence from biotic interference. *Cashew Causerie* 2: 86; pp 6-8.

Satpathy, -B (1987) Providing shelter belt and wind breaks around cashew plantations in the coastal sands. *Cashew Causerie* 4: 87; pp 15-17.

Satpathy, -B; Rath, -S (1986) Optimum spacing and plant population of cashew for different agro-climatic regions of Orissa. *Cashew Causerie* 1: 86; pp 9-12.

Sawke, -DP; Salvi, -MJ; Patil, -MM (1986) “Soft wood grafting” a sur technique of clonal propagation in cashew. *Indian-Cashew-Journal*; 17: 1; 17-18.

Schery, -RW (1954) *Plants for man.* George Allan & Unwin LTD; London.

Sedgley, -M; Ashari, -S; Wunnachit, -W (1992) The application of scientific techniques to fruit and nut production in the tropics. *Acta Horticulturae*; No. 292; pp 61-67.

Sekar, -C; Karunakaran, -KR (1994). Economic analysis of cashew plantations under agroforestry conditions of Central Tamil Nadu. *Journal of Tropical*

Forest Science **6** (4) pp 523-28

Sen, -SK; Debnath, -S; Bandyopadhyay, -A; Poi, -A (1991) Propagation of cashewnut *Anacardium occidentale* L. from cuttings. *Environment-and-Ecology* 9: 1, pp 268-271.

Seshadri, -KW; Rao, -RR (1985) Modified method of 'epicotyl grafting' in cashew for commercial propagation. *Indian-Cashew-Journal*, 17: 4, pp 11-13.

Shetty, -KK; Melanta, -KR (1990) Hardening of cashew (*Anacardium occidentale* L.) air layers in planting media to improve field establishment. *Mysore-Journal-of-Agricultural-Sciences.* 24: 3, 375-378.

Shiomi, -T; Mulya, -K; Oniki, -M (1991) Bacterial wilt of cashew (*Anacardium occidentale* L.) caused by *Pseudomonas solanacearum* in Indonesia. *Industrial Crops Research Journal*; 2: 1; pp 29-35.

Shomari, -SH (1988) Cashewnut Research in Tanzania. *Proceedings of the national workshop on national agriculture and livestock research in Tanzania*; Arusha; April 1988.

Shoo,-J (1994) *Personal communication*.

Sijaona, -MER; Shomari, -SH (1987) The powdery mildew disease of cashew in Tanzania. *TARO-Newsletter*; 2: 3; 4-5.

Singh, -JP (1995) *Personal Communication* (Flowering and harvesting period in Orissa).

Smith, -NJH; Williams, -JT; Plucknett, -DL; Talbot, -JT (1992) *Tropical forests and their crops.* Comstock Publishing Associates; Ithaka and London.

Steiner, -KG (1984) *Intercropping in tropical smallholder agriculture with special reference to West Africa.* 2nd Edition, Eschborn.

Subba Rao, -MS (1984) Scope for development of alkoholic beverage from cashew apple. In: Rao, -EVVB; Khan, -HH (1984) *Cashew research and development.* Indian Society for Plantation Crops. Kasaragod; Kerala; India.

Sundararaju, -D (1984) Cashew pests and their natural enemies in Goa. *Journal of Plantation Crops*; 12: 1; pp 38-46;.

Sundararaju, -D (1992) Biological control of tea mosquito bug and other sucking pests of cashew. *Annual Report 1991-'92*; National Research Centre for Cashew. Kasagarod; Kerala; India; pp 40-44

Suryanarayana,-MA; Melanta,-KR (1989) Effect of age of shoots on rooting of cashew stool layers. *Indian-Cashew-Journal.*, 19: 2, 10-11.

Sy, -MO; Martinelli, -L; Scienza, -A (1991) In vitro organogenesis and regeneration in cashew (*Anacardium occidentale* L.) *Acta-Horticulturae.* No. 289, 267-268;

Tachibana, -S (1990) Relationships between fruit productivity, leaf area index and crown density and yield in different planting densities in Wase satsuma mandarin (Citrus unshiu) trees. *Journal of the Japanese Society for Horticultural Science*., 58: 4, 871-875;

Thiele, -GF; Schilden, -Mvd (ed.); Lookeren-Campagne, -Pv (ed.) (1991) Apple monitoring: a whole system approach to grower education and research: Germany and the Netherlands. *Acta Horticulturae*., No. 295, pp 39-46.

Tirimanna, -ASL (1984) Prospects for cashew cultivation in Suriname. In: Rao, -EVVB; Khan, -HH (1984) *Cashew research and development.* Indian Society for Plantation Crops. Kasaragod; Kerala; India.

Traore, -M (1988) *Practical demonstrations of local cashew nut processing in Sokone; Senegal.*

Tropical Products Institut (1961) *Cashew nut kernels: Their production and market.*

Tsakiris, -A (1990) Review of current method of disease control in cashew. *Research and Training Newsletter*; Tanzania; 5: 2; pp 7-9.

Tyman, -JH; Kiong, -LS (1978) Long chain phenols: Part XI. Composition of natural cashew nut shell liquid (*Anacardium occidentale*) from various sources. *Lipids.* Vol. 13 No. 8; pp 525-533

Tyman, -JHP (1980) Cultivation; processing and utilisation of the cashew. *Chemistry and Industry* 19; January 1980; pp 59-62.

Udofia, -S (1995) *Personal Communication.*

Valsalakumari, -PK; Vidyadharan, -KK; Damodaran, -VK (1985) A comparative study of different methods of vegetative propagation of cashew.*Acta-Horticulturae,* No. 108, 289.

Varela, -AM (1991) Biology of *Oecophylla longinoda.* In: Annual report July 1990 to June 1991, National Coconut Development Programm, Dar es Salaam, Tanzania.

Venugopal, -K; Khader, -KBA (1991) Influence of soils and climate on the productivity of cashew. *Indian Cashew Journal*; 20: 3; pp 19-24.

Waller, -JM; Nathaniels, -N; Sijoana, -MER; Shomari, -SH (1992) Cashew powdery mildew (*Oidium anacardii* Noack) in Tanzania. *Tropical Pest Management*; 38: 2; pp 160-163.

Wardowski, -WF; Ahrens, -MJ (1991) Cashew apple and nut. In: Nagy, -S; Shaw, -PE; Wardowski, -WF) *Fruits of tropical and subtropical origin; composition; properties and uses.* pp 67-87; Florida Science Source INC; Lake Alfred; Florida.

Watanabe, -H; Sahunalu, -P; Khemnark, -C (1988) Combinations of trees and crops in the taungya method as applied in Thailand. *Agroforestry Systems*. 6: 2, pp

169-177.

Wilson, -H; Ovid, -A (1994) Influence of fertilizers on cassava production under rainfed conditions. *Journal-of-Plant-Nutrition*. 17: 7, pp 1127-1135.

Wilson, R.J. (1975). *The market for cashew nut kernels and cashew nut shell liquid*. Tropical products institute, London

Wolcott;-GN (1944) How to make wood unpalatable to the West Indian drywood termite *Cryptotermes brevis* Walker. II. With organic compounds.; *Caribean. Forester*. 5 pp 171-80.

Wunnachit, -W; Jenner, -CF; Sedgley, -M (1992a) Floral and extrafloral nectar production in *Anacardium occidentale* L. (Anacardiaceae): an andromonoecious species. *International-Journal-of-Plant-Sciences*. 153: 3; I; pp 413-420.

Wunnachit, -W; Jenner, -CF; Sedgley, -M (1992b) Pollen vigour and composition in relation to andromonoecy in cashew (*Anacardium occidentale* L.: Anacardiaceae). *Sexual Plant Reproduction*; 5: 4; pp 264-269.

Wunnachit, -W; Pattison, -SJ; Giles, -L; Millington, -AJ; Sedgley, -M (1992) Pollen tube growth and genotype compatibility in cashew in relation to yield. *Journal of Horticultural Science*.; 67: 1; 67-75) 29 ref.

Wunnachit, -W; Sedgley, -M (1992) Floral structure and phenology of cashew in relation to yield. *Horticultural Science*; 67(6) pp 769-777.

Zech, -W; Krebs, -M; Barkow, -A (1992) *Cashew (*Anacardium occidentale *L.) in Senegal; an example for an ecological study in West Africa*. Unpublished.