UNIVERSITY OF ZULULAND

MORPHOLOGY AND SELECTION OF HIGH YIELDING CASHEW (*Anacardium occidentale* L.) STRAINS FOR MAPUTALAND, SOUTH AFRICA

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by

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PREFACE

The work described in this dissertation was carried out at Coastal Cashews farm, Maputaland, KwaZulu-Natal and in the Department of Botany, University of Zululand, KwaDlangezwa, under the supervision of Prof. D.P. Ferreira.

These studies have not otherwise been submitted in any form for any degree or diploma to any University. Where use has been made of work of others, it is duly acknowledged in the text.

Ramiakajato

Vololona RAMIAKAJATO

I certify that the above statement is correct

Professor D.P. FERREIRA

ABSTRACT

The Industrial Development Corporation (IDC) and Ithala Development Finance Corporation Limited (ITHALA) are in the process of establishing a cashew industry in South Africa at Coastal Cashews, Maputaland. This study concentrated on the morphology and yield characteristics of most of the strains already planted at Coastal Cashew farm. One hundred and thirty different strains, originating from various countries such as Zambia and Brazil, have been studied.

Morphological and yield characteristics were considered for suggestions about strains for inclusion in a propagation program. Most morphological characteristics such as apple size and colour, leaf surface area and others, varied between strains, reflecting the diverse origin of plant material. Similarly, most of the yield characteristics such as nut production, nut size and others, varied between strains and within strains between seasons.

Based on the morphological (number of panicles per tree, number of perfect flowers per panicle, and others) and the yield characteristics (nut per panicle, nut size, and others), a model has been proposed where the number of panicles per tree and the number of perfect flowers per panicle are used to predict the yield of a tree (strain).

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CHAPTER ONE

1 INTRODUCTION

1.1 Classification

Anacardium occidentale L. belongs to the family Anacardiaceae of the class Dicotyledonae with about 170 000 flowering species. The class is extremely diverse vegetatively but is characterised by the flower structure. The family includes trees and shrubs with 70 genera and over 500 species. Widespread mainly in warmer parts of the world, the trees are dioecious but occur sometimes with occasionally bisexual flowers. The trees have tough, simple leaves, which are alternate and pinnately veined. Flowers are small, regular, tetra- to pentamerous with stamens usually twice the number of petals, ovary superior and bi- to pentalocular with solitary ovules. The fruit is usually a drupe, and sometimes an achene (Dryer, 1975). The indigenous South African marula (*Sclerocarya birrea* ssp), karee (*Rhus lancea* L.) and some notoriously poisonous plants such as poison ivy (*R. toxicodendron* L.), and poison sumac (*R. vernix* L.) are also members of this family (Morton, 1961; Coates Palgrave, 1988 and Frankel, 1991).

1.2 Distribution

Originating from the Amazon, the cashew fruit was part of the local Tupi Indians' diet, when André Thevet, a French naturalist, first recorded it during his visit to Brazil in 1558 (Ohler, 1979 and Smith *et al.*, 1992). Cashew was brought to India by the Portuguese during the first half of the sixteenth century to prevent soil erosion (first recorded in Cochin during 1578) but has adapted itself along the entire west and south coast of the Indian subcontinent. The production and export of cashew nuts soon became one of India's leading industries, as it remains today. Later on, the cashew spread rapidly into the islands of Sri Lanka, Adaman and Nicobar and into Indonesia (Smith *et al.*, 1992).

The Spanish explorers carried the cashew to the Philippines and Central American countries around 1560 (Ohler, 1979 and Rosengarten, 1984). The Portuguese introduced cashew into Africa during the second half of the sixteenth century where ecological conditions were very favourable for growing these trees and today it is spread over the eastern coast of the continent (Mozambique, Tanzania and Kenya) as well as into Madagascar. Cashew has thus established itself in widely different areas and has contributed greatly to the economic potential of various countries (Agnoloni and Giuliani, 1977; Ohler, 1979; Ascenso, 1986 and Giuliani, 1986).

In South Africa, cashew trees had been established in Kwazulu-Natal (Maputaland, *viz.* Makhatini Research Station, Hluhluwe and Ingwavuma), in the Northern province (Burgershall, Messina) and in Mpumulanga (Malelane) (Roe, 1994).

1.3 World production

Cultivated both in small plots and large commercial plantations, cashew is a major crop grown for its nut and fruit in a number of tropical countries. Cashew is the second most traded nut in the world, after almond.

Major producers include India, Brazil, Mozambique, Tanzania and Indonesia (Duke, 1989). The USA, Europe and the former Soviet Union are the major importers of cashews, followed by Canada, Japan and Hong-Kong (FAO, 1993).

Brazilian and Indian production accounted for 38% of world production during 1969-1971 and for 56% during 1989-1991 (Figures 1.1). During the last nine years, new producers, particularly in Australasia and Africa, contributed to the total production of cashew nuts.

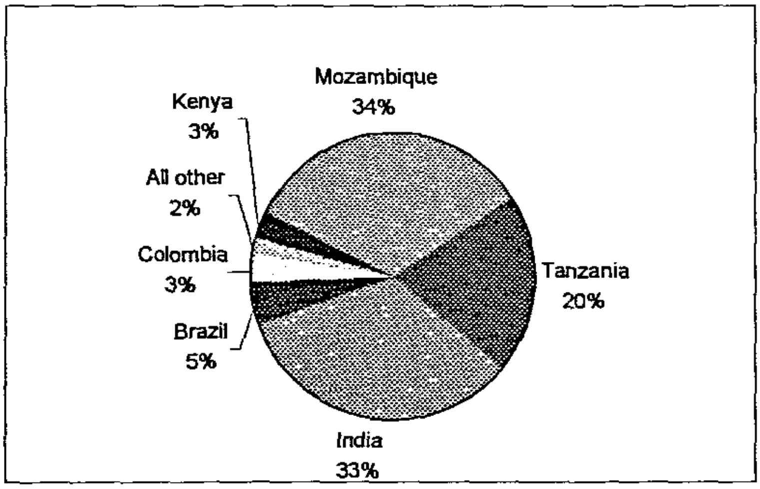
Cashew nut production of major nut producing continents is shown in Table 1.1. According to the Food and Agriculture Organisation (FAO, 1999), the total annual world production of nut-in-shell during 1999 reached 1 179 508 tons, excluding home consumption, but it has become more and more difficult to predict future production. Hudson (1999) stated that world supply increased by 12.8 per cent during 1996-1997 compared to an annual increase of 5 per cent during 1998.

Table 1.1 World's Cashew Nut production (in tons)

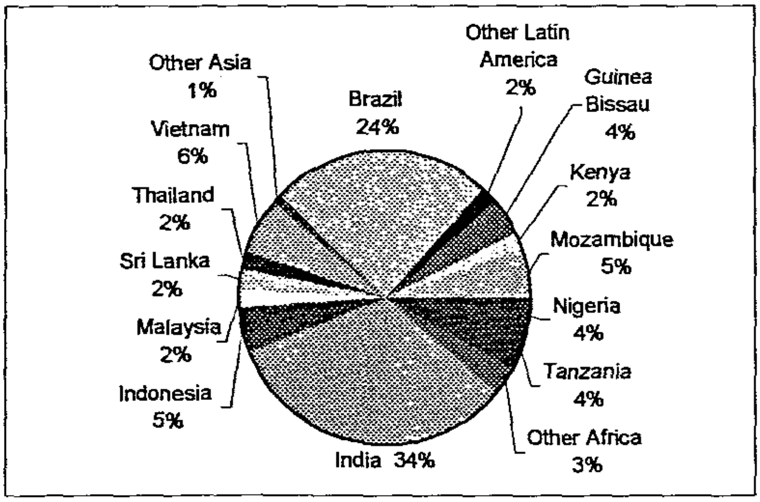
Continent	Quantity 1999	Quantity 2000*
Asia	638 037	650 000
Africa	411 068	450 000
America	130 403	180 000
World	1 179 508	1 280 000

* Estimate

Source: FAO and National cashew nut kernel export industries (1999)



(a)



(b)

Figure 1.1 Production share of cashew producing countries

(a) 1969-1971 (Ohler 1979, Jaffe *et al.* 1995)

(b) 1989-1991 (NOMISMA, 1994, FAO, 1993, FAO, 1994)

Future world production could increase considerably because of new producers, in particular Australasia, Vietnam, the Philippines, Thailand, Sri Lanka and Malaysia. Latin American countries such as Colombia, the West Indies, as well as East and West African countries (Senegal, Nigeria, Ghana, Ivory Coast, etc.) also produce and export cashews (Falzetti *et al.*, 1985 and FAO, 1993).

Mozambique still controls the supply to the Southern African market because the South African cashew industry is relatively new and production is not sufficient to meet the high demand. Import of cashew kernel into South Africa was 800 to 900 tons per annum for 1998 with 61% from Mozambique and 24% from Brazil (Coastal Cashews, 1999).

1.4 Economic importance

Many species of the Anacardiaceae family have been widely cultivated because of their economic importance as sources of timber, oil, wax, dye and for their edible fruit such as *Mangifera indica* L. (mangoes) and nuts *Anacardium occidentale* L. (cashew) and *Pistacia vera* L. (pistachio) (Ohler, 1979). Besides the cashew nuts, cashew apple and oil extracted from the shell are also of economic importance.

1.4.1 Cashew nut

Cashew nut, or kernel, has been a treasured delicacy all over the world for decades. The nut, rich in minerals (phosphorus, magnesium and iron) and vitamins (A, D, K and particularly E) essential for humans, is toxic when raw but very nutritious after being roasted. The cashew nut is also very rich in proteins and its high content of much needed amino acids and energy makes it an ideal diet supplement. Contrary to popular belief, cashew nut contains little or no harmful cholesterol and is lower in fat content than most other nuts (appendix I). The kernel contains about 47% fat, but 82% of this is comprised of unsaturated fatty (oleic, linoleic) acids (Purseglove, 1968; Ohler, 1979; FAO, 1993; IDRC, 1997 and Greencottage, 2000).

1.4.2 Cashew apple

The cashew apple is very sour and astringent, due to its tannin content, until fully ripe when it becomes very juicy. It is fibrous and has a very thin skin that bruises easily. The ripe apple has a peculiar smell and since they become spoiled within a couple of hours after harvest, they are often thrown away or left to rot. The apple contains about 85% juice, which has a sugar content of around 10 %, is very rich in riboflavin and vitamin C (five times more than oranges) and contains a relatively high level of mineral salt (Morton, 1987; FAO, 1993; Rain-tree, 1996 and IDRC 1997).

1.4.3 Cashew oil

The cashew shell contains a viscous, balsam-like substance known as cashew oil or cashew nut shell liquid (CNSL). It has caustic properties and when heated gives off pungent and choking fumes (Duke, 1989). The CNSL is a highly toxic fluid, about 90% of which is comprised of anacardic acid. The remaining 10% consists of cardol and is mainly responsible of the activity of the liquid

(Cornelius, 1966). When in contact with the skin, the liquid may cause swelling, rubefaction, vesication and even acute dermatitis. Therefore, cashew nuts must be cleaned to remove the cardol and then roasted to remove the toxins before the kernels are ready for consumption. The CNSL also occurs in other parts of the cashew tree (Table 1.2).

Table 1.2 CNSL level in different parts of the cashew tree (in ppm)

	Root	Wood	Leaves	Bark	Apples	Kernels
CNSL	75	25	250	85	60	35

Source: Hammonds (1977)

The CNSL has many industrial uses, such as in brake linings, disc grinders, preservatives, waterproof paints, varnishes, insulating enamel, lacquer and pesticides (Wolcott, 1944; Evans, 1955; Masefield *et al.*, 1969; Ramaiah, 1976 and Rudeco, 1989). The supply of CNSL on the world market has risen considerably and the price varies enormously from year to year and from export country to export country (FAO, 1993).

1.4.4 Medicinal value and other economical uses

Cashew wood is water-resistant and is used in the construction of boats and ferries. The bark provides indelible ink which is used for a natural dye (Purseglove, 1968).

In addition to its fresh consumption as fruit, the cashew apple is used in the manufacture of sweets, jam, jelly, alcoholic and non-alcoholic beverages, and candied fruit (Morton, 1987).

Cashew tree has been used medicinally worldwide (Table 1.3). The vitamins in cashew assist in assimilation of fats and to increase the immunity level. Unsaturated fatty acids in cashew kernel enhance the possibility of lowering the cholesterol level in blood. The minerals protect the human nervous system. Cashew nuts are regarded as a first class energy source, and have anti-toxin, anti-enteric and anti-diuretic properties (Rakoto-Ratsimamanga *et al.*, 1968; Rain-tree, 199; Greencottage, 2000).

In the Amazon, Duke (1983) reported that the juice is used against influenza and a bark tea is used for diarrhoea, as a colic remedy, as douche for vaginal secretions or as an astringent to stop bleeding after tooth extraction. The cashew extract is also used in body care products like shampoos and lotions, in treatment of premature ageing and in remineralization of the skin. In Brazil the fruit is taken as a diuretic, a stimulant and as an aphrodisiac. The leaves and/or bark is also used in Brazil and North America for coughs and bronchitis, diabetes, genital problems and venereal diseases (Rain-tree, 1996; Greencottage, 2000).

In Nigeria, the root has been used as a purgative and the leaf is used as a remedy for calcium deficiency. The leaf is also used in the prevention of malaria in the form of a natural insect repellent and insecticide. In some other tropical countries, the cashew resins are used as an expectorant and cough remedy and the cashew oil is used to treat ailments such as scurvy, wart and ringworm (Greencottage, 2000).

Table 1.3 Ethnobotany of cashew: Worldwide uses

ETHNOBOTANY: WORLDWIDE USES	
Africa	Intoxicant, Tattoo
Brazil	Analgesic, Aphrodisiac, Asthenia, Asthma, Bronchitis, Callosity, Corn, Cough, Diabetes, Diuretic, Dyspepsia, Eczema, Gargle, Genital, Impotency, Intestinal Colic, Leishmaniasis, Mouthwash, Muscular Debility, Psoriasis, Scrofula, Stimulant, Syphilis, throat, Tonsillitis, Ulcers (mouth), Urinary, Venereal, Vesicant, Wart, Wounds
Elsewhere	Asthma, Astringent, Cold, Corn, Congestion, Cough, Debility, Diabetes, Dysentery, Liqueur, Piscicide, Purgative, Scurvy, Tumour, Vesicant, Wart
Guatemala	Liqueur, Poison, Skin, Wart
Haiti	Caries, Toothache, Wart, Stomatitis, Diabetes
Malaya	Diarrhoea, Thrush, Catarrh, Dermatosis, Nausea, Constipation
Mexico	Caustic, Diabetes, Diarrhoea, Freckle, Leprosy, Liqueur, Poison, Skin, Swelling, Syphilis, Ulcer, Wart
Panama	Asthma, Cold, Congestion, Diabetes, Diarrhoea, Hypertension, Inflammation
Peru	Antiseptic, Diarrhoea, Douche, Infection, Infections (skin)
Trinidad	Ache (Stomach), Asthma, Cough, Diarrhoea, Dysentery, Dyspepsia
Turkey	Diarrhoea, Fever, Poison, Wart
Venezuela	Dysentery, Gargle, Leprosy, Sore (Throat)

1.5 Problem statement

a) The original cashew plant materials at Coastal Cashews were imported over a number of years from various sources such as Brazil and Zambia. About 200 different selections have been planted and were assessed during an initial research period from 1987 to 1993. Afterwards additional material was imported and planted. Problems arose in identification of the different varieties or strains and in identifying high yielding strains.

b) Research on cashews has been undertaken worldwide for several decades, but there is very little information available concerning cashew production in South Africa as the industry is very young in this country. Cashew trees are also of botanical significance because of their morphological and genetic features. A study of the morphological and phenotypic features may contribute to the identification of strains.

1.6 Aims of this research

The aims of this study were to:

a) use the morphological and phenotypic features of the different strains to determine their possible genetic relationships.

b) select high yielding cashew strains suitable for the environmental conditions at Coastal Cashews and Maputaland.

c) study the phenotypic features that may contribute to decisions on the future planting of trees in order to optimize yield.

d) develop a model to assist in the prediction of future yield.

CHAPTER TWO

2 LITERATURE REVIEW

A literature survey indicated that morphological characteristics of *Anacardium occidentale* L. such as leaves, nuts and apples, together with economic factors such as yield and yielding potential, season of flowering and regularity of bearing, may be of importance in identifying superior trees (Ohler, 1979; Nambiar and Pillai, 1985).

2.1 Growing conditions

Known as a tropical crop, cashew grows at different latitudes between 0°N (North-Eastern Brazil) to 28°S (northern Natal in South Africa). Most other regions where cashew is an important crop fall between the latitudes 10°N and 23°S (Ohler, 1979). The areas in South Africa where cashew cultivation was established are the hot, semi-arid and low-lying regions within the latitudes of 22°S and 28°S (Ascenso, 1988).

Ohler (1979) reported that the altitude for cashew growth depends on latitude. In Songea, Tanzania, at 10°S, cashew can grow at altitudes up to 1000 m, while in Assam, India, at 25°N, conditions were not favourable for cashews at altitudes above 170 m and its distribution on the coastal plains was limited to an elevation of 700 m (Directorate, 1985; Reddy and Rao Rama, 1985). Lower temperatures at higher altitudes and latitudes affect the development of the tree.

Agnoloni and Giuliani (1977) describe cashew as a plant of the hot dry tropics. Cashew tolerates a climate with 4 to 7 dry months per annum, with an annual temperature range of 21 to 28°C (Table 2.1). It thrives at high temperatures, exceeding 40°C in its native habitat as well as in Mozambique, but cannot tolerate frost and heavy dew. The absolute minimum and maximum temperatures for cashew were reported to be 5°C and 45°C respectively (Ohler, 1979; Duke, 1983; Mishra and Shantakerman, 1984; Directorate, 1985). Cool spring conditions tend to delay flowering (Wait and Jamieson, 1986). Duke also reported that in the Amazon, cashew could tolerate humidity of between 65 and 80% saturation, insolation of 1500 to 2000 hours per year and a wind velocity of 2 to 25 km/hr.

Table 2.1 Mean daily temperatures and relative humidity range in dry and wet season of four locations favourable for commercial cashew growing (Ascenso, 1988; Coastal Cashews, 1999) (modified from Roe, 1994).

	SITE			
	NM	NA	NB	CC*
ALTITUDE (m)	171	10	60	70
MINIMA (°C)				
Dry season	16-20	15-20	18-20	11-18
Wet season	18-22	22-24	19-21	16-22
MAXIMA (°C)				
Dry season	28-35	31-35	32-33	24-28
Wet season	32-35	32-36	30-32	25-31
REL. HUMIDITY (%)				
Dry season	52-73	61-71	73-77	50-63
Wet season	54-74	69-87	72-83	59-68

NM = Northern Mozambique, NA = Northern Australia, NB = North eastern Brazil, CC = Coastal Cashews, South Africa. *Data for 1993-1996

Several authors have stated that cashews could be grown with annual rainfall ranging from 500 to 4000 mm, depending on the characteristics of different regions. Heavy rainfall or insufficient water may, however, lead to excessive vegetative growth, to irregular flowering and fruit-setting, to serious flower drop, to severe crop losses from a powdery mildew (*Oidium anarcadii*) and to infections by anthracnose (*Colletotrichum gloeosporioides*) (Agnoloni and Giuliani, 1977; Ohler, 1979). Cashew can be very resistant to drought, but only under conditions where roots can penetrate deeply into the soil and draw water from the water reserve (Ohler, 1979). Cashew also cannot tolerate waterlogging (Staples, undated; Nambiar and Pillai, 1985).

Ohler (1979) suggested that being adapted to climates with long dry seasons and low relative humidity, cashews do best with long periods of sunshine throughout the year. Extremely dry air during the flowering period may wither the flowers and decrease yield. According to Ascenso (1988), the estimated duration of sunshine required annually for cashew is not less than 1500-2500 hours.

Most cashew growing areas are close to the sea and exposed to wind. Ascenco (1988) reported that windbreaks should be established if the wind velocity is greater than 25km/h. During the study period at Coastal Cashew farm, it was noted that some trees had been broken by wind with resultant serious flower drop and fruit fall.

Cashews have a high degree of adaptability for varying soil conditions but the best soil for growth is deep, friable and well drained with a pH between 6.63 and 7.31 (Directorate, 1985). The phreatic water level should, ideally, be at a depth of 5 to 10 m (Ohler, 1979). Cashew can grow on poor or stony soil, but according to Agnoloni and Giuliani (1977), cashew is a sand-loving plant with a preference for coastal plains. The soil at the study site (Ngutshana), is a grey sandy soil of the fernwood type (appendix II) and the water table varies from 0.7 to 3 m (Coastal Cashews, 1999).

2.2 Cashew biology

2.2.1 Morphology

2.2.1.1 Tree habit and size

Phenotypically, cashew trees range from ascending (with erect branches) to decumbent (branches parallel to soil surface). Growing conditions might influence the appearance of the tree. Some trees may grow tall, up to a height of 15 m.

2.2.1.2 *Canopy and trunk diameter*

The cashew tree can have a conical or umbrella-shaped canopy and an erect trunk (Auckland, 1961; Ohler, 1979). Reddy Narayana *et al.*, (1988) observed in Chintamani, India, tree canopies ranging from compact to sparse, with diameters from 2.5 to 6.1 m. Tsakiris (1967) measured the canopy development of young trees in Tanzania. It appeared that under favourable conditions, young cashew trees grew at a rate of about 1m per year and the canopy diameter increased by 1.5 to 2 m per year for the first five to six years. Thereafter, growth did slow down. Shoot growth may occur throughout the year, especially when rainfall is well distributed (Ohler, 1979).

Canopy shape might influence the yield per tree as cashew trees bear their fruit at the periphery and fruit production becomes almost nil on branches. Trees with a narrow and highly conical-shaped canopy would form a much larger surface area than a tree with a low spreading canopy. The latter is preferred for easy harvesting, especially when apples are to be harvested, before they fall on the ground (Ohler, 1979).

2.2.1.3 Leaves

According to Ohler (1979), Duke (1983) and Welsh (1998), the cashew leaves are glabrous, thick and leathery, oblong to obovate, rounded to emarginate at the apex, 10 to 20 cm long and 5 to 10 cm wide. The petioles are about 0.5 to 1 cm long. The leaves are simple, entire and pinnately veined, each leaf having 6 to 20 pairs of prominent veins. They are alternately arranged on the twigs. The young leaves are reddish-brown to pale green, gradually turning to dark green when reaching maturity. Leaves on the same twig may be of different sizes and shapes. Growing conditions may influence leaves. Reddy Narayana *et al.*, (1988) reported a maximum leaf length of 167.78 mm and a minimum of 88.48 mm. Rao and Hassan (1957) also reported that the number of leaves produced on the new leader shoots varied, either on the same tree or between different trees, and ranged from 3 to 14, with a mean of 9 per shoot.

2.2.1.4 Roots

The cashew tree has a taproot penetrating deeply into the soil with an extensive lateral root system (Ohler, 1979). Adams (1975) showed that after emergence, the radicle rapidly developed into a taproot, which started producing lateral roots four days later. The laterals also grew quickly at first and were produced progressively lower along the taproot as it elongated.

Tsakiris and Northwood (1967) recorded in Tanzania that a taproot of a 42-month old tree reached a depth of more than 2.3 m and had a diameter of 8.8 cm, tapering gradually to 1.9 cm. Lefèbvre (1969) and Andrianirina (1990) observed in Madagascar on various occasions that young trees of 2 to 3 months had tap-roots with a length of more than 80 cm and 5-month old trees had tap-roots of 120 cm. They found that trees could utilise a large volume of soil because their roots grew not only vertically to a considerable depth but also in a large radius.

2.2.1.5 Inflorescence

The inflorescence is a panicle with variable shape (Figure 2.1), from conical to pyramidal or irregular (Rao and Hassan, 1957; Ohler, 1979).

According to Copeland (1961), the ultimate cluster of flowers is a typical monochasial cyme and the apparent panicle is actually a thyrse. Ohler (1979) reported that a lateral inflorescence does occur, particularly when the terminal shoot is damaged for various reasons.

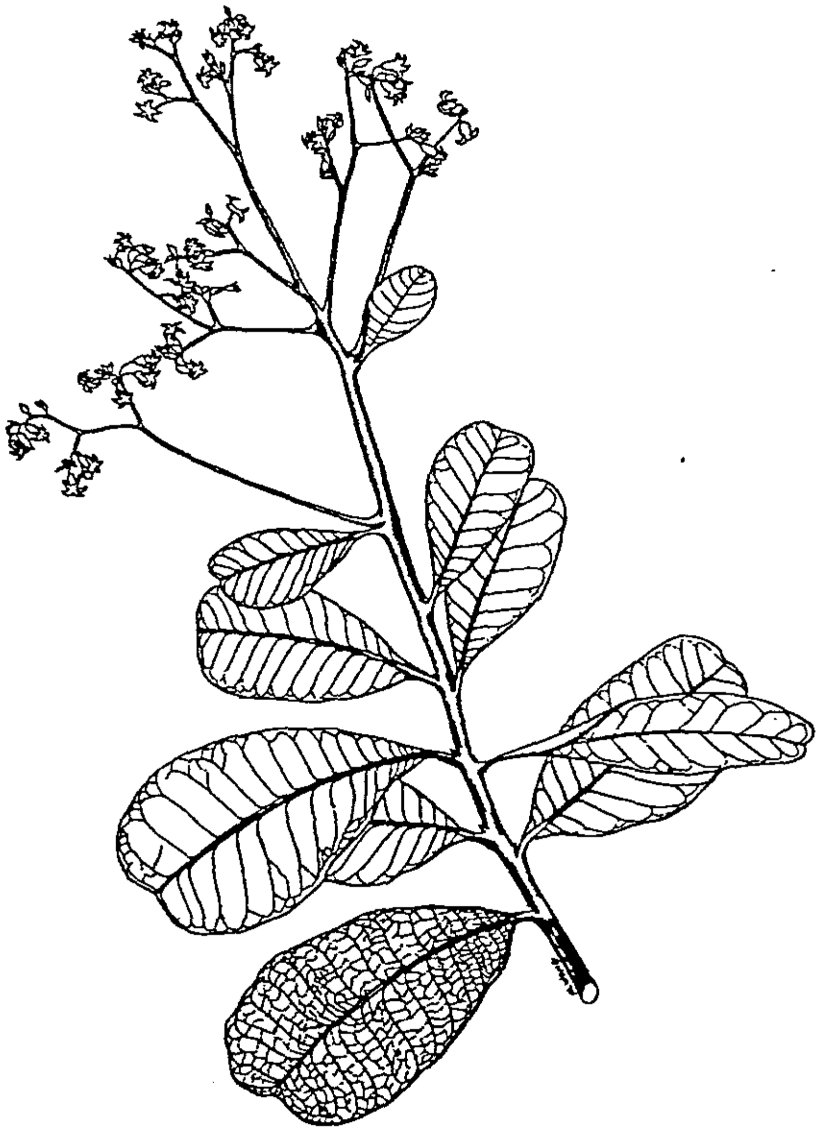


Figure 2.1 *Anacardium occidentale* L.: Cashew. Flowering branch (Purseglove, 1968)

Depending on the vigour of the plant, each panicle carries from 3 to 11 floral peduncles, each of which carries about 40 to 100 individual florets, totalling between 120 and 1000 flowers per inflorescence with a mean of 320 (Morada, 1941). However, the number of flowers per panicle varies with the location and growing conditions. Moncur (1988) counted one to 200 flowers per panicle and Damodaran *et al.*, (1966) reported 300 to 1600 flowers with a mean of 486 flowers per healthy panicle.

The first buds of the panicle produce the panicle branches and flower buds are produced only after some weeks. The time of the first appearance of the inflorescence until the opening of the first flower is about five to six weeks (Copeland, 1961; Veeraragavathatham and Palaniswamy, 1985). The duration of visible bud initiation to full development and opening varied between types. Godwa *et al.*, (1986) recorded an average of 13.5 days for bud development under Chintamani conditions (India) while it took 17 days in Bangalore (Thimma Raju *et al.*, 1980).

2.2.1.6 Flowers

The cashew flower is typically pentamerous but previous researchers have indicated the occurrence of abnormalities of cashew flowers (Reddy *et al.*, 1988; Fofifa, 1981). The normal flower of cashew is small and scented, with pale greenish cream petals at the opening which turn pink after a few days as the flowers age (Ohler, 1979; Heard *et al.*, 1990). The cashew tree is andromonoecious, producing male (staminate) flowers and perfect (hermaphrodite) flowers on the same panicle (Figures 2.2). The flower opens almost any time of the day but the peak period of opening ranges between 11 a.m. and 12 p.m. (Rao and Hassan, 1957).

Male flowers normally possess one large stamen with a long filament and five to nine small ones, all arranged in an ellipse. The anthers are basifixed, bilobed, with dehiscence through a slit between the two pollen sacs of each lobe. The anthers are rounded and pink coloured, turning grey at the time of dehiscence. Petals and sepals alternate with each other and usually there are five of each, although this number may vary. Ascenco & Mota (1972b) observed that sepal number varies between four and seven and the number of petals between four and nine. The lanceolated petals, more than 10 mm long, develop within a tube formed by the overlapping sepals around the pedicel. At anthesis the petals curve back, bringing the tips to the level of the receptacle (Agnoloni and Giuliani, 1977; Nair *et al.*, 1979; Ohler, 1979). The flowers produce an abundance of nectar, which is highly attractive to flies, bees, ants and other insects (Morton, 1961; Free and Williams, 1976).

Each perfect flower stands upon a pedicel about 2 mm long and is similar to the male flower except that it also possesses a functional pistil consisting of stigma, style and a single ovule ovary (Ohler, 1979). The style is long and slender, usually longer than the major stamens, tapering to a large stigma (Ohler, 1979; Wunnachit *et al.*, 1992). Ascenco & Mota (1972a) did find that in 98% of the flowers, the pistil was longer than the large stamen.

According to Rao and Hassan (1957) and Damodoran *et al.*, (1965), the flowers have only one true stamen, the others being staminodes, whereas Copeland (1961), Northwood (1966) and Pillai & Pillai (1977) were of the opinion that all stamens are normal and produce pollen. Damodoran *et al.*, (1965) confirmed that staminodes alone do not generally play any part in pollination under natural conditions, unless hand pollination is performed or insects are allowed inside.

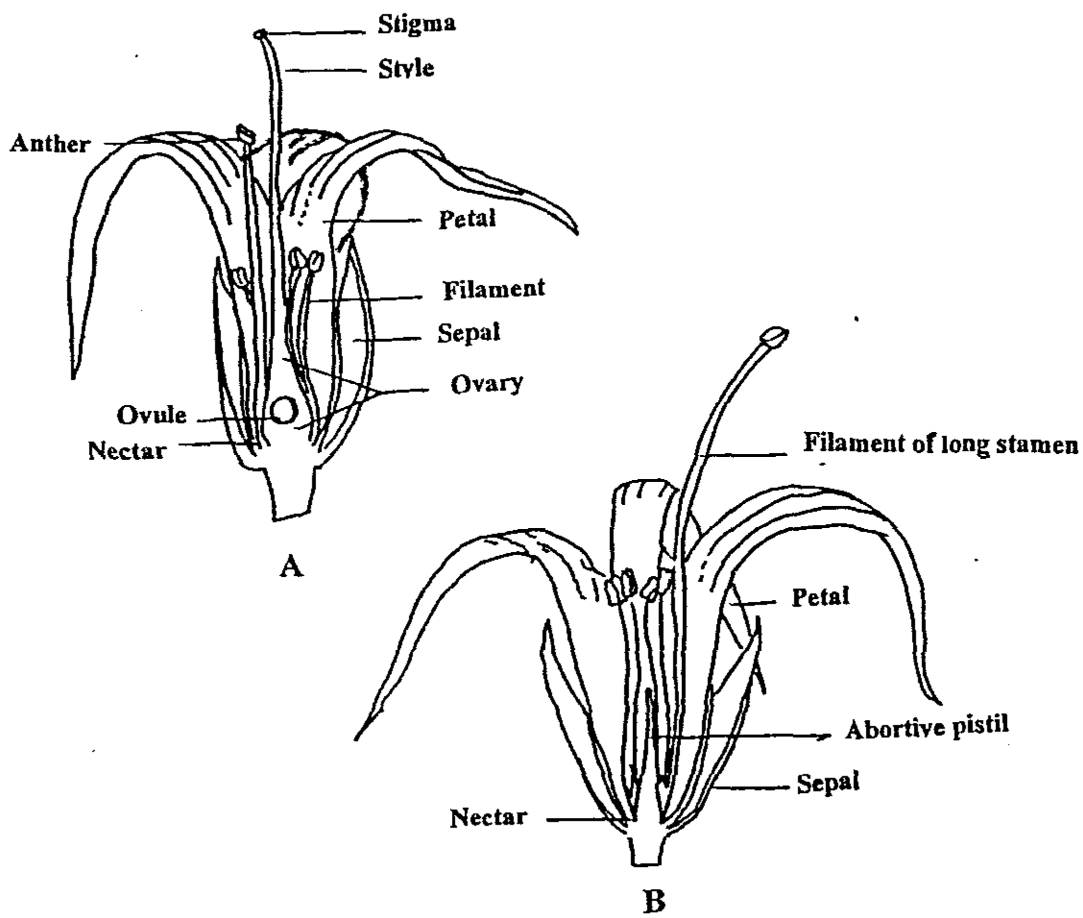


Figure 2.2 Longitudinal section of Cashew flowers.

A, hermaphrodite (perfect); B, male (staminate) flower

(Modified from Purseglove, 1968)

2.2.1.7 Fruit

The cashew fruit has been well studied (Ohler, 1979). The size and shape of the apple and the nut can vary considerably. The kidney-shaped nut is the true fruit of the cashew tree and contains a single seed. It is attached to the juicy swollen pedicel or apple. The shell of the nut has a leathery exocarp, a hard and brittle endocarp, and a spongy mesocarp containing the cashew nut shell liquid (CNSL). The kernel has a wrinkled surface and is covered by a reddish brown or pink testa (Figure 2.3). The kernel itself is white.

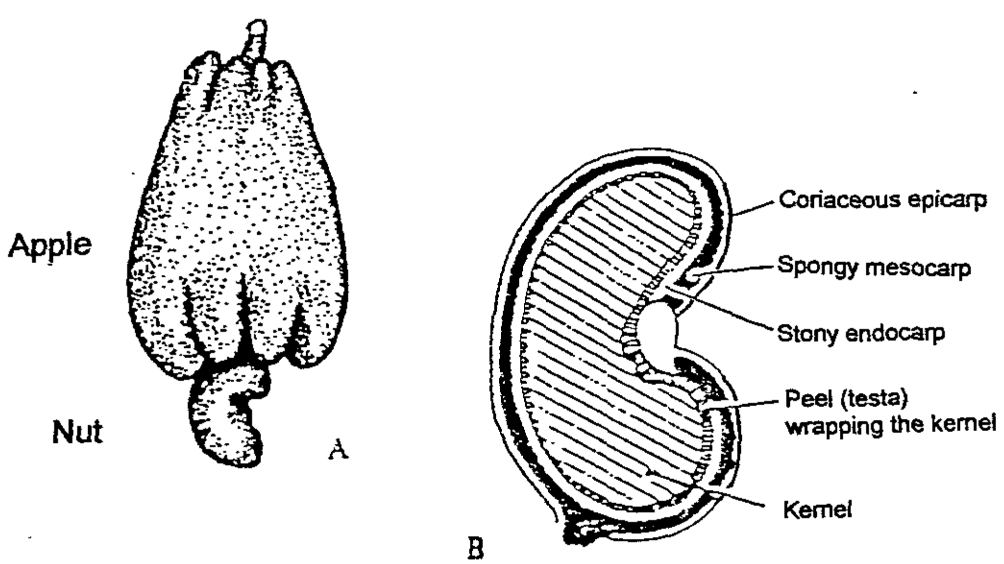


Figure 2.3 ***Anacardium occidentale* L.: Cashew. A, apple and nut; B, longitudinal section of cashew nut (Purseglove, 1968; Agnoloni and Giuliani, 1977)**

Worldwide, the average nut weight varied between 2.3 and 30g (Peixoto, 1960; Correia, 1963; Lefèbvre, 1963; Rochetti & Moselle, 1967; Rakotovao, 1999). The length of most nuts varied between 2.5 and 4 cm and the width between 2 and 3 cm (Ohler, 1979). Often the apples were pear-shaped, hence the name *Anacardium*, which means 'shaped like a heart'. The very young apple is green to purple in colour, later turning red, yellow or an intermediate colour when ripe (Ohler, 1979).

Damodoran *et al.*, (1966) and Roth (1974) indicated that the growth of the apple was much slower than that of the nut during the first two thirds of the development stage, but by the seventh week, the apple suddenly increased to twice the length of the nut in the final stage of growth.

2.2.2 Reproduction

2.2.2.1 Age of tree

The reproductive structures of cashew have been well described (Rao and Hassan, 1957; Copeland, 1961; Ascenco and Mota, 1972b; Moncur and Wait, 1986; Heard *et al.,* 1990). The age at which cashew trees start flowering is very important and is probably influenced by different ecological and biological factors. Ohler (1979) reported that under favourable conditions, trees may start yielding after three years but a few flowers and fruits were produced even in the second year. Typically, new flushes grew at the end of a rainy season and the terminal ends of the newly developed shoots produced the inflorescence.

2.2.2.2 Period and duration of flowering and fruiting

The period and the duration of flowering of cashew differed with location (Table 2.2). In India, the flowering season for most of the trees was between November and early February with its peak in December and January. Few varieties flowered earlier in September, and the late ones started flowering only in January and extended up to February (Reddy *et al.*, 1986). In Tanzania, June to November is the flowering period with its peak between August and September (Northwood, 1966). Behrens (1996) observed trees flowering throughout the year in Senegal, with only 4 months of rainfall and low relative humidity, while in Australia, Wunnachit *et al.*, (1992) noted that the period of flowering extended from August to March.

Table 2.2 Comparison of the flowering period of cashew in different countries (modified from Roe, 1994; Behrens, 1996)

Country/region	Latitude/longitude	Flowering period	Fruiting period
Brazil: Ceara	3°44'S, 38°33'W	July-Oct	Oct-Jan
Paraiba	6°51'S, 35°28'W	Oct-Jan	Mid Oct-Jan
Senegal (Kaolack)	14°08'N, 16°04'W	Jan-Mar	Apr-June
India: Orissa	20°28'N, 85°56'E	Nov-Jan	Mid Jan-Apr
Karnataka	12°52'N, 74°51'E	Nov-Jan	Jan-Apr
Kerala	9°58'N, 76°14'E	Sept-Dec	Mid Jan-Apr
Tamil Nadu	10°46'N, 79°51'E	Mar-May	Mid May-Aug
Tanzania (Lindili)	10°00'S, 39°42'E	June-Sept	Mid Sept-Dec
Australia (Queensland)	12°40'S,131°50'E	June-Sept	Sept-Dec
Madagascar (Mahajanga)	15°40'S,46°21'E	Aug-Nov	Nov-Feb
Mozambique (Chinde)	18°35'S, 36°28'E	Sept-Dec	Oct-Feb

Bigger (1960) observed perfect flowers which reached their maximum number by the third week of flowering and finally disappeared by the sixth week, whereas the male flowers were at their peak by the sixth and continued until the tenth week. Northwood (1966) also found that most of the male flowers were produced within the first three weeks. However, such early or late flowering trees should be observed for a few years to verify the consistency of the flowering habit.

2.2.2.3 Flowering patterns

Flowering in cashew appears in various patterns, which vary with different strains and locations (Ghosh, 1988). According to Reddy *et al.,* (1988), a short flowering phase with a high percentage of hermaphrodite flowers is one of the most important characteristics of a high yield in cashew.

Pavithran and Ravindranathan (1974) and Parameswaran *et al.*, (1984), reported two different flowering patterns in most of the Indian cashew selections: first a male phase (only male flowers) then a mixed phase (male and hermaphrodite flowers) followed by a second male phase.

However, in Tanzania (Bigger, 1960; Northwood, 1966), and in some varieties in India (Ghosh, 1988) and in Australia (Heard *et al.*, 1990), the first male phase was absent. Ghosh (1988) also reported that there were more perfect flowers during the first few weeks of flowering on most trees, but later, male flowers predominated, and most of the selections in this group were found to have high yields.

Besides the two major patterns, Pavithran and Ravindranathan (1974) noted two other phases at Jhargram in India, the first with only a male phase and the second with alternation of two mixed phases and male phases.

The flowers may start opening as early as 7.00 a.m. and continue to open until 12.30 p.m. The opening of the perfect flowers showed a peak between 9 a.m. and 11 a.m. (India), and between 11.30 a.m. and 0.30 p.m. (Tanzania) (Northwood, 1966). Flowers remained opened for about 8 days after which they became withered (Fofifa, 1981).

2.2.2.4 Number of flowers per panicle

Reddy *et al.*, (1985) stated that one of the various factors responsible for poor yields of cashew trees in India was the presence of a large number of male flowers. The presence of a high percentage of hermaphrodite flowers is a desirable characteristic of high yield varieties. They recorded that the total number of flowers per panicle varied from 201 to 643. Damodaran *et al.*, (1966) found 200 to 1600 flowers under humid coastal conditions of Kerala. Raju (1979) recorded 4880 flowers under Bangalore conditions while Patnaik *et al.*, (1985), counted 43.77 to 115.80 flowers per panicle at Orissa. Khan and Kumar (1988) recorded a high number of flowers per panicle of up to 837 under Mangalore conditions. The difference in the number of flowers per panicle may be due to the difference in the age of trees, type and source of plant material and climatic conditions (Table 2.3).

2.2.2.5 Number of male (staminate) flowers per panicle

In India, the percentage of male flowers per panicle ranged between 25.82% and 96% (Morada, 1941; Rao and Hassan, 1957; Reddy *et al.*, 1985 and Ghosh, 1988). There is a marked difference in the ratio of hermaphrodite flowers to male flowers per panicle. It ranges from 0.004 to 0.689 with the highest recorded in Bengal (Damodaran *et al.*, 1965; Patnaik *et al.*, 1985; Reddy and Rao, 1985; Ghosh, 1988; Khan and Kumar, 1988) (Table 2.3).

2.2.2.6 Number of perfect (hermaphrodite) flowers per panicle

In order to have a high fruit-set, a tree should possess a high percentage of perfect flowers. Rao and Hassan (1957), Damodaran *et al.*, (1965); Sriram (1970) and Parameswaran (1979) indicated a positive correlation between yield and number of perfect flowers and each panicle possessed an average of 286.1 flowers of which 199.8 were male and 86.3 perfect. Srihari Babu (1981) stated that in the case of high yielding trees, the hermaphrodite flowers should on average be up to 45 per cent of total flower number. The number of flowers per panicle and the ratio of hermaphrodite to male flowers in various countries are shown in Table 2.3.

2.2.2.7 Sex ratio

The sex ratio is indicated in two possible ways: the number of hermaphrodite to male flowers, or the number of male to hermaphrodite flowers. The ratio varies between regions (Table 2.3) and the majority produce more male than hermaphrodite flowers. In India, the ratio even varies with localities; but the figures showed little difference between male and hermaphrodite flowers produced.

Table 2.3 Number of flowers per panicle and ratio male to perfect flower in different regions (modified from Morada[1], 1941; Rao and Hassan[2], 1957; Damodaran *et al.*[3], 1965; Northwood[4], 1966; Ohler[5], 1979; Patnaik *et al.*[6], 1985; Fofifa[7], 1981; Ghosh *et al.*[8], 1988; Reddy *et al.*[9], 1989; Heard *et al.*[9], 1990 and Behrens[10], 1996)

Region	Number of flowers/ panicle	Perfect flowers/ panicle	% perfect flowers/ panicle	Male flowers/ panicle	% male flowers/ panicle	Ratio perfect to male
Australia[9]	413	32.1		410.8		1:12.80
Jamaica[5]	193 - 801	13 - 96		180 - 705		Up to 1:28
Madagascar[7]	187	21		166		1:7.9
Senegal[10]	1005	152		853		1: 6.61
Tanzania[4]	767	63 - 67		250 - 400		1:3.7 - 1:6.7
India						
Karnataka[9]	201-643	53.0-212.75	17.08-74.18	25.82 - 83	90-91	1:1.19-
Kerala[3]	200-1600		0.45-24.9			1:1.45
Orissa[6]	43.77-116		5.94-20.69		up 96	
Mangalore[2]	329	13	2.27-65.2		36 - 95	
West Bengal[8]		4.97-65.2				

2.2.2.8 Fruit set

Patnaik *et al.*, (1985) found that under normal conditions in Orissa, India, 11.9% to 54.5% of the total flowers set fruit while 45.80% to 88.08% dropped off without fertilization. Nawale *et al.*, (1984) reported 8% to 26.6% fruit set under Konkan conditions. Rao (1956) observed only 3 % fruit set on the west coast of India and Murthy *et al.*, (1975) found 6 to 12 % on the east coast. The reason for a poor fruit set might be due to imbalances in the sex ratio, the condition of the pistil, and inadequate pollination and fertilization (Rao and Hassan, 1957; Nawale *et al.*, 1984). The final yield was therefore in proportion to the initial fruit setting. According to Reddy *et al.*, (1985), high yielding cashew trees should have a high percentage of fruit set of more than 6%. Smith (1958) suggested that bee colonies be introduced into orchards to increase pollination and fruit set. Heard *et al.*, (1990) confirmed the effectiveness of honey bees and native Australian bees as good pollinators that have a positive effect on fruit set and total yield.

2.2.2.9 Nut matured and nut dropped

Pillai and Pillai (1977) have reported that 15% of dropped fruits were unfertilized. Of the 85% fertilized fruits, only 4% were retained up to maturity and 20% dropped due to insect damage. The remaining 61% might have dropped due to physiological disorder, imbalance or defective metabolism. Bigger (1960), reported that the fruit drop at a late stage of development appears to be due to insect damage and disease. Damodoran *et al.*, (1966) observed that the number of nuts that matured was only 17 % of the flowers that had set fruits. Most of the nuts had dropped when they were very small.

2.2.2.10 Yield

The first characteristic of importance to the farmer is the yield capacity of nuts, expressed in nut returns, so this seems to be the most important selection criterion. Yield should be expressed in mass and quality of the kernels, as these comprise by far the greatest part of the nut value (Ohler, 1979 and Roe, 1994).

Ohler (1979) stated that high yielding trees normally have more than one mature nut per inflorescence. In India, it was found that the number of perfect flowers produced governed the yield of the cashew tree.

Different environmental conditions affect yield of the same cashew strain differently (Behrens, 1996). Table 2.4 shows yield parameters (age, yield/kg, and weight of nut and percentage of kernel) for selected material in different countries.

The figures in Table 2.4 indicate that production improvement through the use of selected plant materials from existing cashew plantations might be possible. Selection and breeding offer considerable opportunities for increasing the cashew production.

Total yield of nuts per tree was influenced by several genetically determined factors, including the number of panicles produced, number of perfect flowers produced per panicle, average mass per nut, pest and disease resistance and extent of premature nut drop (Ohler, 1979; Wait and Jamieson, 1986).

Table 2.4 Yield parameters (age, yield/kg, weight of nut and percentage of kernel) of different countries

([1] Reddy *et al.*, 1985; [2] Rao, 1989; [3] Nalini and Santhakerman, 1994b; [4] Kumar and Hedge, 1994; [5] Ohmstedt, 1991; [6] Behrens, 1986; [7] Mutter and Bigger, 1962; [8] Northwood, 1966; [9] Rakotovao, 1999 and [10] Gondins , 1973)

Location	Age (years)	Mean yield (kg)	Weight nut (g)	Kernel (%)
India				
Andhra Pradesh[1]	33-38	13.57	5	27
Tamil Nadu[2]	17	7.40	5	20
Karnataka[2]	25	19	7	31
Kerala[2]	7-14	17.14	7.3	26
Anakkayana[3]	-	3.29	3.6	46
Ullal[4]	11-20	14.68	7	30
Senegal[5]	29-32	36.48	6.9	
Australia[6]	5	3.91	5.46	
Tanzania				
Lulindi[7]	5	3.6		
Nachingwea[8]	3	2.6	4.9	
Mahajanga[9]	5-15	6.5	5.66	
Brazil[10]	3-14	17.50	6	

2.2.2.11 Factors influencing flowering and nut production

Cashew essentially depends on cross-pollination. Elsy *et al.*, (1987) stated that various factors influence the flowering and yield of cashew, namely: synchronized flowering, availability of a large number of male and perfect flowers and the sex ratio. Ohler (1979) reported that climatic factors like temperature, hours of sunshine, relative humidity and wind velocity do not seem to have any significant influence on flowering.

According to Northwood (1966), the ratio of male flowers to hermaphrodite flowers varied considerably during development and between localities and varieties. He also stated that pollination was not a limiting factor in Tanzania and that large numbers of insects visited the inflorescence, the percentage of opened flowers with pollen on their stigmas was high and many fruit aborted before maturation.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1 Study site

This research on the morphology and selection of high yielding cashew strains was done at Coastal Cashews farm, the biggest commercial producer of cashew nuts in South Africa. The farm is situated approximately 22 km inland from the Maputaland coast in north-eastern KwaZulu-Natal (Figure 3.1). Coastal Cashews is presently being developed and sponsored by the Industrial Development Corporation (IDC) and Ithala Development Finance Corporation Limited (ITHALA) and it will be 1000 hectares in extent when fully established. It is situated in an area where there are few or no employment opportunities for the local people. It thus fulfils an important role in job creation and provides opportunity for entrepreneurial development in an envisaged outgrower programme, which encourages local people to grow their own nuts.

3.2 Materials

a) During the 1999-2000 growing season, one hundred and thirty different strains, scattered over an area of 90 ha, were selected to study their morphological and yield characteristics (Table 3.1). The cloned strains were originally multiplied by different techniques such as grafting, budding or airlayering (Damodaran, 1985). The selected trees, mostly ten per strain, received similar agricultural treatment such as fertilisation, irrigation and pest management.

TABLE 3.1 LIST OF SELECTED CASHEW STRAINS STUDIED

a) During 1999-2000 season

M	Unknown	MZ			NZ		Br	
M1	G17	MZ7	MZ44	MZ73	NZ1	NZ28	A1-18	D1-10
M2	G24	MZ12	MZ46	MZ74	NZ2	NZ29	A1-32	D1-26
M3	G53	MZ17	MZ47	MZ75	NZ7	NZ31	A2-18	D1-32
M4	GJ1	MZ21	MZ48	MZ76	NZ8	NZ32	A3-42	D1-42
M5	GL15	MZ22	MZ50	MZ80	NZ9	NZ33	A4-17	D2-15
M6	MD6	MZ23	MZ51	MZ81	NZ11	NZ34	B1-17	D2-40
M7	MD18	MZ24	MZ54	MZ82	NZ12	NZ35	B1-20	D2-46
M9	MM16	MZ25	MZ55	MZ100	NZ13	NZ36	B1-28	D4-36
M11		MZ26	MZ57	MZ101	NZ14	NZ41	B2-32	D5-35
M14		MZ28	MZ58		NZ15	NZ42	B5-17	D5-46
M26		MZ29	MZ59		NZ18	NZ43	C1-18	E1-6
M27		MZ32	MZ61		NZ22	NZ45	C1-45	E3-41
M28		MZ35	MZ64		NZ23	NZ46	C3-19	F1-29
M30		MZ37	MZ65		NZ24	NZ55	C3-46	F4-1
M39		MZ38	MZ69		NZ25	NZ52	C5-44	F4-45
M40		MZ42	MZ71		NZ26	NZ54	C5-5	
					NZ27	NZ65		

b) During 2000-2001 season

M		MZ		NZ		Br
M1	M11	MZ21	MZ57	NZ23	NZ43	A2-18
M2	M14	MZ26	NZ45	NZ25	NZ45	B5-17
M3	M26	MZ28	NZ46	NZ26	NZ46	C1-18
M4	M27	MZ35	MZ61	NZ27		C1-45
M5	M28	MZ42	MZ64	NZ28		D1-10
M6	M30	MZ44	MZ74	NZ33		D1-32
M7	M39	MZ51	MZ80	NZ34		D4-36
M9	M40	MZ54		NZ42		F4-45

M: Zambia strains

Br: Brazilian strains

MZ: Mosi *\Zambia strains

NZ: Ngutshana *\Zambia strains

Uk: Unknown

*Mosi: Research station for the first establishment of cashew plantation in Maputaland

*Ngutshana: Study site (Coastal Cashews Farm)

b) The trees were 3-3½ years old, being planted before July 1996. These trees were selected because trees older than three years usually start to produce economically. They were limited to blocks 1 to 7 and trial plots 15 to 18 (Figure 3.2).

c) Based on the retention of nut results (high, intermediate and low) of the 1999-2000 season, the number of strains to study during the 2000-2001 season was reduced to forty-eight (Table 3.2).

Table 3.2 Selected strains for further study during 2000-2001 season

Strains	**Yield per panicle**		
	High	***Intermediate***	**Low**
Zambian M	M1, M2, M3, M4, M5, M40	M6, M7, M9, M14, M30, M39	M11, M26, M27, M28
Zambian MZ	MZ42, MZ51, MZ54, MZ21, MZ80	MZ26, MZ28, MZ35, MZ44, MZ64, MZ74	MZ57, MZ61
Zambian NZ	NZ23, NZ34	NZ33, NZ42, NZ43, NZ45, NZ46	NZ25, NZ26, NZ27, NZ28
Brazilian	C1-18, D1-32	B5-17, A2-18, D1-10, F4-45	D4-36, C1-45

One of these strains, NZ46, died off. The reason why these low and intermediate yielding strains were included were, firstly, that due to the abnormally wet weather conditions of 1999-2000, it could be possible that the conditions were detrimental to otherwise high yielding strains. Secondly, for further crossbreeding programs, intermediate and low yielding strains need to be identified which might be of importance in carrying genes for resistance to disease, detrimental environment conditions, etc.

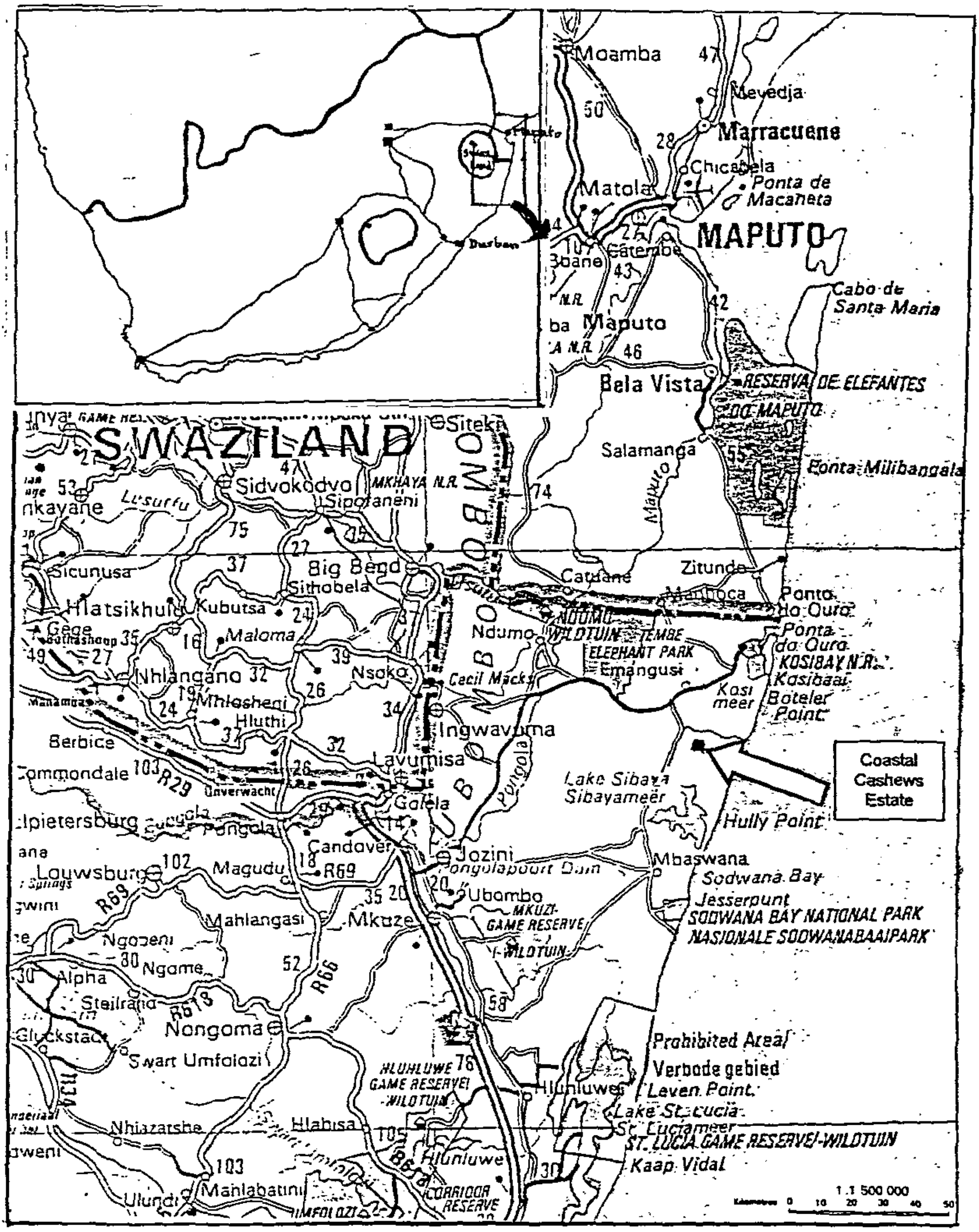


Figure 3. 1 Map of KwaZulu-Natal indicating the study site

(Coastal Cashews)

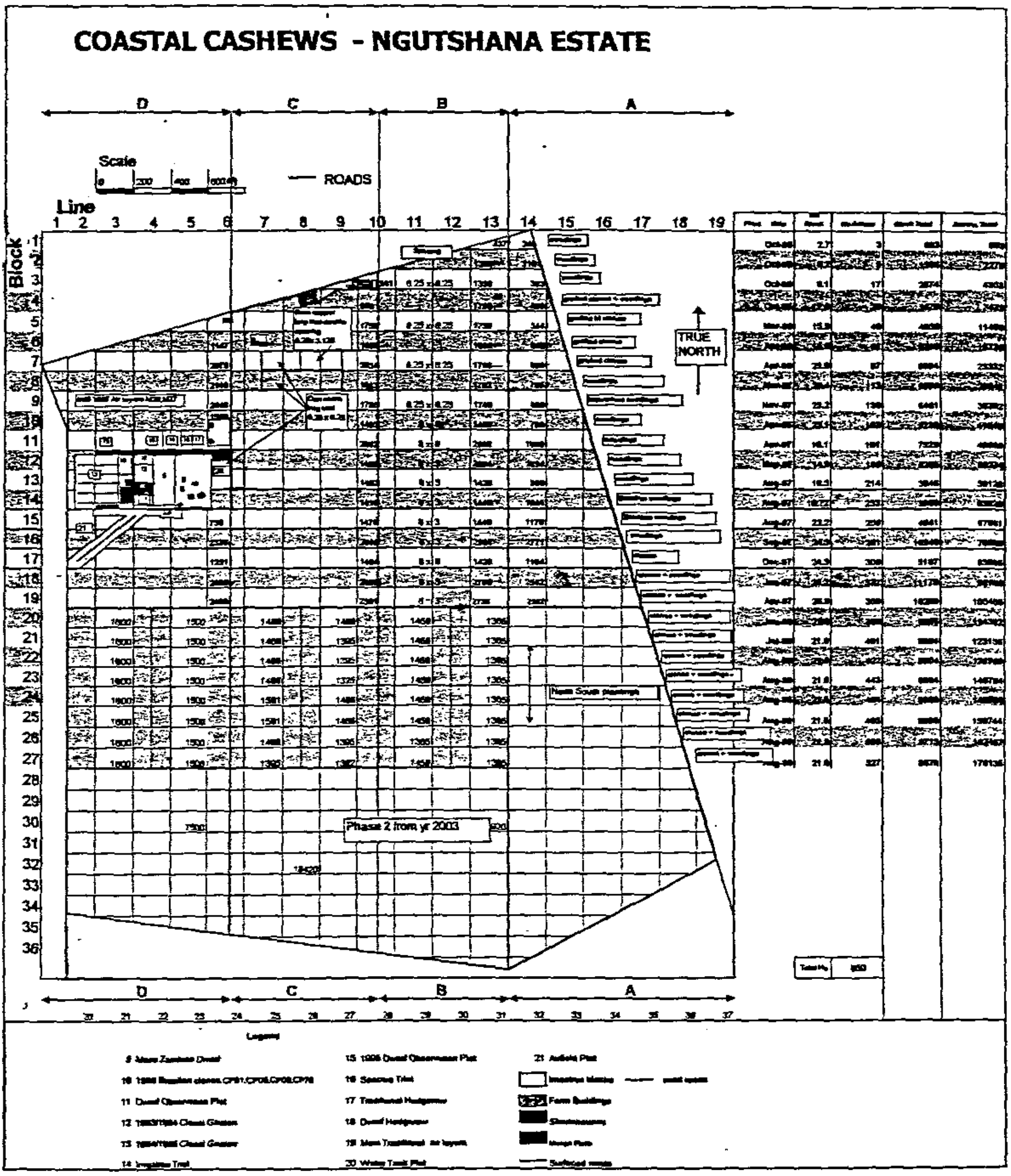


Figure 3.2 Map of Coastal Cashews – Ngutshana estate

A selection of ten trees per strain was made randomly from the middle of each block (lines 4 to 12), leaving out the three rows on either side closest to the casuarina windbreaks (lines 1 to 3 and 13 to15) (Figure 3.2). Any effects of the casuarinas on the growth and yield of the strains would therefore be minimised. Some strains were represented by a limited number of trees, especially those planted at the trial plots.

Line	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Line
www	X		X		X		X		X		X		X		X	www
www		X		X		X		X		X		X		X		www
⋮																⋮
www	X		X		X		X		X		X		X		X	www
www		X		X		X		X		X		X		X		www
www	X		X		X		X		X		X		X		X	www

www casuarina windbreaks x tree

Figure 3.3 Study field layout (Block)

3.3 Methods

The methods described below were applicable for data collection during both the 1999-2000 and 2000-2001 growing seasons. Criteria used for evaluating the different characteristics were according to the "Cashew Descriptors" published by the International Board for Plant Genetic Resources (IBPGR) in 1966 (De la Cruz and Fletcher, 1996). These cashew descriptors were modified for the purposes of this study.

3.3.1 Marking of trees

Each selected tree was marked with a painted stick to indicate the strain's name and the tree number. The name of the strain usually gives an indication of the country (source) of origin (Table 3.3).

Table 3.3 Name of strains and country of origin

Name	Tree number	Marked	Origin
M1	1	1M1	Zambia
MZ61	5	5MZ61	Zambia
NZ42	3	3NZ42	Zambia
C1-18	2	2C1-18	Unknown
MD6	2	2MD6	Unknown
G53	1	1G53	Unknown
GJ1	2	2GJ1	Unknown

3.3.2 Collection of data

3.3.2.1 Trunk diameter

The diameter of the trunk at 10 cm above the soil was measured with a DBH (Diameter Breast Height) tape and recorded.

3.3.2.2 Leaves

The largest visible leaves at breast height were sampled. Their leaf surface area and petiole size were measured, the venation counted and leaf characteristics such as shape, margin, apex and base of the lamina were noted. Three leaves for each strain were measured.

3.3.2.3 Inflorescence

Four panicles for each tree were randomly selected (2 from the north facing and 2 from the south facing side) to study flower and nut production over the growing season. The panicles for observation were marked with a special tape around the base.

3.3.2.4 Flowers

Initial dates were recorded when the buds on the marked panicles were fully developed. The following data were recorded:

a) total number of opened flowers per panicle,

b) number of opened male (staminate) flowers,

c) number of opened hermaphrodite (perfect) flowers and

d) number of fruits that had set.

To avoid the flowers being recounted, two petals of the opened and counted flowers were carefully removed by cutting them with a small scissors. Each selected tree for this study was visited every two weeks because of the large number of existing strains and of the abundance of flowers per panicle that needed to be counted. Swelling of the ovary was recognized as an indication of initial fruit set (Ashok and Thimma Raju, 1983). Observations continued until the last flower in the panicle opened.

3.3.2.5 Fruits

The selected four panicles per tree were also used for the study of fruit and yield:

a) Apples: the shape, colour, size, length, diameter of the thickest part and weight of the apples were recorded.

b) Nuts: the size, length, diameter of the thickest part and weight were measured.

c) Yield: data collected include the number of panicles per tree, the number of retained nuts, the number of nuts that reached maturity per panicle and the nut yield for the four panicles.

3.3.2.6 Additional data

Additional criteria recorded during the 2000-2001 growing season included:

a) the habit of the tree for all the strains studied,

b) height of the trees, divided into three categories: dwarf (<1.5 m), medium (1.5-3 m) and tall (>3 m),

c) canopy diameter (spreading of the tree from one direction to another),

d) yield in kilograms per tree,

e) number of nuts per 100 grams nut in shell per strain, and

f) fresh mass of kernel per 100 grams nut in shell. The nuts were longitudinally cut, the kernels were removed and weighed (fresh mass). The fresh kernels were placed in a pre-heated oven (at 90°C) and their masses were recorded every hour for 6 hours.

CHAPTER FOUR

4. RESULTS

4.1 Morphology

The results were divided into four groups of strains according to their origins:

a) Zambian strains planted directly at Ngutshana (M) and those with unknown origins (G, GJ, GL, MD and MM),

b) Zambian strains planted firstly at Mosi estate and then transferred to Ngutshana (MZ),

c) Zambian strains cloned from (M) known as (NZ), and

d) Brazilian strains (A1-18,..., F4-45).

The results of the morphological study will be discussed according to the tree, leaf, inflorescence and fruit characteristics.

4.1.1 Tree characteristics

The tree characteristics of the strains studied include tree habit and size (Table 4.1); canopy and trunk diameter (Table 4.2).

4.1.1.1 Tree habit

The tree habit ranged from ascending to decumbent (Figure 4.1) and the results were divided into three categories (Figure 4.2):

(i) ascending with erect branches,

(ii) intermediate (between ascending and decumbent), and

Figure 4.1 Cashew trees with ascending (a) and decumbent (b) habit

(iii) decumbent with branches spreading horizontally.

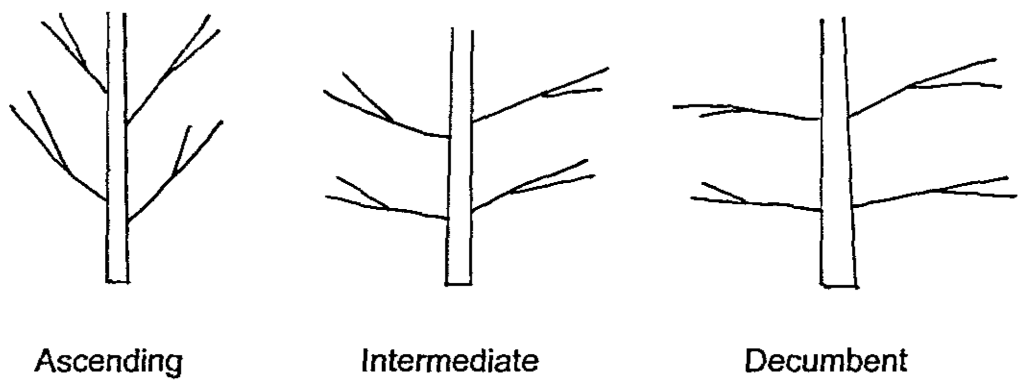


Figure 4.2 Tree habit of cashews

According to Table 4.1, 43 strains were categorized as ascending, 58 were intermediate and 29 were decumbent. Forty-seven of the Zambian strains had intermediate habit. These 47 strains comprised one M and 4 unknowns from the M/Unknown group, 21 from MZ group and 19 from NZ group. For the Zambian strains, the number of strains with ascending habit was more or less the same as those with decumbent habit, except the unknowns, which did not have any decumbent habit. For the Brazilian strains, 9 had ascending, 12 intermediate and 9 decumbent habits.

4.1.1.2 Tree size

According to the height, tree size was divided into three categories (Table 4.1)

(i) dwarf (< 1.5 m),

(ii) medium (1.5 to 3 m), and

(iii) tall (> 3 m).

Table 4.1 Tree habit and size of studied strains

a) Zambian M/unknown strains

Strains	Tree habit			Tree Height in cm	Tree size		
	ascending	*intermediate*	*decumbent*		Dwarf h<1.5m	Medium 1.5<h<3	Tall h>3.5m
M1	x			241		x	
M2	x			202		x	
M3	x			291		x	
M4			x	228		x	
M5			x	254		x	
M6		x		258		x	
M7	x			289		x	
M9	x			269		x	
M11			x	222		x	
M14	x			198		x	
M26			x	233		x	
M27			x	250		x	
M28			x	144	x		
M30			x	263		x	
M39			x	263		x	
M40	x			245		x	
G17	x			200		x	
G24	x			280		x	
G53		x		350			x
GJ1	x			430			x
GL15		x		310			x
MD6	x			230		x	
MD18		x		230		x	
MM16		x		380			x

Table 4.1 Tree habit and size of studied strains (continued)

b) Zambian MZ strains

Strains	Tree habit: *ascending*	*intermediate*	*decumbent*	Tree Height in cm	Tree size: Dwarf h<1.5m	Medium 1.5<h<3	Tall h>3.5m
MZ7		x		220		x	
MZ12		x		210		x	
MZ17		x		210		x	
MZ21	x			290		x	
MZ22		x		240		x	
MZ23		x		220		x	
MZ24			x	150	x		
MZ25	x			230		x	
MZ26	x			270		x	
MZ28			x	360			x
MZ29			x	180		x	
MZ32			x	180		x	
MZ35	x			410			x
MZ37			x	170		x	
MZ38		x		190		x	
MZ42	x			259		x	
MZ44			x	242		x	
MZ46		x		280		x	
MZ47		x		230		x	
MZ48		x		300			x
MZ50		x		240		x	
MZ51			x	201		x	
MZ54	x			181		x	
MZ55	x			210		x	
MZ57			x	220		x	
MZ58		x		220		x	
MZ59		x		130	x		
MZ61	x			224		x	
MZ64	x			229		x	
MZ65		x		150	x		
MZ69		x		230		x	
MZ71		x		270		x	
MZ73			x	270		x	
MZ74	x	x		206		x	
MZ75		x		300			x
MZ76		x		190		x	
MZ80			x	280		x	
MZ81		x		230		x	
MZ82			x	200		x	
MZ100		x		200		x	
MZ101		x		300			x

Table 4.1 Tree habit and size of studied strains (continued)

c) Zambian (NZ) strains

Strains	Tree habit			Tree Height in cm	Tree size		
	ascending	intermediate	decumbent		Dwarf h<1.5m	Medium 1.5<h<3	Tall h>3.5m
NZ1		x		340			x
NZ2	x			180		x	
NZ7		x		230		x	
NZ8		x		350			x
NZ9		x		250		x	
NZ11	x			140	x		
NZ12	x			180		x	
NZ13		x		280		x	
NZ14		x		230		x	
NZ15		x		250		x	
NZ18		x		170		x	
NZ22	x			300			x
NZ23	x			201		x	
NZ24		x		240		x	
NZ25	x			240		x	
NZ26		x		280		x	
NZ27	x			310		x	
NZ28		x		250		x	
NZ29	x			350			x
NZ31		x		250		x	
NZ32		x		240		x	
NZ33	x			212		x	
NZ34			x	259		x	
NZ35		x		210		x	
NZ36		x		240		x	
NZ41	x			250		x	
NZ42		x		340			x
NZ43	x			264		x	
NZ45	x			170		x	
NZ46							
NZ52		x		240		x	
NZ54		x		210		x	
NZ55	x			250		x	
NZ65		x		240		x	

Table 4.1 Tree habit and size of studied strains (continued)

d) Brazilian strains

Strains	Tree habit			Tree	Tree size		
	ascending	intermediate	decumbent	Height	Dwarf	Medium	Tall
				in cm	h<1.5m	1.5<h<3	h>3.5m
A1-18		x		210		x	
A1-32	x			240		x	
A2-18			x	244		x	
A3-42			x	200		x	
A4-17	x			280		x	
B1-17		x		230		x	
B1-20			x	190		x	
B1-28		x		240		x	
B2-32	x			230		x	
B5-17		x		180		x	
C1-18			x	186		x	
C1-45	x			314			x
C3-19	x			145	x		
C3-46	x			390			x
C5-44		x		230		x	
C5-5		x		260		x	
D1-10			x	296		x	
D1-26		x		150	x		
D1-32	x			220		x	
D1-42	x			220		x	
D2-15		x		250		x	
D2-40		x		250		x	
D2-46		x		250		x	
D4-36			x	280		x	
D5-35		x		180		x	
D5-46		x		200		x	
E1-6			x	170		x	
E3-41	x			260		x	
F1-29			x	230		x	
F4-1		x		250		x	
F4-45			x	288		x	

The height ranged from 1.3 to 4.3 m. Most of the selected strains (108) were medium sized with heights between 1.5 and 3 m. Seven strains were dwarfed with MZ59 the smallest (1.3 m), while 15 were tall with MZ35 and GJ1 the tallest, at 4.10 and 4.30 m respectively.

4.1.1.3 Canopy diameter

Canopy diameter is the spread of the canopy measured from side to side through the centre. Measurements were only done during the 2000-2001 season (Table 4.2). The average canopy diameters of the strains varied between 1.5 and 4.4 m. Most of the strains have a canopy diameter of between 2 and 4 m. Fifteen strains have a canopy diameter of at least 4 m. The maximum diameter was found in MZ26 and MZ76 (both 4.4 m) and the minimum in B2-32 (1.5 m) and MZ58 (1.8 m).

4.1.1.4 Trunk diameter

The trunk diameters were measured during the two growing seasons (Table 4.2). During 1999-2000, the average diameters ranged from 50 (B1-20) to 135 mm (MZ26 and B2-32). Most of the strains had an average trunk diameter of between 80 and 100 mm.

During 2000-2001, trunk diameters ranged from 100 mm (NZ28) to 250 mm (MZ35). The results indicate that there were diameter increases of the 47

Table 4.2 Canopy and trunk diameter of studied strains

a) Zambian M/Unknown strains

Strains	Canopy diameter in cm	Trunk diameter in mm		Strains	Canopy diameter in cm	Trunk diameter in mm	
		1999-2000	2000-2001			1999-2000	2000-2001
M1	300	97	143	M28	270	84	131
M2	286	82	121	M30	344	118	170
M3	291	98	146	M39	325	112	147
M4	354	105	157	M40	309	104	145
M5	370	98	174	G17	320	80	
M6	314	95	143	G24	300	70	
M7	308	84	137	G53	430	83	
M9	327	110	172	GJ1	290	110	
M11	351	116	156	GL15	220	115	
M14	327	85	142	MD6	400	95	
M26	321	92	144	MD18	350	70	
M27	335	96	149	MM16	300	93	

b) Zambian (MZ) strains

Strains	Canopy diameter in cm	Trunk diameter in mm		Strains	Canopy diameter in cm	Trunk diameter in mm	
		1999-2000	2000-2001			1999-2000	2000-2001
MZ7	310	88		MZ51	310	77	136
MZ12	250	83		MZ54	274	92	145
MZ17	250	88		MZ55	260	78	
MZ21	430	100	170	MZ57	290	84	136
MZ22	300	70		MZ58	180	60	
MZ23	220	90		MZ59	250	88	
MZ24	220	78		MZ61	325	95	150
MZ25	340	98		MZ64	316	79	129
MZ26	440	135	210	MZ65	240	75	
MZ28	340	110	150	MZ69	300	68	
MZ29	300	78		MZ71	320	58	
MZ32	240	65		MZ73	230	95	
MZ35	430	125	240	MZ74	259	94	115
MZ37	300	73		MZ75	440	80	
MZ38	230	80		MZ76	350	83	
MZ42	316	82	131	MZ80	260	120	190
MZ44	331	73	127	MZ81	380	85	
MZ46	330	90		MZ82	200	83	
MZ47	300	95		MZ100	230	70	
MZ48	410	103		MZ101	300	110	
MZ50	300	98					

Table 4.2 Canopy and trunk diameter of studied strains (continued)

c) Zambian (NZ) strains

Strains	Canopy diameter in cm	Trunk diameter in mm		Strains	Canopy diameter in cm	Trunk diameter in mm	
		1999-2000	2000-2001			1999-2000	2000-2001
NZ1	320	108		NZ28	210	95	100
NZ2	400	123		NZ29	270	100	
NZ7	330	85		NZ31	300	100	
NZ8	340	118		NZ32	410	80	
NZ9	240	110		NZ33	288	90	133
NZ11	300	75		NZ34	354	98	171
NZ12	320	110		NZ35	410	100	
NZ13	310	83		NZ36	350	70	
NZ14	320	73		NZ41	340	98	
NZ15	360	90		NZ42	400	115	192
NZ18	400	98		NZ43	376	89	138
NZ22	230	103		NZ45	325	85	120
NZ23	240	99	136	NZ46		85	
NZ24	330	90		NZ52	320	95	
NZ25	325	90	150	NZ54	310	85	
NZ26	390	100	190	NZ55	280	115	
NZ27	340	120	145	NZ65	310	80	

d) Brazilian strains

Strains	Canopy diameter in cm	Trunk diameter in mm		Strains	Canopy diameter in cm	Trunk diameter in mm	
		1999-2000	2000-2001			1999-2000	2000-2001
A1-18	210	90		D1-10	332	101	149
A1-32	240	101		D1-26	270	105	
A2-18	331	93	151	D1-32	345	96	145
A3-42	210	78		D1-42	240	92	
A4-17	350	100		D2-15	310	95	
B1-17	200	78		D2-40	400	118	
B1-20	280	50		D2-46	410	106	
B1-28	300	108		D4-36	366	102	158
B2-32	150	135		D5-35	300	105	
B5-17	256	78	115	D5-46	230	85	
C1-18	274	81	118	E1-6	250	88	
C1-45	342	110	152	E3-41	360	103	
C3-19	320	108		F1-29	250	106	
C3-46	430	104		F4-1	300	110	
C5-44	210	118		F4-45	382	123	193
C5-5	310	110					

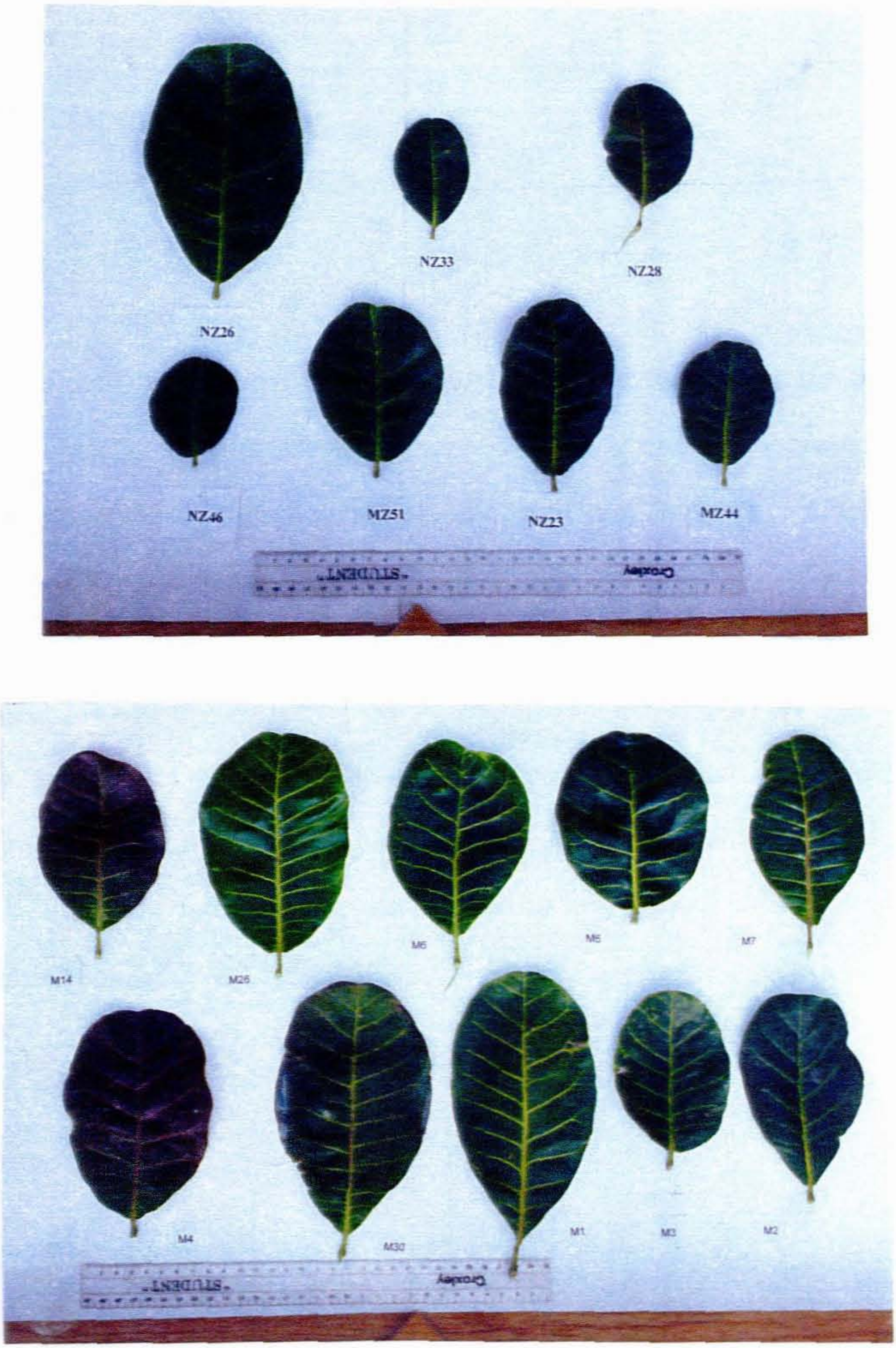


Figure 4.3 Cashew leaf characteristics

studied strains from the previous 1999-2000 season. These increases ranged from 5 mm to 115 mm, or from 5.26% to 92%.

4.1.2 Leaf characteristics

The measured leaf characteristics appear in Figure 4.3 and Table 4.3.

4.1.2.1 Shape

Leaf shape ranged from oblong (width and length approximately equal) to elliptic. Most of the strains had elliptical leaves but 27 had oblong leaves: 2 from the Zambian and unknown group, 8 each from the 2 Zambian groups (MZ and NZ), and 9 from the Brazilian group.

4.1.2.2 Apex

The leaf apex of the strains varied from pointed, to rounded to retuse (with a slight notch) (Figure 4.4). Five strains (MZ12, MZ21, M29, NZ45 and D1-26) had pointed apexes, forty-eight strains had retuse apexes and seventy-seven had rounded apexes.

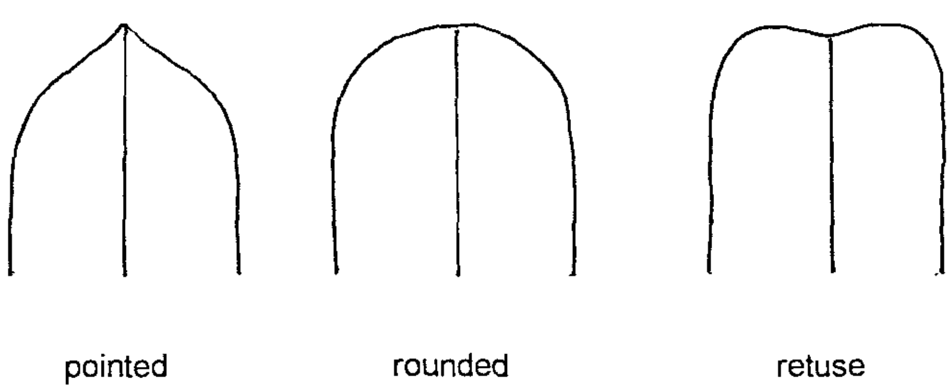
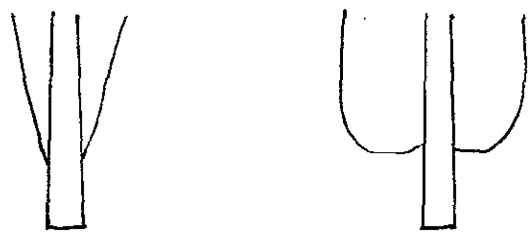


Figure 4.4 Leaf apex of Cashews

4.1.2.3 Base

The cashew strains had alternate or obtuse leaf bases (Figure 4.5 and Table 4.3).



(a) (b)

Figure 4.5 Attenuate (a) and obtuse (b) Cashew leaf bases

Fifty-one strains had obtuse bases and 79 had alternate bases. Of the Zambian (NZ) strains, 17 had alternate and 17 had obtuse bases. For the other strains, 10 Brazilians, 16 Zambian (MZ) and 8 Zambian (M/Unknown) strains had obtuse bases.

4.1.2.4 Margin

Leaf margins were wavy or smooth. The majority of strains, eighty-three, had smooth margins and forty-seven had wavy margins (12 from Brazilian, 16 from Zambian MZ, 12 from NZ and 7 from Zambian M/unknown group).

4.1.2.5 Veins\Venation

The leaves of cashew strains had 9 to 20 pinnately (paired) veins, which were visible on both sides of the leaf (Table 4.4).

Table 4.3 Leaf characteristics of studied strains (shape, apex, base and margin)

a) Zambian M/Unknown strains

Strains	Shape		Apex			Base		Margin	
	oblong	elliptic	pointed	rounded	notch	attenuate	obtuse	wavy	smooth
M1		x			x	x			x
M2		x			x	x			x
M3		x		x			x	x	
M4		x		x		x			x
M5	x			x			x		x
M6		x		x		x			x
M7		x			x	x			x
M9		x		x			x		x
M11		x			x		x		x
M14		x			x	x			x
M26		x			x		x	x	
M27		x		x		x			x
M28		x		x			x		x
M30		x			x	x		x	
M39		x		x		x		x	
M40		x			x	x		x	
G17	x				x		x		x
G24		x		x		x			x
G53		x			x		x	x	
GJ1		x		x		x		x	
GL15		x		x		x			x
MD6		x			x	x			x
MD18		x			x	x			x
MM16		x		x		x			x

Table 4.3 Leaf characteristics of studied strains (shape, apex, base and margin) (continued)

b) Zambian (MZ) strains

Strains	Shape		Apex			Base		Margin	
	oblong	elliptic	pointed	rounded	notch	attenuate	obtuse	wavy	smooth
MZ7		x		x		x			x
MZ12		x	x			x			x
MZ17	x			x			x	x	
MZ21		x	x			x		x	
MZ22	x			x		x			x
MZ23		x		x			x		x
MZ24		x		x		x		x	
MZ25		x		x		x			x
MZ26		x			x	x		x	
MZ28		x		x			x	x	
MZ29		x	x			x		x	
MZ32		x		x		x			x
MZ35		x			x	x		x	
MZ37	x			x		x		x	
MZ38		x		x		x			x
MZ42		x		x		x		x	
MZ44	x				x		x	x	
MZ46	x				x	x			x
MZ47		x		x		x			x
MZ48	x			x		x			x
MZ50		x			x	x			x
MZ51	x				x		x		x
MZ54	x			x		x		x	
MZ55		x			x	x			x
MZ57		x			x		x		x
MZ58		x		x			x		x
MZ59		x			x		x	x	
MZ61		x		x			x	x	
MZ64		x		x			x		x
MZ65		x		x			x		x
MZ69		x		x		x			x
MZ71		x		x			x		x
MZ73		x		x		x			x
MZ74		x		x			x	x	
MZ75		x		x			x		x
MZ76		x		x			x		x
MZ80		x			x	x		x	
MZ81		x			x		x		x
MZ82		x		x		x			x
MZ100		x		x		x		x	
MZ101		x		x		x			x

Table 4.3 Leaf characteristics of studied strains (shape, apex, base and margin) (continued)

c) Zambian (NZ) strains

Strains	Shape		Apex			Base		Margin	
	oblong	elliptic	pointed	rounded	notch	attenuate	obtuse	wavy	smooth
NZ1	x				x		x	x	
NZ2	x			x		x			x
NZ7		x		x		x		x	
NZ8	x				x	x			x
NZ9		x		x		x		x	
NZ11		x		x		x		x	
NZ12		x			x		x	x	
NZ13	x			x			x		x
NZ14	x			x			x	x	
NZ15		x		x		x			x
NZ18		x		x			x	x	
NZ22		x		x		x			x
NZ23		x		x		x			x
NZ24		x		x		x			x
NZ25		x		x			x		x
NZ26		x			x	x		x	
NZ27		x		x			x		x
NZ28		x		x			x		x
NZ29		x		x		x			x
NZ31	x				x	x		x	
NZ32	x				x		x		x
NZ33		x			x	x			x
NZ34		x			x		x		
NZ35		x			x	x		x	
NZ36		x			x	x			x
NZ41		x			x		x	x	
NZ42		x			x	x			x
NZ43		x		x		x			x
NZ45		x	x				x		x
NZ46	x			x			x		x
NZ52		x		x			x		x
NZ54		x			x		x		
NZ55		x		x			x		x
NZ65		x		x		x		x	

Table 4.3 Leaf characteristics of studied strains (shape, apex, base and margin) (Continued)

d) Brazilian (NZ) strains

Strains	Shape		Apex			Base		Margin	
	oblong	*elliptic*	*pointed*	*rounded*	*notch*	*attenuate*	*obtuse*	*wavy*	*smooth*
A1-18	x			x			x		x
A1-32		x			x	x			x
A2-18		x		x		x		x	
A3-42		x		x			x	x	
A4-17		x		x		x			x
B1-17		x			x		x	x	
B1-20		x		x		x		x	
B1-28		x		x		x			x
B2-32	x				x	x			x
B5-17	x				x	x			x
C1-18	x			x		x			x
C1-45	x			x		x			x
C3-19	x			x			x		x
C3-46		x			x	x		x	
C5-44		x			x	x	x		x
C5-5		x			x	x		x	
D1-10		x		x		x			x
D1-26		x	x				x		x
D1-32		x		x		x			x
D1-42		x		x			x		x
D2-15		x		x		x			x
D2-40		x			x		x	x	
D2-46	x			x		x		x	
D4-36		x			x	x			x
D5-35	x			x			x		x
D5-46		x		x			x	x	
E1-6		x			x	x			x
E3-41	x				x	x		x	
F1-29		x			x	x		x	
F4-1		x		x		x			x
F4-45		x			x	x		x	

Zambian M/Unknown strains, G53 and MD6, had the smallest number of veins (9 pairs), and the Zambian MZ, MZ29, had the biggest number (20). The majority of the strains had 11 to 14 pairs of veins.

4.1.2.6 Petiole size

The leaf petioles were glabrous and the length ranged from 0.5 (MZ58) to 3 cm (MM16) (Table 4.4). The length of petioles for the majority of the strains was 1.4 to 1.6 cm.

4.1.2.7 Leaf dimensions and colour

The results for the length, width and surface area of the leaves are shown in Table 4.4. The lamina of the different strains ranged from 8.1 to 22 cm in length and from 5 to 16.9 cm wide with a coriace texture.

The surface area ranged from 46.88 to 126.63 cm^2. In the Brazilian group, F1-29 had the smallest (46.88 cm^2) and A3-42 had the biggest (59.50 cm^2) leaf surface area. In the M/unknown group, G53 had the biggest (126.63 cm^2) and M40 had the smallest (65.88 cm^2) leaf surface area. In the Zambian (MZ) group, MZ100 (121.88 cm^2) had the maximum and MZ50 (62.88 cm^2) had the minimum leaf surface area. In the Zambian (NZ) group, NZ45 had the biggest (115.15 cm^2) and NZ14 had the smallest (71 cm^2) leaf surface area.

The leaves varied from reddish green to dark green with the abaxial surfaces lighter in colour.

Table 4.4 Venation, petiole size and leaf dimensions of studied strains

a) Zambian M/Unknown strains

Strains	Veins Nb (pairs)	Petiole (cm)	Lamina (cm) length	Lamina (cm) width	Leaf surface area (cm2)
M1	14	1.7	13.0	9.0	78.88
M2	12	1.7	14.0	8.6	96.38
M3	13	1.5	13.8	7.9	101.50
M4	13	1.1	14.9	8.9	83.50
M5	13	1.3	13.4	9.5	113.50
M6	11	0.6	13.6	8.5	82.40
M7	13	1.1	14.4	8.8	82.63
M9	15	2.4	17.4	12.0	83.88
M11	13	0.8	13.6	8.0	104.88
M14	11	1.7	13.3	8.7	74.92
M26	12	1.5	13.4	9.2	81.38
M27	11	1.6	12.3	7.5	70.88
M28	16	1.5	13.0	7.4	70.40
M30	13	1.4	16.8	10.1	109.25
M39	12	1.7	14.5	9.2	76.50
M40	11	1.6	13.7	8.3	65.88
G17	13	1.3	21.8	16.9	91.25
G24	13	1.6	15.9	9.8	72.25
G53	9	1.1	12.7	9.0	126.63
GJ1	14	2.0	16.7	9.3	71.00
GL15	13	2	15.1	8.9	84.63
MD6	9	1.8	17.5	10.8	78.38
MD18	12	2.0	16.3	11.2	71.13
MM16	11	3.0	16.2	10.2	69.54

Table 4.4 Venation, petiole size and leaf dimensions of studied strains (continued)

b) Zambian (MZ) strains

Strains	Veins Nb(pairs)	Petiole (cm)	Lamina (cm) length	Lamina (cm) width	Leaf surface area (cm2)
MZ7	13	1.0	15.3	8.2	89.31
MZ12	14	1.0	13.8	7.0	76.50
MZ17	14	2.4	18.0	10.7	78.50
MZ21	12	0.8	13.5	8.7	103.75
MZ22	18	1.5	22.0	11.3	86.75
MZ23	15	1.0	14.1	9.5	74.88
MZ24	14	2.5	18.0	10.1	74.50
MZ25	17	1.6	19.8	10.0	68.98
MZ26	14	1.2	12.5	8.0	88.33
MZ28	13	1.4	12.3	7.7	106.50
MZ29	20	1.0	16.3	8.8	80.51
MZ32	11	1.0	11.9	8.2	91.90
MZ35	10	1.1	13.0	8.7	93.25
MZ37	13	2.1	15.3	9.0	78.00
MZ38	15	1.9	15.9	8.8	108.49
MZ42	11	1.8	15.8	8.5	81.50
MZ44	12	1.6	15.2	9.8	117.89
MZ46	16	1.4	14.1	9.0	96.06
MZ47	14	1.1	17.0	11.0	101.50
MZ48	13	0.7	11.8	7.8	85.00
MZ50	11	1.3	14.2	10.2	62.88
MZ51	12	1.0	13.1	8.5	74.93
MZ54	10	1.0	12.6	8.5	68.00
MZ55	15	1.7	14.0	8.1	83.40
MZ57	12	1.4	18.3	7.9	64.63
MZ58	13	0.5	12.2	8.2	74.56
MZ59	13	0.7	12.1	8.1	67.00
MZ61	13	1.6	13.1	8.9	81.06
MZ64	13	1.0	15.6	8.2	94.21
MZ65	14	1.4	15.5	11.2	86.88
MZ69	15	1.2	14.3	9.0	75.27
MZ71	13	1.9	14.5	8.4	69.13
MZ73	15	1.0	12.8	7.9	79.13
MZ74	16	1.6	18.9	10.1	110.50
MZ75	18	1.3	15.3	9.5	84.83
MZ76	14	1.0	12.9	7.7	94.18
MZ80	12	1.4	14.4	9.9	99.60
MZ81	11	0.7	13.1	8.1	84.78
MZ82	14	1.8	16.6	8.5	71.88
MZ100	15	1.4	20.4	11.0	121.88
MZ101	13	1.9	16.0	10.5	86.98

Table 4.4 Venation, petiole size and leaf dimensions of studied strains (continued)

c) Zambian (NZ) strains

Strains	Veins Nb(pairs)	Petiole (cm)	Lamina (cm) length	Lamina (cm) width	Leaf surface area (cm2)
NZ1	14	1.3	14.1	7.8	89.68
NZ2	12	1	14	8.5	84.83
NZ7	12	1.8	14.9	9.0	89.50
NZ8	11	0.7	11.9	7.4	93.75
NZ9	13	0.7	14.0	8.5	89.63
NZ11	15	1.8	17.5	10.6	74.45
NZ12	14	1.4	14.6	10.2	79.68
NZ13	12	1.1	11	8.6	68.33
NZ14	13	1.1	12.5	6.6	71.00
NZ15	10	0.7	8.5	5.7	84.00
NZ18	11	0.8	8.1	6.1	111.13
NZ22	10	0.8	9.2	7.0	83.63
NZ23	11	1.1	13.7	8.1	90.10
NZ24	11	0.9	11.7	8.1	112.28
NZ25	13	1.6	17.0	10.2	79.25
NZ26	14	1.5	16.7	11.3	96.23
NZ27	10	0.8	11.1	9.1	91.63
NZ28	12	0.8	13.5	7.9	83.88
NZ29	12	2.2	14.9	9.0	95.59
NZ31	12	0.6	9.3	6.6	79.00
NZ32	14	1.5	13.9	8.2	93.80
NZ33	12	0.9	14.1	9.4	92.00
NZ34	10	0.9	14.2	8.9	74.00
NZ35	12	0.8	12.1	7.2	77.00
NZ36	13	0.9	10.5	5.9	81.28
NZ41	11	0.9	12.3	9.3	92.66
NZ42	13	1.5	13.9	9.3	88.63
NZ43	14	1.4	15.8	9.2	83.50
NZ45	13	1.0	14.2	9.3	115.15
NZ46	13	1.4	15.0	9.9	100.25
NZ52	12	1.1	12.3	8.2	84.16
NZ54	13	0.9	14.2	8.0	104.50
NZ55	13	0.9	13.9	9.4	97.38
NZ65	13	1.7	17.0	10.1	91.55

Table 4.4 Venation, petiole size and leaf dimensions of studied strains (continued)

d) Brazilian strains

Strains	Veins Nb(pairs)	Petiole (cm)	Lamina (cm) length	Lamina (cm) width	Leaf surface area (cm2)
A1-18	11	1.0	11.3	8.8	94.63
A1-32	13	1.5	12.4	7.9	79 63
A2-18	13	1.5	13.4	9.3	89.13
A3-42	11	1.4	13.9	9.3	102.40
A4-17	14	1.8	15.9	9.1	70 63
B1-17	13	1.4	18.2	10.6	85.00
B1-20	16	1.4	14.9	9.0	84.00
B1-28	15	1.1	14.4	8.6	77.38
B2-32	13	1.5	16.1	10.3	81.63
B5-17	13	1.5	16.1	10.3	94.00
C1-18	11	0.9	17.9	11.7	75.00
C1-45	10	1.3	13.4	8 6	59 50
C3-19	12	1.0	11.1	8.5	93.00
C3-46	12	1.4	14.4	9.4	74.13
C5-44	14	1.0	15.5	9.8	82.08
C5-5	13	0.8	13.4	8.4	74.25
D1-10	15	1.6	15.1	8.7	69 88
D1-26	11	0.7	8.7	5.0	78.50
D1-32	15	1.3	15.4	8.7	69 88
D1-42	15	0.8	13 0	7.9	84.31
D2-15	14	1 5	15.5	9.2	59 13
D2-40	14	0.7	11.8	8.0	67.25
D2-46	13	0 8	10.0	8 4	81.75
D4-36	11	1.0	13.4	8.2	53.50
D5-35	14	0.8	12.1	8 0	73 25
D5-46	13	1.6	17.5	10.6	83.25
E1-6	12	1.4	15.9	8.4	85.38
E3-41	11	1.9	14 5	9.8	70 00
F1-29	14	1.2	13.5	7.7	46.88
F4-1	14	1.0	14 4	8.5	95 25
F4-45	14	1.2	13.5	7.7	70.38

4.1.3 Inflorescence and flower characteristics

4.1.3.1 Inflorescence

The inflorescence of cashews consists of a panicle, which carries a large number of flowers, which could be male or hermaphrodite. The shape and size of some panicles are shown in Figure 4.6.

The average number of panicles for the different strains is shown in Table 4.5. The number varied from 180 (MD6) to 559 (NZ28), with a mean of 370 for all of the strains. All the unknown strains in the Zambian group had low numbers except GL15 (440). In the Zambian (MZ), only MZ48 (513) had more than 500 and in the Zambian (NZ), the lowest recorded was for NZ24 (200). The average number of panicles for the Brazilian strains ranged from 309 (A3-42) to 458 (A1-32). The variation in the number of panicles between strains might be genetically or environmentally determined.

The time span for the development of floral buds on the panicle was recorded. The duration from bud initiation to floral opening was slightly different from one season to another. During 1999-2000, the floral buds emerged during the first week of November and the last recorded was on the 27th of December. During 2000-2001, the earliest bud initiation was noted towards the end of October, ten days earlier. Bud development from initiation to opening took 8 to 25 days for the studied strains, with an average of 16.5 days. The small, fragrant cashew flowers are shown in Figure 4.7.

Figure 4.6 Shape and size of panicles

Table 4.5 Average number of panicle per strain

a) Zambian M/Unknown strains

Strains	Average number of panicle/tree
M1	402
M2	419
M3	419
M4	501
M5	534
M6	400
M7	401
M9	514
M11	544
M14	450
M26	435
M27	438

Strains	Average number of panicle/tree
M28	390
M30	387
M39	406
M40	472
G17	431
G24	312
G53	329
GJ1	379
GL15	441
MD6	180
MD18	288
MM16	340

b) Zambian (MZ) strains

Strains	Average number of panicle/tree
MZ7	340
MZ12	322
MZ17	420
MZ21	381
MZ22	325
MZ23	320
MZ24	375
MZ25	366
MZ26	430
MZ28	260
MZ35	457
MZ29	400
MZ32	313
MZ37	295
MZ38	376
MZ42	415
MZ44	360
MZ46	361
MZ47	346
MZ48	513
MZ50	356

Strains	Average number of panicle/tree
MZ51	281
MZ54	355
MZ55	264
MZ57	372
MZ58	469
MZ59	410
MZ61	416
MZ64	243
MZ65	451
MZ69	488
MZ71	406
MZ73	376
MZ74	349
MZ75	461
MZ76	446
MZ80	406
MZ81	380
MZ82	441
MZ100	452
MZ101	320

Table 4.5 Average number of panicle per strain (continued)

c) Zambian (NZ) strains

Strains	Average number of panicle/tree
NZ1	375
NZ2	321
NZ7	300
NZ8	395
NZ9	428
NZ11	320
NZ12	389
NZ13	355
NZ14	391
NZ15	377
NZ18	333
NZ22	428
NZ23	267
NZ24	200
NZ25	495
NZ26	301
NZ27	398

Strains	Average number of panicle/tree
NZ28	559
NZ29	349
NZ31	371
NZ32	370
NZ33	409
NZ34	492
NZ35	260
NZ36	280
NZ41	343
NZ42	393
NZ43	442
NZ45	205
NZ52	390
NZ54	461
NZ55	452
NZ65	400

d) Brazilian strains

Strains	Average number of panicle/tree
A1-18	330
A1-32	458
A2-18	428
A3-42	309
A4-17	376
B1-17	385
B1-20	419
B1-28	361
B2-32	365
B5-17	369
C1-18	376
C1-45	419
C3-19	390
C3-46	388
C5-44	444
C5-5	309

Strains	Average number of panicle/tree
D1-10	389
D1-26	334
D1-32	320
D1-42	368
D2-15	342
D2-40	447
D2-46	359
D4-36	453
D5-35	415
D5-46	394
E1-6	378
E3-41	348
F1-29	376
F4-1	390
F4-45	418

(a)

(b)

Figure 4.7 Cashew flowers: male (a) and hermaphrodite (b)

4.1.3.2 Flower characteristics

a) Average number of opened flowers per panicle

The average number of opened flowers per panicle during 1999-2000 and 2000-2001 appears in Table 4.6.

During 1999-2000, the average number of opened flowers varied from 54.50 (NZ65) to 592 (G53) per panicle. During 2000-2001, it ranged between 284.4 (M39) and 1005.2 (MZ61). In comparison, an average of only 252.40 for M39 and 466.40 (MZ61) flowers were opened during the first growing season. The increase (12.68 % for M39 and 115.52 % for MZ61) of opened flowers per panicle from 1999-2000 to 2000-2001 may be due to the difference in age of the trees (3.5 and 4.5 years) and also to climatic conditions which were very different between the growing seasons.

b) Average number of male (staminate) flowers per panicle

The average number of opened male flowers (Figure 4.7a) per panicle varied from 23.50 (G53) to 348 (MZ-58) during 1999-2000, and from 137.4 (NZ23) to 794 (NZ26) during 2000-2001 (Table 4.7).

During 2000-2001 (Figures 4.8a, b, c), all the selected strains had an increase in the average number of opened male flowers compared to 1999-2000, except MZ44, which had a decrease of about 63.36% (from 250 to 158.4), and MZ35 with more or less equal numbers (from 179 to 178).

Table 4.6 Average number of opened flowers per panicle per studied strains

a) Zambian M/Unknown strains

Strains	Average opened flowers	
	1999-2000	2000-2001
M1	337.50	371.5
M2	356.80	634.9
M3	334.60	527.2
M4	300.10	587.4
M5	409.70	697.7
M6	232.40	407.7
M7	268.70	342.4
M9	253.80	444.6
M11	219.20	540.5
M14	204.50	380.9
M26	295.70	469.5
M27	227.50	324.5

Strains	Average opened flowers	
	1999-2000	2000-2001
M28	282.10	396.9
M30	278.20	386.6
M39	252.40	284.4
M40	181.60	440.6
G17	350.00	
G24	211.50	
G53	54.50	
GJ1	345.00	
GL15	297.50	
MD6	361.00	
MD18	286.00	

b) Zambian (MZ) strains

Strains	Average opened flowers	
	1999-2000	2000-2001
MZ7	185.50	
MZ12	79.00	
MZ17	216.00	
MZ21	453.00	518
MZ22	262.00	
MZ23	184.00	
MZ24	349.00	
MZ25	435.50	
MZ26	463.00	462
MZ28	478.00	456
MZ35	201.50	336
MZ29	188.00	
MZ32	311.00	
MZ37	482.00	
MZ38	349.00	
MZ42	347.40	537
MZ44	391.20	318.8
MZ46	139.00	
MZ47	387.50	
MZ48	348.00	
MZ50	300.50	

Strains	Average opened flowers	
	1999-2000	2000-2001
MZ51	276.80	558.2
MZ54	344.00	502
MZ55	316.50	
MZ57	298.80	606.2
MZ58	386.00	
MZ59	178.50	
MZ61	466.40	1005.2
MZ64	312.40	509.2
MZ65	159.00	
MZ69	99.50	
MZ71	356.00	
MZ73	369.00	
MZ74	219.20	597
MZ75	97.00	
MZ76	193.00	
MZ80	418.00	686
MZ81	208.00	
MZ82	414.00	
MZ100	75.00	
MZ101	339.00	

Table 4.6 Average number of opened flowers per panicle per studied strains
(Continued)

c) Zambian (NZ) strains

Strains	Average opened flowers	
	1999-2000	2000-2001
NZ1	299.50	
NZ2	432.00	
NZ7	347.00	
NZ8	178.00	
NZ9	341.00	
NZ11	253.00	
NZ12	557.00	
NZ13	451.00	
NZ14	314.00	
NZ15	277.50	
NZ18	426.50	
NZ22	82.50	
NZ23	201.20	324
NZ24	341.00	
NZ25	85.00	371
NZ26	374.00	999
NZ27	289.00	473

Strains	Average opened flowers	
	1999-2000	2000-2001
NZ28	370.00	664
NZ29	328.00	
NZ31	468.00	
NZ32	186.50	
NZ33	324.20	782.4
NZ34	313.60	695
NZ35	405.00	
NZ36	314.00	
NZ41	219.00	
NZ42	407.00	652
NZ43	322.40	435.4
NZ45	211.00	719
NZ46	354.00	0
NZ52	66.00	
NZ54	218.00	
NZ55	176.00	
NZ65	592.00	

d) Brazilian strains

Strains	Average opened flowers	
	1999-2000	2000-2001
A1-18	403.00	
A1-32	290.25	
A2-18	262.40	485
A3-42	134.50	
A4-17	145.00	
B1-17	237.50	
B1-20	251.50	
B1-28	156.33	
B2-32	158.50	
B5-17	312.60	474
C1-18	239.40	512.8
C1-45	445.60	653.8
C3-19	253.25	
C3-46	300.80	
C5-44	400.75	
C5-5	232.20	

Strains	Average opened flowers	
	1999-2000	2000-2001
D1-10	242.00	760.8
D1-26	256.25	
D1-32	343.40	730.6
D1-42	414.67	
D2-15	268.75	
D2-40	100.50	
D2-46	401.00	
D4-36	291.80	821
D5-35	225.25	
D5-46	62.50	
E1-6	332.00	
E3-41	274.67	
F1-29	432.25	
F4-1	135.00	
F4-45	345.20	665.2

Table 4.7 Average number of male flowers per panicle per studied strains

a) Zambian M/Unknown strains

Strains	Average male flowers	
	1999-2000	2000-2001
M1	193.30	276
M2	267.90	467.4
M3	151.20	254.6
M4	182.00	398.9
M5	130.20	428.5
M6	110.50	292.4
M7	166.90	240.8
M9	73.90	200.1
M1 1	109.90	356.7
M1 4	78.10	249 4
M26	230.60	386.5
M27	124.30	223.3

Strains	Average male flowers	
	1999-2000	2000-2001
M28	224.70	287
M30	144.93	243 3
M39	176 60	207.3
M40	83.80	321.4
G17	150.50	
G24	50.00	
G53	23.50	
GJ1	285 50	
GL15	255.00	
MD6	287.00	
MD18	225.00	

b) Zambian (MZ) strains

Strains	Average male flowers	
	1999-2000	2000-2001
MZ7	58.00	
MZ12	70.50	
MZ17	77.00	
MZ21	255.00	355
MZ22	78.00	
MZ23	95.00	
MZ24	175.50	
MZ25	145.50	
MZ26	267.00	291
MZ28	252.00	237
MZ29	91.50	
MZ32	82.50	
MZ35	179.00	178
MZ37	161.00	
MZ38	105.50	
MZ42	236.00	347.4
MZ44	250.00	158.4
MZ46	34.00	
MZ47	324.00	
MZ48	243.50	
MZ50	260.00	

Strains	Average male flowers	
	1999-2000	2000-2001
MZ51	134.00	360.8
MZ54	122.00	252.2
MZ55	231.50	
MZ57	75.00	409.2
MZ58	348.00	
MZ59	64.50	
MZ61	135.40	600.4
MZ64	222.20	418.8
MZ65	96.00	
MZ69	40.50	
MZ71	106.50	
MZ73	218.50	
MZ74	123.60	364
MZ75	68.00	
MZ76	93 00	
MZ80	241.00	506
MZ81	113 50	
MZ82	151.50	
MZ100	62.00	
MZ101	211.00	

Table 4.7 Average number of male flowers per panicle per studied strains (continued)

c) Zambian (NZ) strains

Strains	Average opened flowers	
	1999-2000	2000-2001
NZ1	172.00	
NZ2	174.00	
NZ7	233.00	
NZ8	137.50	
NZ9	82.00	
NZ11	91.00	
NZ12	88.00	
NZ13	250.50	
NZ14	262.00	
NZ15	59.00	
NZ18	151.00	
NZ22	32.50	
NZ23	97.80	137.4
NZ24	306.00	
NZ25	56.00	209
NZ26	166.00	794
NZ27	192.00	372

Strains	Average opened flowers	
	1999-2000	2000-2001
NZ28	158.00	373
NZ29	304 00	
NZ31	165.00	
NZ32	124.00	
NZ33	196.40	541
NZ34	124.20	490.6
NZ35	199.00	
NZ36	131 00	
NZ41	77.50	
NZ42	274.00	471
NZ43	100.60	258.2
NZ45	57.00	578
NZ46	278.00	0
NZ52	30.00	
NZ54	78.00	
NZ55	122.00	
NZ65	228.00	

d) Brazilian strains

Strains	*Average opened flowers*	
	1999-2000	2000-2001
A1-18	133.50	
A1-32	105.50	
A2-18	160 00	228.4
A3-42	70.50	
A4-17	74.00	
B1-17	207.25	
B1-20	137.00	
B1-28	98.00	
B2-32	43 00	
B5-17	169.80	335.4
C1-18	130 20	252.8
C1-45	307.00	320.6
C3-19	157.75	
C3-46	136.60	
C5-44	323.75	
C5-5	84.20	

Strains	Average opened flowers	
	1999-2000	2000-2001
D1-10	141 60	354.4
D1-26	111 50	
D1-32	263.40	447.8
D1-42	283 33	
D2-15	183.75	
D2-40	52.75	
D2-46	143.50	
D4-36	153 60	607.6
D5-35	104.75	
D5-46	55.00	
E1-6	177.50	
E3-41	156.33	
F1-29	259 00	
F4-1	63.50	
F4-45	212.60	259 2

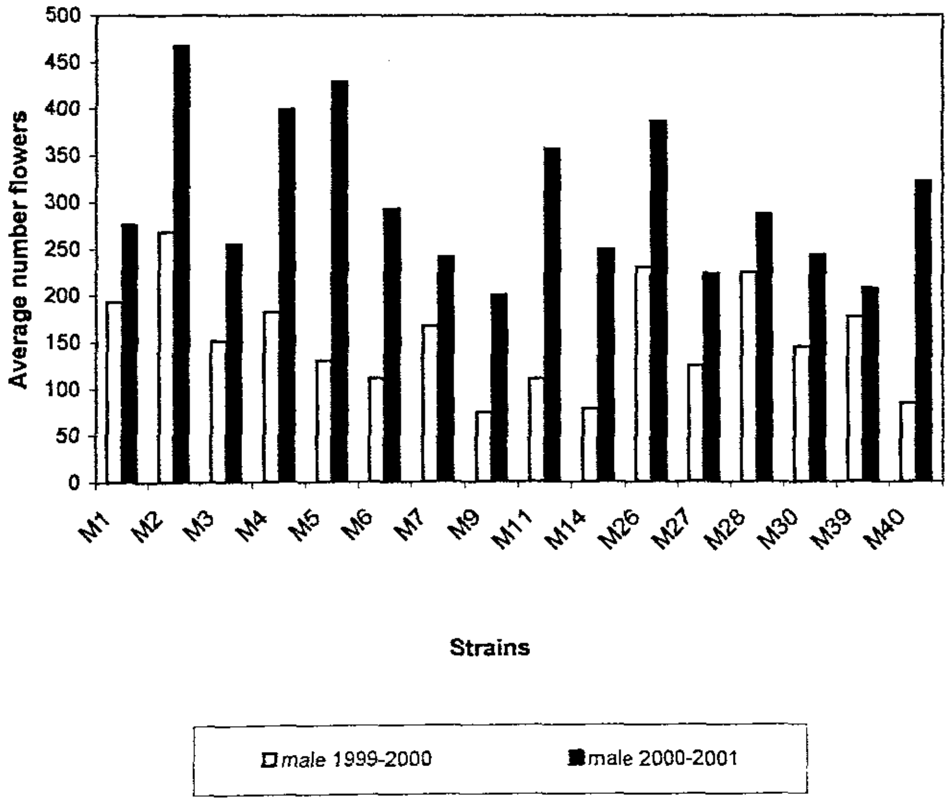


Figure 4.8a Average number of male flowers per panicle

(Strains based on average of ten trees)

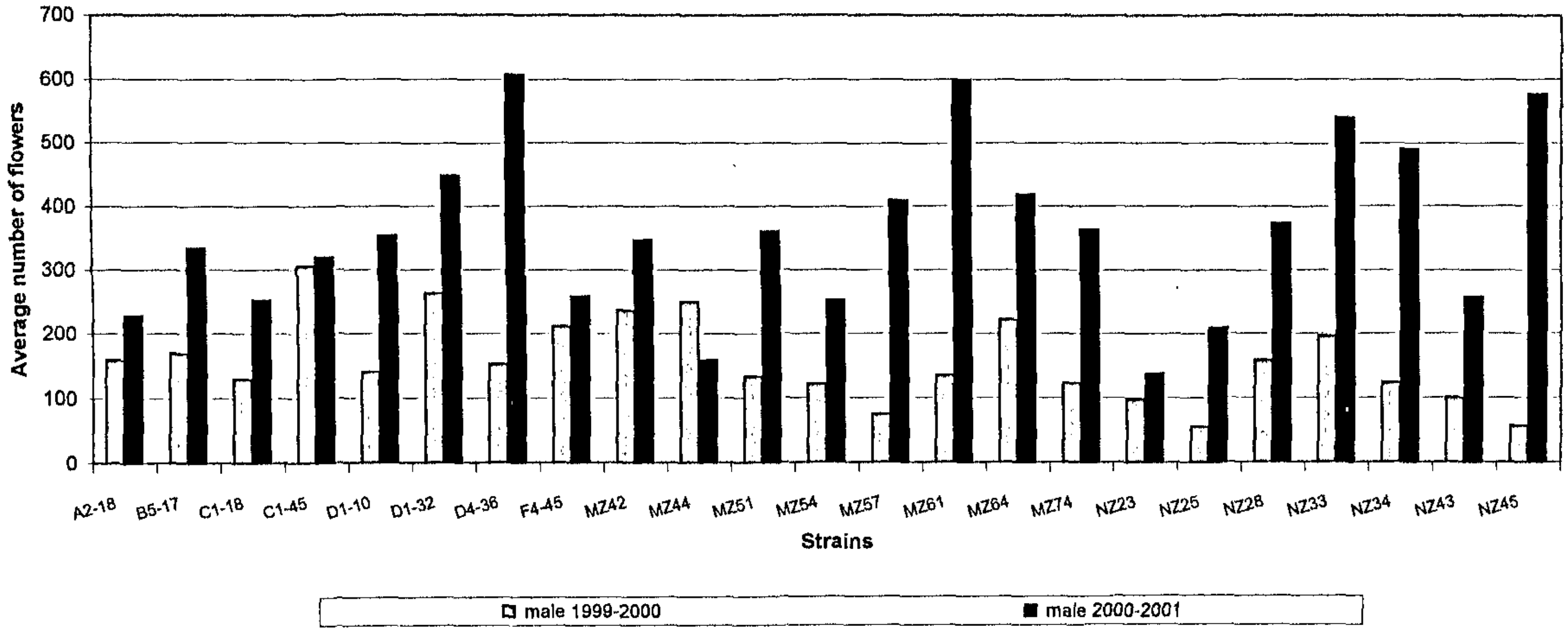


Figure 4.8b Average number of male flowers per panicle

(Strains based on average of five trees)

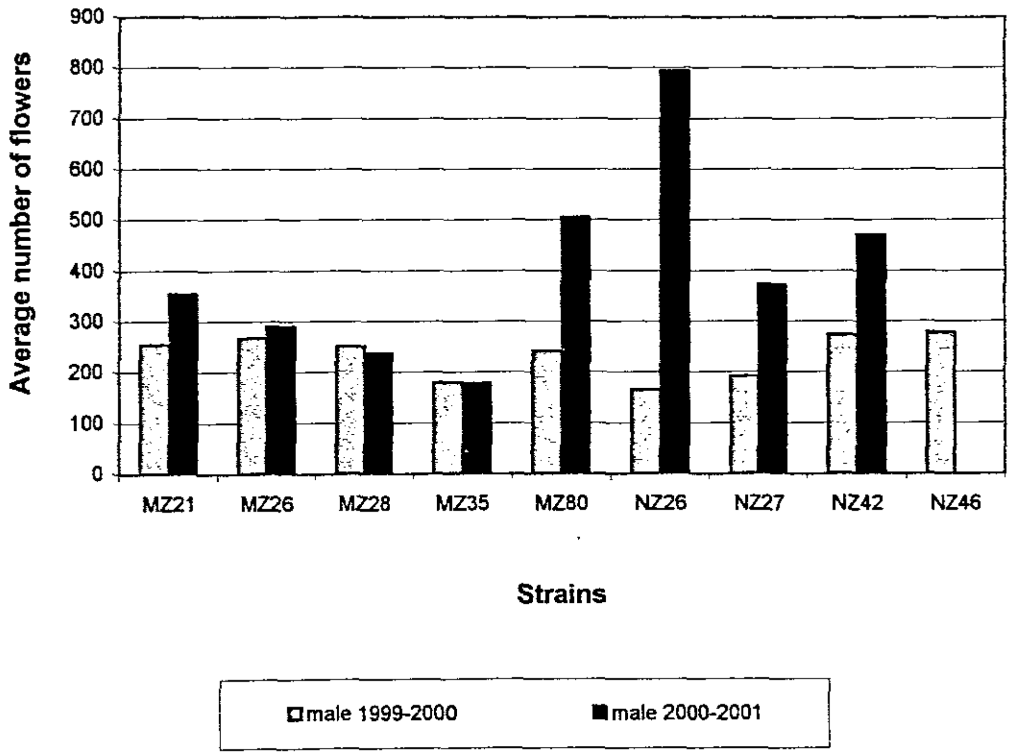


Figure 4.8c Average number of male flowers per panicle

(Strains based on average of one tree)

For high pollen production, a high percentage of male flowers per panicle is desirable. The top ten strains to be considered for improved pollination would be: NZ26, D4-36, MZ61, NZ45, NZ33, M280, NZ34, NZ42, M2 and D1-32. The average number of male flowers per panicle for these strains was 794, 607.6, 600.4, 578, 541, 506, 490.6, 471, 467.4 and 447.8 respectively.

Table 4.8 shows the five highest producers of male flowers during the two growing seasons.

Table 4.8 Strains ranked for five highest producers of male flowers

Rank	1999-2000	2000-2001
1	MZ58	NZ26
2	MZ47	D4-36
3	C5-44	MZ61
4	C1-45	NZ45
5	NZ24	NZ33

None of the highest strains during 1999-2000 appeared amongst the highest during 2000-2001 season.

c) Average number of perfect (hermaphrodite) flowers per panicle

The average number of opened hermaphrodite flowers per panicle for the different strains is presented in Table 4.9 and Figures 4.9a, 4.9b and 4.9c.

The results indicated a marked difference in the number of hermaphrodite flowers between strains. During 1999-2000, five strains (MZ37, MZ61, NZ12,

Table 4.9 Average number of hermaphrodide flowers per panicle per studied strains

a) Zambian M/Unknown strains

Strains	Average hermaphrodite flowers/panicle	
	1999-2000	2000-2001
M1	144.20	95.5
M2	88.90	167.5
M3	183.40	272.6
M4	118.10	188.5
M5	279.50	269.2
M6	121.90	115.3
M7	101.80	101.6
M9	179.90	244.5
M11	109.30	183.8
M14	126.40	131.5
M26	65.10	83
M27	103.20	101.2

Strains	Average hermaphrodite flowers/panicle	
	1999-2000	2000-2001
M28	57.40	109.9
M30	115.52	143.3
M39	75.80	77.1
M40	97.80	119.2
G17	199.50	
G24	161.50	
G53	31.00	
GJ1	59.50	
GL15	42.50	
MD6	74.00	
MD18	61.00	

b) Zambian (MZ) strains

Strains	Average hermaphrodite flowers/panicle	
	1999-2000	2000-2001
MZ7	127.50	
MZ12	8.50	
MZ17	139.00	
MZ21	198.00	163
MZ22	184.00	
MZ23	89.00	
MZ24	173.50	
MZ25	290.00	
MZ26	196.00	171
MZ28	226.00	219
MZ29	110.00	
MZ32	105.50	
MZ35	132.00	158
MZ37	321.00	
MZ38	243.50	
MZ42	111.40	189.6
MZ44	141.20	160.4
MZ46	105.00	
MZ47	63.50	
MZ48	104.50	
MZ50	40.50	

Strains	Average hermaphrodite flowers/panicle	
	1999-2000	2000-2001
MZ51	142.80	197.4
MZ54	222.00	249.8
MZ55	85.00	
MZ57	223.80	197
MZ58	38.00	
MZ59	114.00	
MZ61	331.00	404.8
MZ64	90.20	90.4
MZ65	63.00	
MZ69	59.00	
MZ71	249.50	
MZ73	150.50	
MZ74	95.60	233
MZ75	29.00	
MZ76	100.00	
MZ80	177.00	180
MZ81	94.50	
MZ82	262.50	
MZ100	13.00	
MZ101	128.00	

Table 4.9 Average number of hermaphrodide flowers per panicle per studied strains (Continued)

c) Zambian (NZ) strains

Strains	Average hermaphrodite flowers/panicle 1999-2000	2000-2001
NZ1	127.50	
NZ2	258.00	
NZ7	114.00	
NZ8	40.50	
NZ9	259.00	
NZ11	162.00	
NZ12	469.00	
NZ13	200.50	
NZ14	52.00	
NZ15	218.50	
NZ18	275.50	
NZ22	50.00	
NZ23	103.40	186.6
NZ24	35.00	
NZ25	29.00	162
NZ26	208.00	205
NZ27	97.00	101

Strains	Average hermaphrodite flowers/panicle 1999-2000	2000-2001
NZ28	212.00	291
NZ29	24.00	
NZ31	303.00	
NZ32	62.50	
NZ33	127.80	241.4
NZ34	189.40	204.4
NZ35	206.00	
NZ36	183.00	
NZ41	141.50	
NZ42	133.00	181
NZ43	221.80	177.2
NZ45	154.00	141
NZ46	76.00	0
NZ52	36.00	
NZ54	140.00	
NZ55	54.00	
NZ65	364.00	

d) Brazilian strains

Strains	Average hermaphrodite flowers/panicle 1999-2000	2000-2001
A1-18	269.50	
A1-32	184.75	
A2-18	102.40	256.6
A3-42	64.00	
A4-17	71.00	
B1-17	30.25	
B1-20	114.50	
B1-28	58.33	
B2-32	115.50	
B5-17	142.80	138.6
C1-18	109.20	260
C1-45	138.60	333.2
C3-19	95.50	
C3-46	164.20	
C5-44	77.00	
C5-5	148.00	

Strains	Average hermaphrodite flowers/panicle 1999-2000	2000-2001
D1-10	100.40	406.4
D1-26	144.75	
D1-32	80.00	282.8
D1-42	131.33	
D2-15	85.00	
D2-40	47.75	
D2-46	257.50	
D4-36	138.20	213.4
D5-35	120.50	
D5-46	7.50	
E1-6	154.50	
E3-41	118.33	
F1-29	173.25	
F4-1	71.50	
F4-45	132.60	406

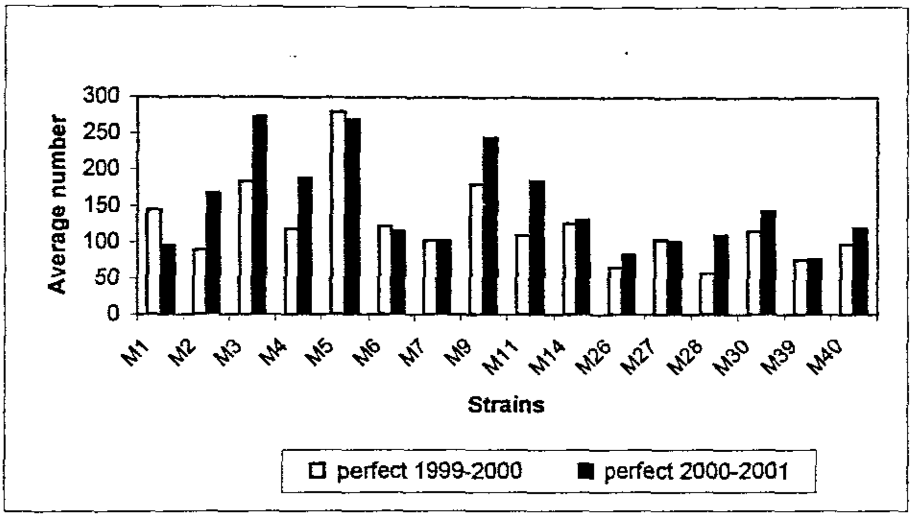


Figure 4.9a Average number of hermaphrodite flowers per panicle (Strains based on average of ten trees)

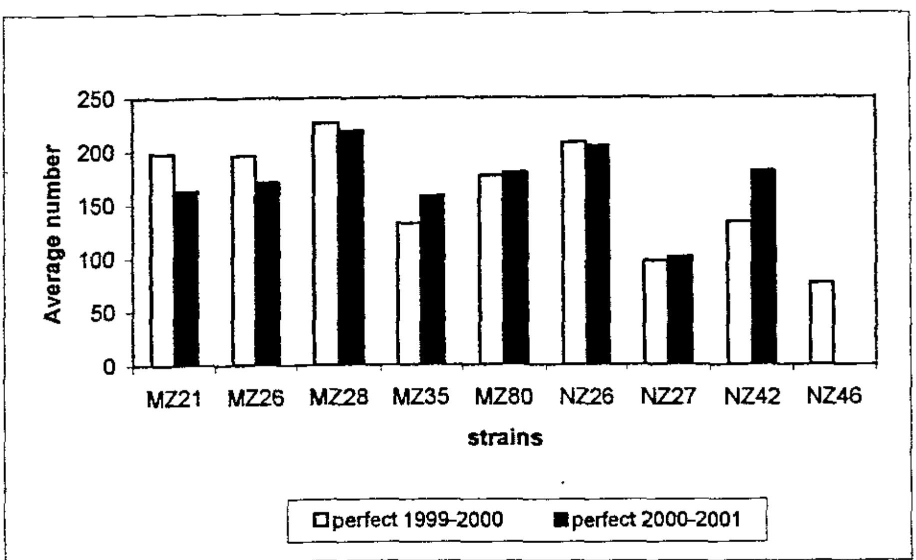


Figure 4.9c Average number of hermaphrodite flowers per panicle (Strains based on average of one tree)

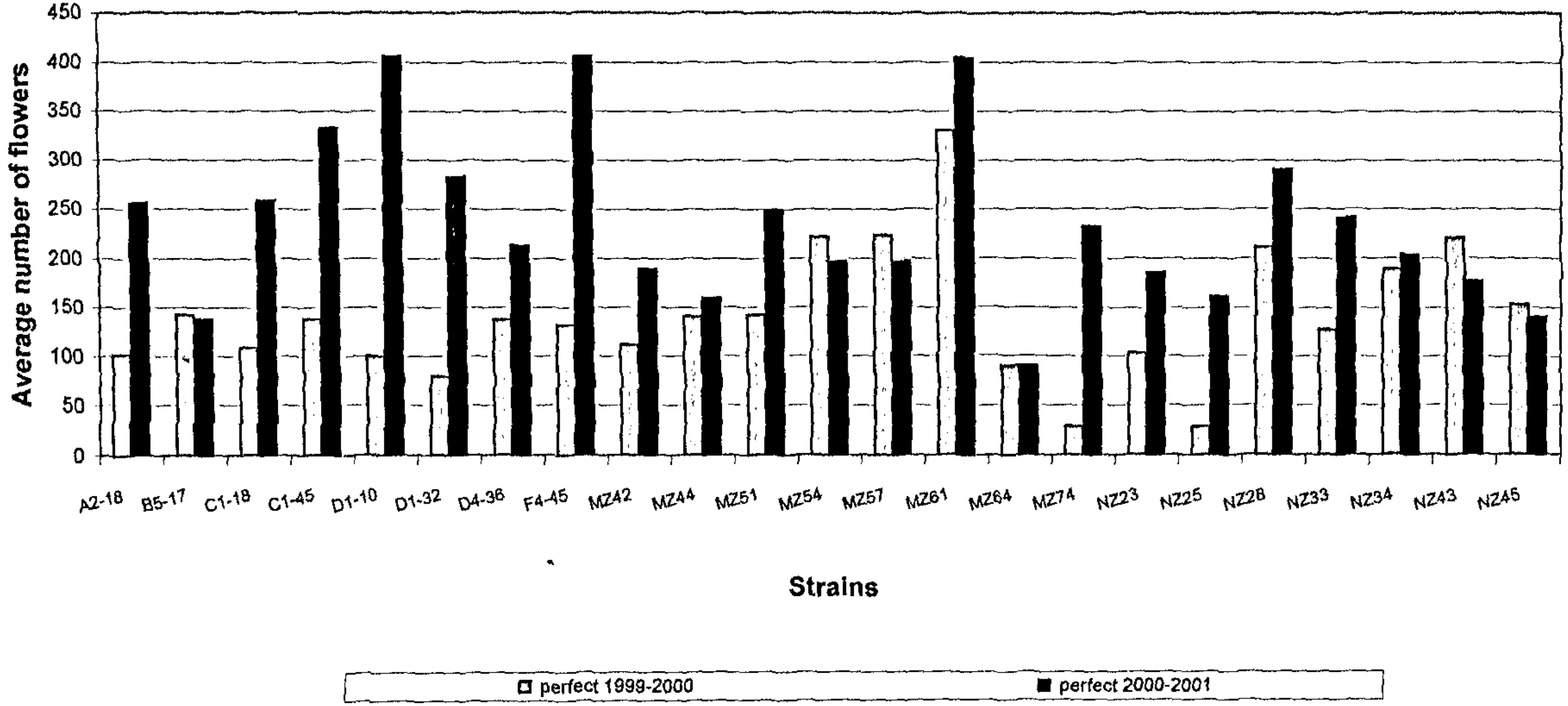


Figure 4.9b Average number of hermaphrodite flowers per panicle

(Strains based on average of five trees)

NZ31 and NZ65) had more than 300 hermaphrodite flowers per panicle (Tables 4.9b and 4.9c). Twelve strains (M1, M5, M6, MZ21, MZ26, MZ28, NZ26, B5-17, MZ54, MZ57, NZ43 and NZ45) showed a decrease in number, between 1.44 and 33.77%, from 1999-2000 to 2000-2001 (Figure 4.9a-c). There was not much difference between D1-10 and F4-45 of the Brazilian strains: both had the same number of hermaphrodite flowers per panicle and were regarded as the highest (406.4 and 406 respectively) during 2000-2001. The minimum number was found in M39 (77.1) during the same season. A marked contrast was seen when the results for the 47 strains studied during both seasons were compared. The results were as low as 7.5 hermaphrodite flowers for D5-46 during 1999-2000 and the highest number was found in NZ12 (469). Only strain MZ61 was selected for studying during the 2000-2001 growing season because others had low yield (Table 4.10).

Table 4.10 Strains ranked for five highest producers of hermaphrodite flowers

Rank	1999-2000	2000-2001
1	NZ12	D1-10
2	MZ65	F4-45
3	MZ61	MZ61
4	MZ37	C1-45
5	NZ31	NZ28

As the number of hermaphrodite flowers is one of the most important indications of yield, the top ten strains to be considered would be: D1-10, F4-45, MZ61, C1-45, NZ28, D1-32, M3, M5, C1-18 and A2-18, as they show an increase in number of hermaphrodite flowers from one year to another.

d) Sex Ratio

The sex ratio can be expressed in two ways: firstly, the number of hermaphrodite flowers in relation to the number of male flowers (Table 4.11 and Figures 4.10a-c) and secondly, the number of male flowers in relation to the number of hermaphrodite flowers (Table 4.12).

From the results, it is clear that most of the selected strains had a very low ratio of hermaphrodite to male flowers. During the two growing seasons a ratio of less than one indicated that there are more opened male flowers than hermaphrodite flowers. On the contrary, if the ratio is more than one, there are more opened hermaphrodite flowers than male flowers. During the 1999-2000 season, only three strains, M11 (Table 4.11a), MZ24 (Table 4.11b) and A4-17 (Table 4.11d) had a ratio of 1, in which the number of hermaphrodite and male flowers were the same. During the 2000-2001 season, four strains, MZ44, C1-18 and C1-45 (Figure 4.10b), had the same number of opened male and hermaphrodite flowers.

A high hermaphrodite to male ratio flower is important because it can be used as a criterion for selection of high yielding cashew strains.

e) Flowering period

The flowering period is taken as the time required from the initiation of flowers on the panicle until the visible initiation of fruit set.

Table 4.11 Ratio hermaphrodite to male flowers of the studied strains

a) Zambian M/Unknown strains

Strains	Ratio hermaphrodite to male flowers		Strains	Ratio hermaphrodite to male flowers	
	1999-2000	2000-2001		1999-2000	2000-2001
M1	0.7	0.35	M28	0.3	0.38
M2	0.3	0.36	M30	0.8	0.59
M3	1.2	1.07	M39	0.4	0.37
M4	0.6	0.47	M40	1.2	0.37
M5	2.1	0.63	G17	1.3	
M6	1.1	0.39	G24	3.2	
M7	0.6	0.42	G53	1 3	
M9	2.4	1.22	GJ1	0.2	
M11	1.0	0.52	GL15	0.2	
M14	1.6	0.53	MD6	0 3	
M26	0.3	0 21	MD18	0 3	
M27	0.8	0.45	MM16	0.0	

b) Zambian (MZ) strains

Strains	Ratio perfect to male flowers		Strains	Ratio perfect to male flowers	
	1999-2000	2000-2001		1999-2000	2000-2001
MZ7	2.2		MZ51	1.1	0.55
MZ12	0.1		MZ54	1.8	0 99
MZ17	1.8		MZ55	0 4	
MZ21	0.8	0 46	MZ57	3.0	0.48
MZ22	2.4		MZ58	0.1	
MZ23	0.9		MZ59	1.8	
MZ24	1.0		MZ61	2.4	0 67
MZ25	2.0		MZ64	0.4	0.22
MZ26	0.7	0.59	MZ65	0.7	
MZ28	0.9	0.92	MZ69	1.5	
MZ29	1.2		MZ71	2.3	
MZ32	1.3		MZ73	0 7	
MZ35	0 7	0.89	MZ74	0.8	0.64
MZ37	2.0		MZ75	0.4	
MZ38	2.3		MZ76	1.1	
MZ42	0 5	0 55	MZ80	0.7	0 36
MZ44	0.6	1.01	MZ81	0.8	
MZ46	3.1		MZ82	1 7	
MZ47	0.2		MZ100	0.2	
MZ48	0.4		MZ101	0.6	
MZ50	0 2				

Ratio = 1: number male flowers = number perfect flowers
Ratio < 1: more male flowers than perfect flowers
Ratio > 1: more perfect flowers than male flowers

Table 4.11 Ratio hermaphrodite to male flowers of the studied strains (continued)

c) Zambian (NZ) strains

Strains	Ratio perfect to male flowers		Strains	Ratio perfect to male flowers	
	1999-2000	*2000-2001*		*1999-2000*	*2000-2001*
NZ1	0.7		NZ28	1.3	0.78
NZ2	1.5		NZ29	0.08	
NZ7	0.5		NZ31	1.8	
NZ8	0.3		NZ32	0.5	
NZ9	3.2		NZ33	0.7	0.45
NZ11	1.8		NZ34	1.5	0.42
NZ12	5.3		NZ35	1.0	
NZ13	0.8		NZ36	1.4	
NZ14	0.2		NZ41	1.8	
NZ15	3.7		NZ42	0.5	0.38
NZ18	1.8		NZ43	2.2	0.69
NZ22	1.5		NZ45	2.7	0.24
NZ23	1.1	1.36	NZ46	0.3	
NZ24	0.1		NZ52	1.2	
NZ25	0.5	0.78	NZ54	1.8	
NZ26	1.3	0.26	NZ55	0.4	
NZ27	0.5	0.27	NZ65	1.6	

d) Brazilian strains

Strains	Ratio perfect to male flowers		Strains	Ratio perfect to male flowers	
	1999-2000	*2000-2001*		*1999-2000*	*2000-2001*
A1-18	2.0		D1-10	0.7	1.15
A1-32	1.8		D1-26	1.3	
A2-18	0.6	1.12	D1-32	0.3	0.63
A3-42	0.9		D1-42	0.5	
A4-17	1.0		D2-15	0.5	
B1-17	0.1		D2-40	0.9	
B1-20	0.8		D2-46	1.8	
B1-28	0.6		D4-36	0.9	0.35
B2-32	2.7		D5-35	1.2	
B5-17	0.8	0.41	D5-46	0.1	
C1-18	0.8	1.03	E1-6	0.9	
C1-45	0.5	1.04	E3-41	0.8	
C3-19	0.6		F1-29	0.7	
C3-46	1.2		F4-1	1.1	
C5-44	0.2		F4-45	0.6	1.57
C5-5	1.8				

Ratio = 1: number male flowers = number perfect flowers
Ratio < 1: more male flowers than perfect flowers
Ratio > 1: more perfect flowers than male flowers

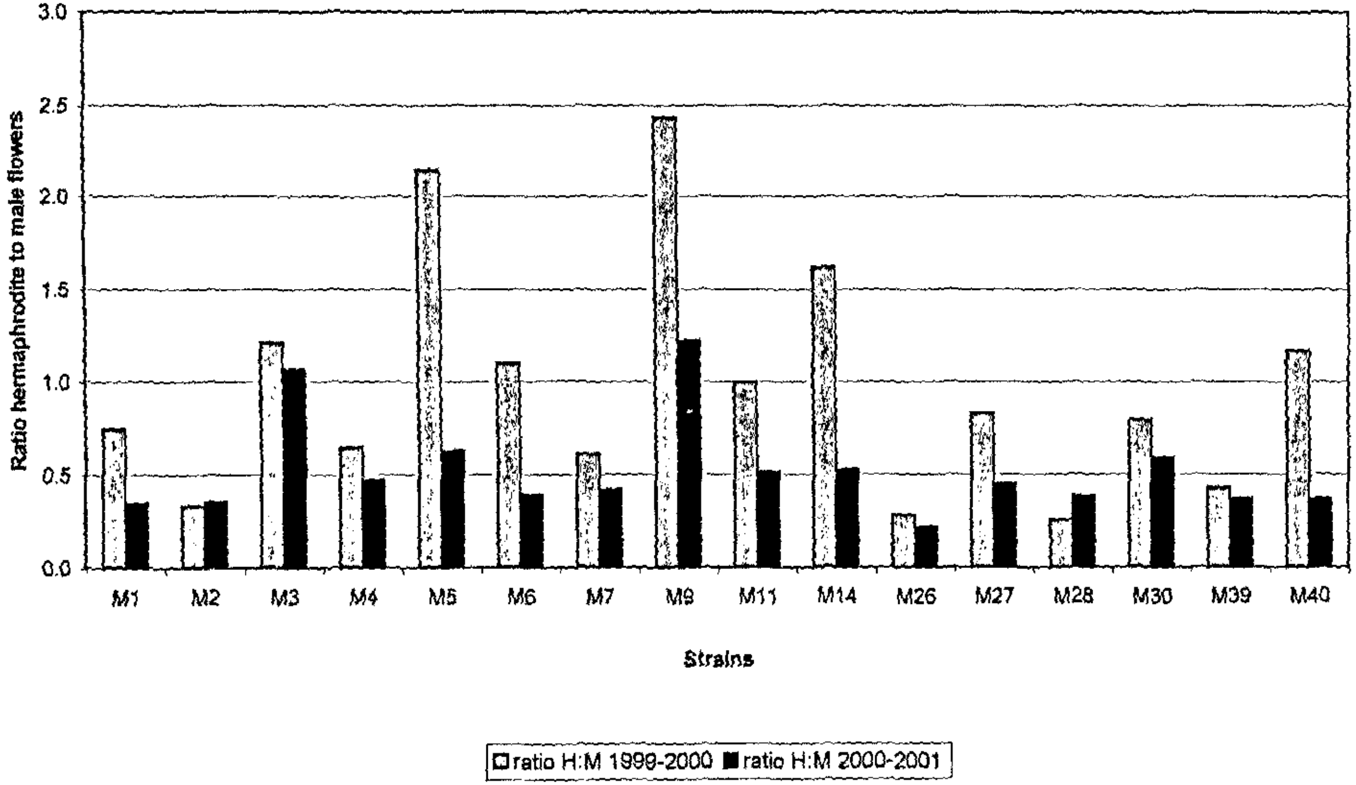


Figure 4.10a Ratio hermaphrodite (H) to male (M) flowers per panicle

(Strains based on average of ten trees)

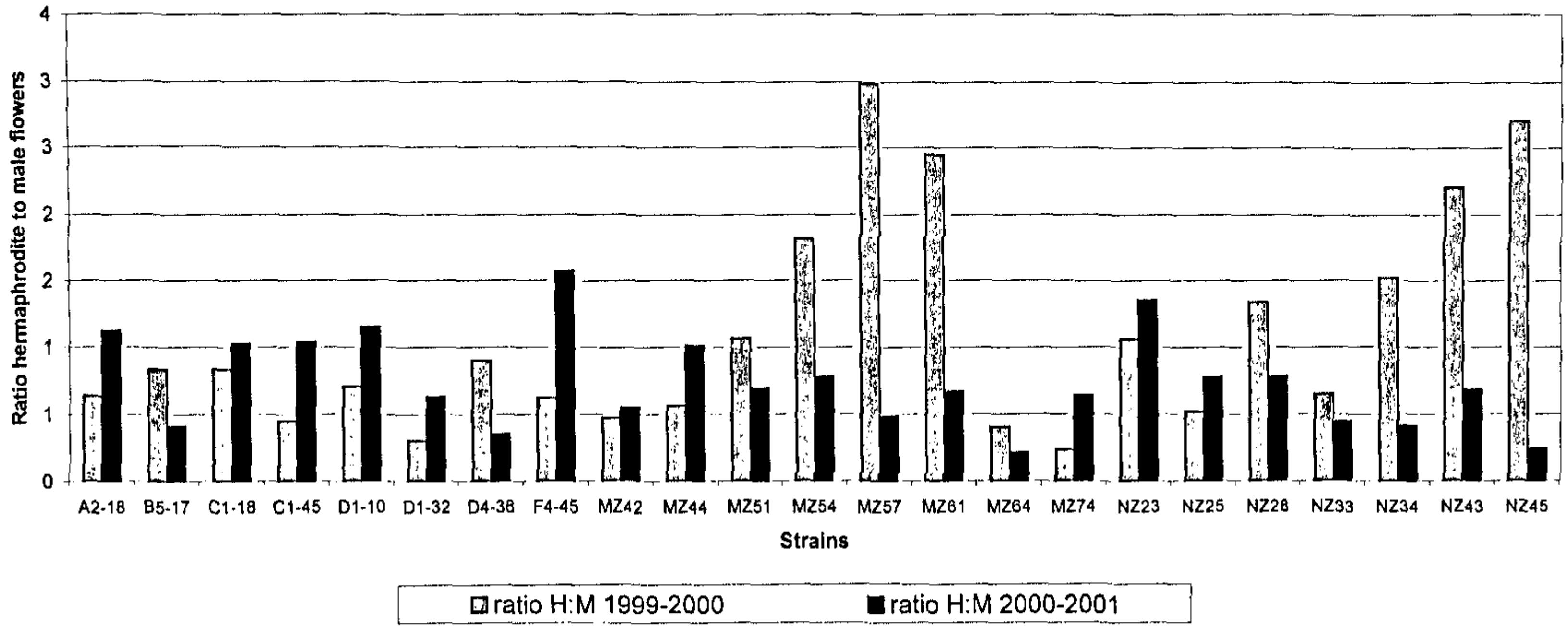


Figure 4.10b Ratio hermaphrodite (H) to male (M) flowers (Strains based on average of five trees)

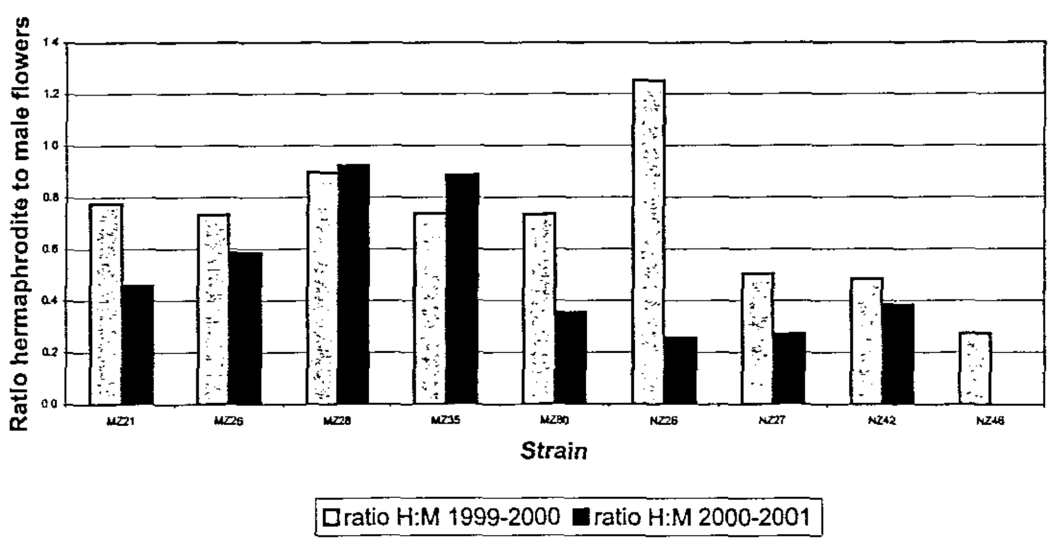


Figure 4.10c Ratio hermaphrodite (H) to male (M) flowers per panicle (Strains based on average of one tree)

Table 4.12 Ratio male to hermaphrodite flowers of the studied strains

a) Zambian M/Unknown strains

Strains	Ratio male *to perfect flowers*	
	1999-2000	2000-2001
M1	1.34	2.89
M2	3.01	2.79
M3	0.82	0.93
M4	1.54	2.12
M5	0.47	1.59
M6	0.91	2.54
M7	1.64	2.37
M9	0 41	0.82
M11	1.01	1.94
M14	0.62	1.90
M26	3.54	4.66
M27	1.20	2.21

Strains	Ratio male *to perfect flowers*	
	1999-2000	2000-2001
M28	3.91	2.61
M30	1.25	1.70
M39	2.33	2.69
M40	0.86	2.70
G17	0 75	
G24	0.31	
G53	0.76	
GJ1	4.80	
GL15	6.00	
MD6	3 88	
MD18	3.69	

b) Zambian (MZ) strains

Strains	Ratio male to perfect flowers	
	1999-2000	2000-2001
MZ7	0 45	
MZ12	8.29	
MZ17	0.55	
MZ21	1.29	2.18
MZ22	0.42	
MZ23	1 07	
MZ24	1.01	
MZ25	0.50	
MZ26	1.36	1.70
MZ28	1 12	1.08
MZ29	0.83	
MZ32	0.78	
MZ35	1.36	1.13
MZ37	0.50	
MZ38	0 43	
MZ42	2.12	1.83
MZ44	1.77	0.99
MZ46	0.32	
MZ47	5.10	
MZ48	2.33	
MZ50	6.42	

Strains	Ratio male to perfect flowers	
	1999-2000	2000-2001
MZ51	0.94	1.83
MZ54	0.55	1.01
MZ55	2.72	
MZ57	0.34	2.08
MZ58	9.16	
MZ59	0.57	
MZ61	0.41	1.48
MZ64	2.46	4.63
MZ65	1.52	
MZ69	0.69	
MZ71	0.43	
MZ73	1.45	
MZ74	1 29	1 56
MZ75	2.34	
MZ76	0 93	
MZ80	1.36	2.81
MZ81	1.20	
MZ82	0.58	
MZ100	4.77	
MZ101	1.65	

Ratio = 1: number male flowers = number perfect flowers

Ratio > 1: more male flowers than perfect flowers

Ratio < 1: more perfect flowers than male flowers

Table 4.12 Ratio male to hermaphrodite flowers of the studied strains (Continued)

c) Zambian (NZ) strains

Strains	Ratio male to perfect flowers	
	1999-2000	2000-2001
NZ1	1 35	
NZ2	0.67	
NZ7	2.04	
NZ8	3.40	
NZ9	0.32	
NZ11	0.56	
NZ12	0.19	
NZ13	1.25	
NZ14	5.04	
NZ15	0.27	
NZ18	0.55	
NZ22	0 65	
NZ23	0.95	0 74
NZ24	8.74	
NZ25	1.93	1.29
NZ26	0.80	3.87
NZ27	1.98	3.68

Strains	Ratio male to perfect flowers	
	1999-2000	2000-2001
NZ28	0.75	1.28
NZ29	12.67	
NZ31	0.54	
NZ32	1.98	
NZ33	1.54	2.24
NZ34	0 66	2.40
NZ35	0.97	
NZ36	0.72	
NZ41	0 55	
NZ42	2.06	2.60
NZ43	0.45	1 46
NZ45	0.37	4.10
NZ46	3.66	
NZ52	0.83	
NZ54	0 56	
NZ55	2.26	
NZ65	0.63	

d) Brazilian strains

Strains	*Ratio male* to perfect flowers	
	1999-2000	2000-2001
A1-18	0.50	
A1-32	0.57	
A2-18	1 56	0 89
A3-42	1.10	
A4-17	1.04	
B1-17	6.85	
B1-20	1.20	
B1-28	1 68	
B2-32	0.37	
B5-17	1.19	2.42
C1-18	1.19	0 97
C1-45	2.22	0 96
C3-19	1.65	
C3-46	0 83	
C5-44	4.20	
C5-5	0.57	

Strains	*Ratio male* to perfect flowers	
	1999-2000	2000-2001
D1-10	1.41	0.87
D1-26	0.77	
D1-32	3 29	1.58
D1-42	2.16	
D2-15	2 16	
D2-40	1.10	
D2-46	0.56	
D4-36	1.11	2.85
D5-35	0 87	
D5-46	7.33	
E1-6	1.15	
E3-41	1.32	
F1-29	1.49	
F4-1	0.89	
F4-45	1.60	0.64

Ratio = 1: number male flowers = number perfect flowers
Ratio > 1: more male flowers than perfect flowers
Ratio < 1: more perfect flowers than male flowers

During the 1999-2000 season, the flowering period of most of the strains ranged from mid November until the first week of February, about 12 weeks (Table 4.13). For the 2000-2001 season, the duration of the flowering period was 16 weeks, from the end of November until the end of March (Table 4.14).

Eight strains, M1, M9, MZ21, MZ61, NZ33, NZ43, B5-17 and F4-45 were selected to illustrate the different peak of flowering over the flowering period. Figure 4.11 shows that all eight strains had a similar pattern with one flowering peak, except for MZ61 during 2000-2001. This change could be the result of the strong wind, which occurred in January 2001.

According to these records, the flowering season of cashew strains at Coastal Cashews was between November to March. However, some early and late flowering strains were observed. The peak flowering period, during which more than fifty percent of the flowers were produced, was in December and January.

Eight strains M1, M9, MZ21, MZ61, NZ33, NZ43, B1-17 and F4-45 were selected to illustrate the peak flowering over the flowering period during1999-2000 and 2000-2001 seasons (Figure 4.11). The results show similar graphs, with one peak, except for MZ61. The two peaks of flowering period of MZ61 could be related to this strain's ability to reflower after damage to the flowers as a result of the strong winds that affected Coastal Cashews.

Table 4.13 Flowering period of the studied strains during 1999-2000

a) Zambian M/unknown strains

Strains	11/11/99 24/11/99	25/11/99 09/12/99	10/12/99 24/12/99	25/12/99 08/01/00	09/01/00 23/01/00	24/01/00 07/02/00
	Average number of opened flowers					
M1		56.50	95.90	170.10	6.30	
M2		16.40	79.20	168.80	85.50	
M3		43.70	89.60	178.10	21.90	
M4		39.90	78.80	105.10	51.00	
M5		117.10	132.90	136 60	7.40	
M6		57 20	99.80	53.30		
M7		34.90	87.00	77 60	62.60	
M9	10.70	82.40	81.20	72.10	6.40	
M11		30.40	143.70	39.00		
M14		48 90	78.60	63.10	8.40	
M26			71.60	131.50	26.90	
M27			64 80	109 80	13.40	
M28			35 20	142.50	64.10	
M30		82.00	109.50	66.40		
M39			34.00	154.10	42.50	
M40		31.60	65.80	61.10	22.10	
G17	8.00	66.00	57.50	153.50	65 00	
G24	6.00	97.50	95.50	9.50		
G53		4 50	29.00	0 00		
GJ1			0.00	298 50	41.50	
GL15			0 00	276.00	21.50	
MD6			0.00	214.00	147.00	0.00
MD18			29.00	77 00	37.00	0.00

Table 4.13 Flowering period of the studied strains during 1999-2000 (Continued)

b) Zambian (MZ) strains

Strains	11/11/99 24/11/99	25/11/99 09/12/99	10/12/99 24/12/99	25/12/99 08/01/00	09/01/00 23/01/00	24/01/00 07/02/00
	Average number of opened flowers					
MZ12			0.00	59 50	19 50	
MZ17		45.00	84.50	73.00	7.50	
MZ21			64.00	170.00	204.00	15.00
MZ7	0.00	94.50	23 00	52.00	11 00	
MZ22	0 00	84.50	75.50	92.00	10 00	
MZ23			0.00	146.00	38 00	
MZ24		60 50	104.00	111.50	65 50	
MZ25	17.50	182.00	141.00	46.00		
MZ26			28.00	205 00	230 00	0 00
MZ28		0.00	182.00	221.00	75 00	
MZ29		0.00	84 50	117.00	0.00	
MZ32		23.50	59.00	92.50	8 00	
MZ35				62.00	175.00	53 00
MZ37	32.00	174.50	109.00	151.50	15.00	
MZ38		42.00	105.50	65 00	127.50	0 00
MZ42			85.00	176 60	75.60	
MZ44		24 20	157.20	149.60	46.00	
MZ46		0.00	129 00	10 00		
MZ47		5.50	102.00	186.00	94.00	
MZ48		4.50	271.00	62.50		
MZ50		0.00	108 00	169.50	23 00	
MZ51		30 80	180.40	53.80		
MZ54		94.40	160.60	63.40		
MZ55		23 50	74.00	127 50	91.50	0.00
MZ57		59.80	132.00	98.40	3.00	
MZ58			0 00	182.00	204.00	0 00
MZ59		35.00	68 50	54.00	21.00	
MZ61	69.40	132 20	81.40	108.40	55 00	
MZ64		16 80	94.00	126.60	72.40	
MZ65			28 00	109.50	21.50	
MZ69		0 00	29.50	17.50	12.00	
MZ71	5.00	101.50	215.00	29.50		
MZ73		39.00	108 00	219 50	2.50	
MZ74			46.60	116.00	31.00	
MZ75			27.00	65 00	5 00	
MZ76	0.00	51.50	9 50	125.00	6.50	
MZ80		0.00	101.00	317.00	0 00	
MZ81		26 50	72.50	100.00	9.00	
MZ82	18.50	105 50	204 50	32.50		
MZ100			0.00	75.00	0 00	
MZ101			10 00	293 00	0.00	

Table 4.13 Flowering period of the studied strains during 1999-2000 (Continued)

c) Zambian (NZ) strains

Strains	11/11/99 24/11/99	25/11/99 09/12/99	10/12/99 24/12/99	25/12/99 08/01/00	09/01/00 23/01/00	24/01/00 07/02/00
	Average number of opened flowers					
NZ1		63.50	214.00	13.50		
NZ2		50.00	215 50	117.00	0.00	
NZ7		89.00	258.00	0.00		
NZ8		0 00	0.00	173.00	5 00	
NZ9	14.00	166.00	159.00	2 00		
NZ11		62.00	167.00	24.00		
NZ12	86.00	216.00	255.00	0.00		
NZ13	8.50	125.00	279.00	38.50		
NZ14			30.00	167.00	107.00	0.00
NZ15		29.00	182.00	23 50		
NZ18	10.00	129.00	157.00	111.50	19.00	
NZ22	1.00	21.50	57.00	3 00		
NZ23		29.40	126.20	11.80		
NZ24			29.00	90.00	222.00	0.00
NZ25		0.00	85.00	0 00		
NZ26			51 00	143 00	123.00	57.00
NZ27			34.00	133.00	122.00	0.00
NZ28		87.00	278.00	5.00		
NZ29				37.00	271.00	0.00
NZ31		97.00	301.00	35.00		
NZ32		15.00	98.00	40.50	28 00	
NZ33		61.20	116.40	114.60	11.00	
NZ34		48.00	202.60	57 40		
NZ35	21.00	118.00	215.00	26.00		
NZ36	21.00	164.00	116.00	13 00		
NZ41		41.00	132.50	30.00		
NZ42	101.00	178.00	128.00	0.00		
NZ43	16 80	101.80	179.80	23 40		
NZ45		13.00	176.00	22 00		
NZ46		0.00	200.00	99.00	55 00	
NZ52		0.00	66.00	0 00		
NZ54		13.00	175.00	30.00		
NZ55		0.00	162.00	10.00		
NZ65	0.00	137.00	301.00	137.00	17.00	

Table 4.13 Flowering period of the studied strains during 1999-2000 (Continued)

d) Brazilian strains

Strains	11/11/99 24/11/99	25/11/99 09/12/99	10/12/99 24/12/99	25/12/99 08/01/00	09/01/00 23/01/00	24/01/00 07/02/00
	Average number of opened flowers					
A1-18	17.00	113.50	218.00	42.50		
A1-32		60 75	101.25	110.00	18.00	
A2-18			30 80	142.80	53.00	
A3-42			26.00	67 00	37.50	
A4-17		0.00	65.00	35.00	45 00	
B1-17			4 75	170.00	60.75	
B1-20			63 00	128.00	60.50	
B1-28		0.00	71.50	71.00	27.50	
B2-32		0.00	158 50	0.00		
B5-17		23 80	98.40	126.80	49.80	
C1-18			37.00	110.40	62.80	
C1-45			6.80	253 00	163.40	
C3-19			21.25	174.75	46.75	
C3-46	1.00	64.60	46.80	99.80	84.40	
C5-44	4.75	84.75	103.50	164 50	38 75	
C5-5		21.40	76 60	80.80	44.00	
D1-10			0.00	152.00	83.80	
D1-26			38.75	151 00	49.50	
D1-32			26.20	174 20	116.20	
D1-42			40.00	231.00	141.00	
D2-15			48 25	185.25	9.75	
D2-40			2.50	58 00	39.75	
D2-46	5 50	102.00	175.00	113.00	5 50	
D4-36			40 40	162.00	60.80	
D5-35			58.75	138 00	8 25	
D5-46			0.00	62.50	0.00	
E1-6		36.50	117.00	146.50	17.50	
E3-41			56 67	129 67	71.67	
F1-29		36 00	108.00	146.75	57.50	82.50
F4-1		2.50	79 00	53.50		
F4-45			50 60	161.80	122.80	

Table 4.14 Flowering period of the studied strains during 2000-2001

a) Zambian M/Unknown strains

	23/11/00 06/12/00	07/12/00 12/12/00	13/12/00 22/12/00	23/12/00 01/01/01	02/01/01 11/01/01	12/01/01 21/01/01	22/01/01 31/01/01	01/02/01 09/02/01	11/02/01 20/02/01	21/02/01 02/03/01
Strains	Average number of opened flowers per panicle									
M1				68.3	72.4	56.4				
M2						89 9	154 9			
M3					124.6	149.1	93 4			
M4				51.6	104.5	79 6	92.8	103.1	72.3	
M5				67.1	135.3	128.7	121.4	99.9	100.9	
M6					66.6	85	60.6			
M7			44.1	62.6	60 6					
M9			36.9	103.6	70.6					
M11			76	140.2	74.2	84.8	53 5			
M14				63.9	85.3	71.3				
M26				77.7	102.4	72.4				
M27			60 3	112	44.7					
M28			25	69.9	130	65				
M30			28 4	63.8	62.1	53.2				
M39							48 7	66 6	39	
M40			56	104.1	51.6	49.6				

b) Zambian (MZ) strains

	23/11/00 06/12/00	07/12/00 12/12/00	13/12/00 22/12/00	23/12/00 01/01/01	02/01/01 11/01/01	12/01/01 21/01/01	22/01/01 31/01/01	01/02/01 09/02/01	11/02/01 20/02/01	21/02/01 02/03/01
Strains	Average number of opened flowers per panicle									
MZ21				53	135	128	128	59		
MZ26					97	104	104	21		
MZ28						123	129	71		
MZ35			33	108	79					
MZ42				104.4	167.4	101.4				
MZ44	22.4	85	35.6	70	40.2					
MZ51			75 2	169 4	192.6	56.8				
MZ54			62.6	129.8	172	40.6				
MZ57				54 4	95.8	49.4		80.2	127.6	78 6
MZ61				116.2	195.2	158 8	121.4	210 4	79 4	
MZ64					90.4	82.2	101.8	70.2	72.2	
MZ74				104	146.6	67.8				
MZ80					97	139	139	108	75	

Table 4.14 Flowering period of the studied strains during 2000-2001 (continued)

c) Zambian (NZ) strains

	23/11/00 06/12/00	07/12/00 12/12/00	13/12/00 22/12/00	23/12/00 01/01/01	02/01/01 11/01/01	12/01/01 21/01/01	22/01/01 31/01/01	01/02/01 09/02/01	11/02/01 20/02/01	21/02/01 02/03/01
Strains	**Average number of opened flowers per panicle**									
NZ23	7.2	90.4	46 6	97.8	27					
NZ25		80	143	36						
NZ26				127	260	240	240	31		
NZ27					70	77	77	83	30	
NZ28	59	193	180	220	12					
NZ33				126.6	203.6	148.2				
NZ34			69.2	133.6	133	146 6	69 4			
NZ42				40	199	129	129	54		
NZ43			92.2	161.2	74 2					
NZ45			61	166	258	0	169	65		
NZ46										

d) Brazilian strains

	23/11/00 06/12/00	07/12/00 12/12/00	13/12/00 22/12/00	23/12/00 01/01/01	02/01/01 11/01/01	12/01/01 21/01/01	22/01/01 31/01/01	01/02/01 09/02/01	11/02/01 20/02/01	21/02/01 02/03/01
Strains	**Average number of opened flowers per panicle**									
A2-18				79 2	169	70.6				
B5-17				48.6	114 2	92 2	90.6	53 8		
C1-18				98 6	170.8	93.4				
C1-45				73	152.2	60 6		85.8	99.6	58 2
D1-10				166	226.4	133.2				
D1-32			68 2	138 6	129.6					
D4-36				75	101.4	69 2	69.4	121 2	134 4	160 2
F4-45				100 8	171.6	101.2				

the apple bulge out and the length and the thickest diameter are equal) and finally pyriform (with a pear-shape). Most of the selected strains had an orange apple with pyriform shape. Only 11 strains had yellow colour and 22 had red apples.

The length of the matured apples ranged between 32 and 70 mm with a mean of 51 mm and the width of the thickest part of the apples varied from 25 to 55 mm, with a mean of 40 mm. The maximum weight was found in F4-45 with a weight of 82.85 g, followed by G17 (80.54 g). MZ75 had the smallest apple size with only 16.92 g.

4.1.4.2 Nut

Nut characteristics taken into consideration were length, width and weight. Table 4.17 contains the length and the width measured through the thickest part of the nuts for the studied strains.

The shell of the nuts was shiny and varied in shape, size and colour, from greyish to dark-brown (Figure 4.14). The length of the nuts varied between 25 mm (C5-44 and MZ32) and 49 mm (MZ75), with a mean of 37 mm. The width ranged from 17 mm (B1-17) to 38 mm (MZ75) with a mean of 28 mm. MZ75 seemed to have the longest nut with the biggest width.

f) Flowering pattern

The time span of flowering in Tables 4.13 and 4.14 indicated that there were two different patterns of flowering:

(i) The first pattern identified consisted of a mixed phase during which male flowers and hermaphrodite flowers opened at the same time, followed by a male phase during which only male flowers opened. The majority of the strains studied during the two growing seasons followed this pattern.

(ii) The second pattern identified consisted of a phase where male flowers opened first, followed by a mixed phase and then a second male phase similar to the first.

g) Fruit set

The swelling of the ovary was taken as an indication of fruit set. The average number of fruits that had set per panicle and the ratio fruit set to hermaphrodite flowers are shown in Table 4.15.

The results indicate that the average number of fruit set per panicle during the 1999-2000 season ranged between 0 and 19. Three strains (G53, MD18 and MM16) of the unknown group (Table 4.15a) did not set fruit and four strains

(MZ58, D5-46, NZ35 and NZ24) had one fruit per panicle, while MZ26 (Table 4.15b) had the maximum of 19.

Table 4.15 Fruit set per panicle and ratio fruit set (FS) to hermaphrodite flowers (H)

a) Zambian M/Unknown strains

Strains	Fruit set / panicle		Ratio FS : H		Strains	Fruit set / panicle		Ratio FS : H	
	1999-2000	2000-2001	1999-2000	2000-2001		1999-2000	2000-2001	1999-2000	2000-2001
M1	7	11	0.20	0.47	M28	5	7	0.34	0.25
M2	8	18	0.36	0.42	M30	5	8	0.17	0.22
M3	7	11	0.14	0.17	M39	3	7	0.17	0.37
M4	8	15	0.27	0.31	M40	3	5	0.12	0.16
M5	10	21	0.14	0.31	G17	4		0.09	
M6	6	7	0.19	0.24	G24	4		0.11	
M7	3	4	0.10	0.16	G53	0		0.00	
M9	5	8	0.11	0.13	GJ1	3		0.20	
M11	3	10	0.11	0.23	GL15	2		0.15	
M14	4	6	0.13	0.20	MD6	8		0.45	
M26	3	4	0.17	0.19	MD18	0		0.00	
M27	3	6	0.11	0.25	MM16	0		0.00	

b) Zambian (MZ) strains

Strains	Fruit set / panicle		Ratio FS : H		Strains	Fruit set / panicle		Ratio FS : H	
	1999-2000	2000-2001	1999-2000	2000-2001		1999-2000	2000-2001	1999-2000	2000-2001
MZ7	2		0.07		MZ51	6	9	0.17	0.15
MZ12	11		0.94		MZ54	8	12	0.15	0.25
MZ17	10		0.30		MZ55	6		0.27	
MZ21	10	25	0.21	0.60	MZ57	7	13	0.12	
MZ22	8		0.18		MZ58	1		0.11	
MZ23	4		0.17		MZ59	5		0.19	
MZ24	8		0.19		MZ61	8	7	0.10	0.07
MZ25	2		0.03		MZ64	7	15	0.29	0.67
MZ26	19	18	0.38	0.42	MZ65	10		0.60	
MZ28	8	16	0.15	0.29	MZ69	3		0.23	
MZ29	8		0.29		MZ71	2		0.02	
MZ32	6		0.21		MZ73	4		0.10	
MZ35	11	12	0.33	0.31	MZ74	7	13	0.96	
MZ37	4		0.04		MZ75	5		0.20	
MZ38	7		0.12		MZ76	5		0.22	
MZ42	12	13	0.42	0.26	MZ80	14	4	0.32	0.08
MZ44	9	12	0.24	0.29	MZ81	8		0.33	
MZ46	2		0.09		MZ82	4		0.05	
MZ47	13		0.83		MZ100	14		0.98	
MZ48	7		0.25		MZ101	8		0.23	
MZ50	2		0.16						

Table 4.15 Fruit set per panicle and ratio fruit set (FS) to hermaphrodite flowers (H)
(Continued)

c) Zambian (NZ) strains

Strains	Fruit set / panicle		Ratio FS : H	
	1999-2000	2000-2001	1999-2000	2000-2001
NZ1	3		0.10	
NZ2	10		0.16	
NZ7	3		0.09	
NZ8	8		0.74	
NZ9	6		0 10	
NZ11	5		0.11	
NZ12	5		0.04	
NZ13	2		0.03	
NZ14	11		0.83	
NZ15	8		0.15	
NZ18	3		0.05	
NZ22	2		0.17	
NZ23	6	7	0.03	
NZ24	1	7	0.70	
NZ25	5	6	0.69	0.15
NZ26	9	5	0.18	0.10
NZ27	5	23	0.20	0.89

Strains	Fruit set / panicle		Ratio FS : H	
	1999-2000	2000-2001	1999-2000	2000-2001
NZ28	8	6	0.16	0.08
NZ29	8		0.92	
NZ31	6		0.08	
NZ32	5		0.31	
NZ33	5	15	0.14	0.24
NZ34	6	21	0.12	0.42
NZ35	1		0.02	
NZ36	4		0.09	
NZ41	2		0.04	
NZ42	13	18	0.38	0.40
NZ43	4	17	0.06	0.39
NZ45	6	8	0.15	0.23
NZ46	8		0.43	
NZ52	2		0.22	
NZ54	2		0.06	
NZ55	2		0 11	
NZ65	1		0.01	

d) Brazilian strains

Strains	Fruit set / panicle		Ratio	
	1999-2000	2000-2001	1999-2000	2000-2001
A1-18	3		0.05	
A1-32	8		0.16	
A2-18	9	11	0.33	0.17
A3-42	7		0.45	
A4-17	4		0.23	
B1-17	3		0.42	
B1-20	14		0 48	
B1-28	4		0.24	
B2-32	8		0.29	
B5-17	5	11	0 15	0.31
C1-18	6	13	0.23	0.19
C1-45	13	18	0.38	0.21
C3-19	6		0.24	
C3-46	8		0.19	
C5-44	2		0.10	
C5-5	7		0.20	

Strains	Fruit set / panicle		Ratio	
	1999-2000	2000-2001	1999-2000	2000-2001
D1-10	6	17	0 23	0.17
D1-26	6		0.17	
D1-32	6	18	0.31	0.25
D1-42	5		0.16	
D2-15	6		0.30	
D2-40	4		0.33	
D2-46	4		0.06	
D4-36	7	18	0.19	0 33
D5-35	4		0.15	
D5-46	1		0 73	
E1-6	5		0.13	
E3-41	6		0.21	
F1-29	5		0.11	
F4-1	3		0.18	
F4-45	7	11	0.22	0.11

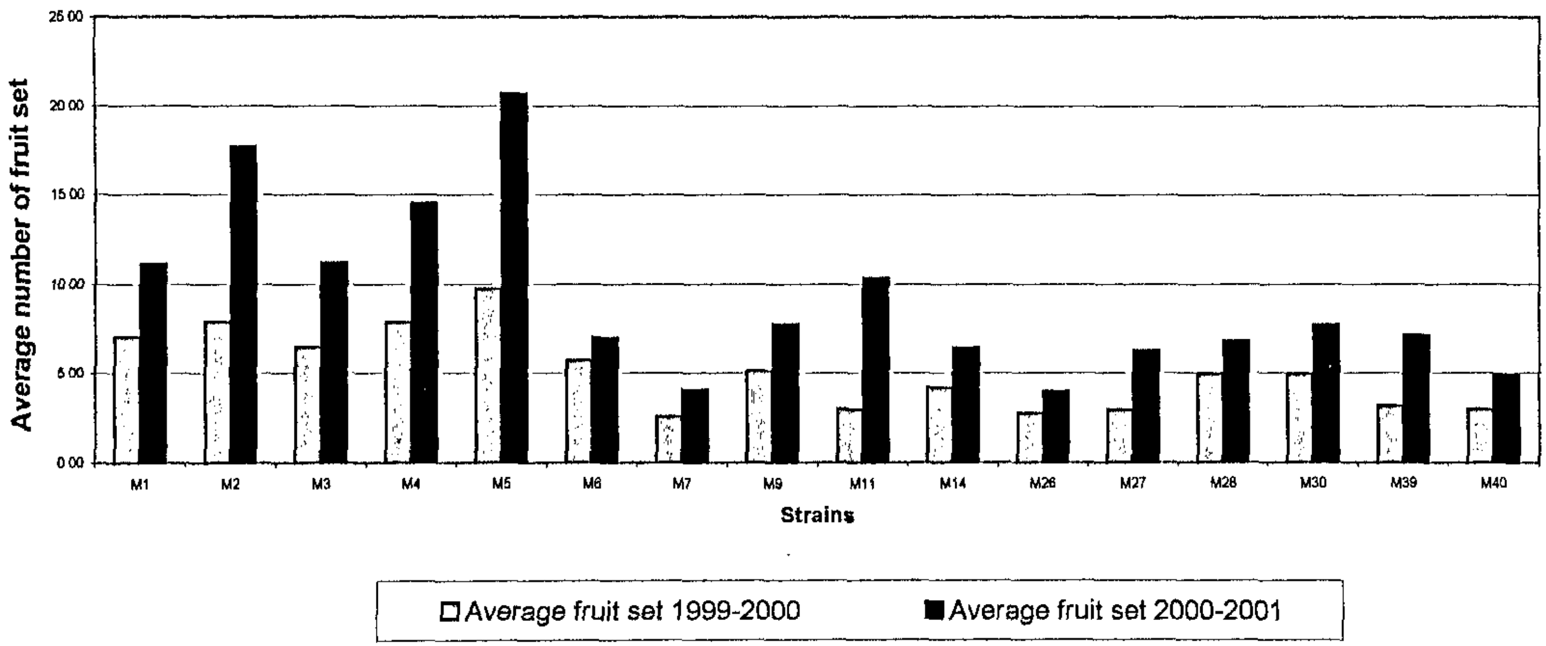


Figure 4.12a Average fruit set per panicle (Strains based on average of ten trees)

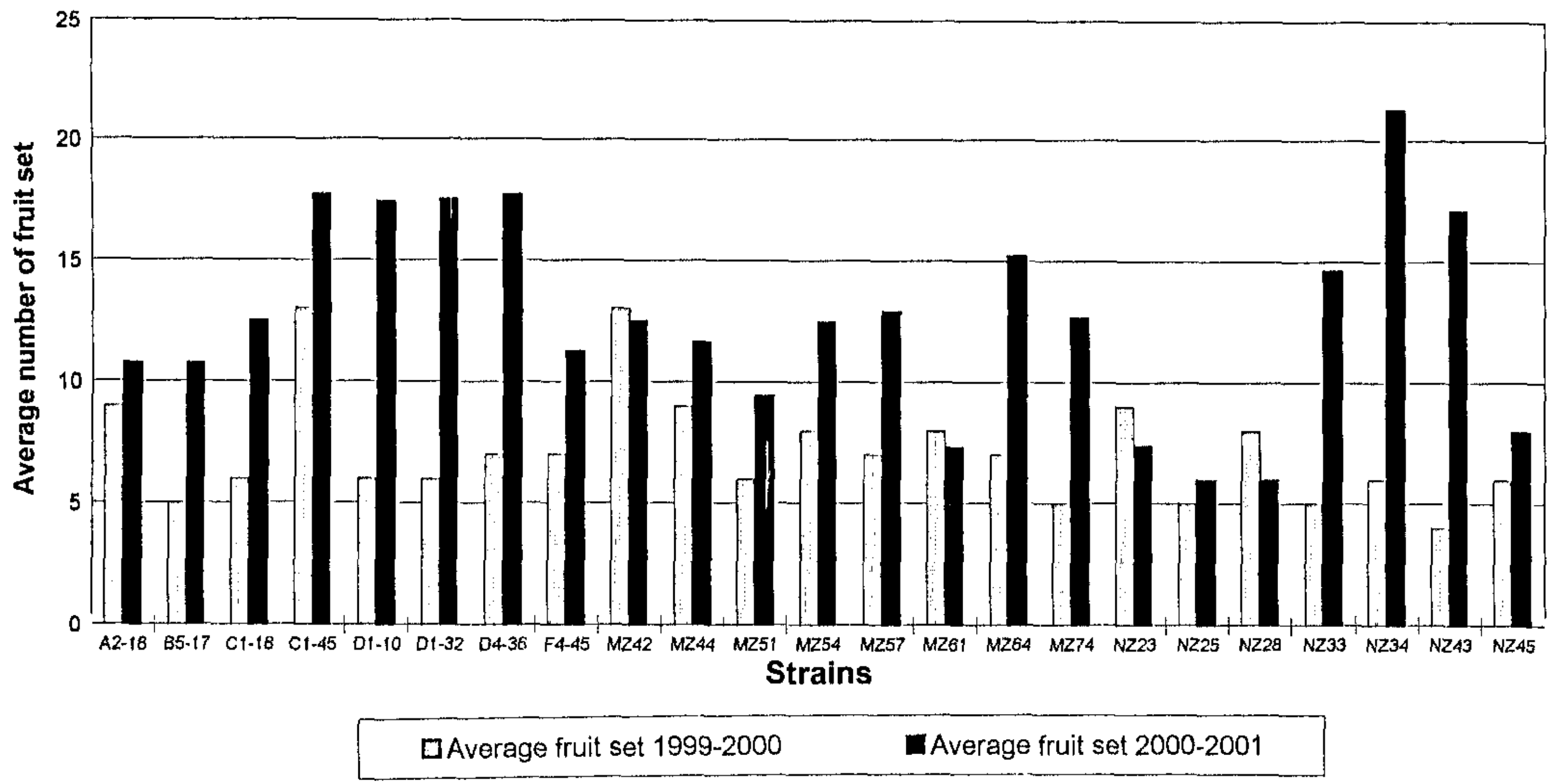


Figure 4.12b Average fruit set per panicle
(Strains based on average of five trees)

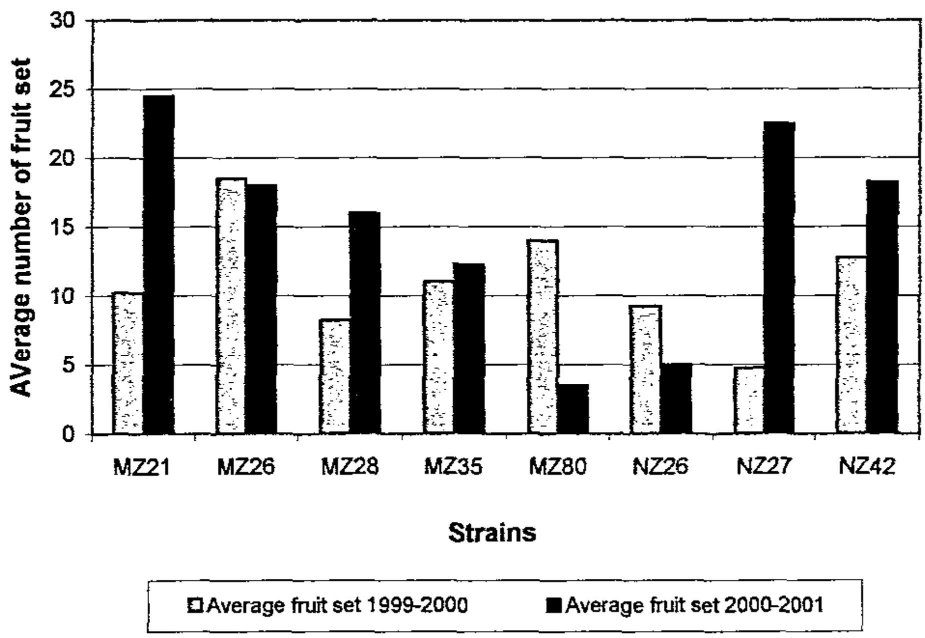


Figure 4.12c Average fruit set per panicle (Strains based on average of one tree)

During 2000-2001, M7, M26 (Figure 4.12a) and MZ80 (Figure 4.12c) had the minimum fruit set of 4 and MZ21 (Figure 4.12c) had the maximum of 25.

In comparison to the number of hermaphrodite flowers per panicle, the fruit that had set was very low in most of the strains. The results shown in Table 4.15 confirm that during 1999-2000, only three strains, MZ12, MZ100 and NZ29, had a ratio of one, in which the number of fruit set equalled the number of hermaphrodite.

Eight strains showed between 50 and 84 percent of the hermaphrodite flowers had set fruit and the rest of the strains produced less than 50 percent.

4.1.4 Fruit characteristics

4.1.4.1 Apple

The apple characteristics of cashew strains are shown in Table 4.16: colour, shape, and weight, average length and widest diameter. The average weight of the apple was based on measurements of 10 ripe apples per strain. Figure 4.13 also illustrates the variation in colour, shape and size of the apples of some strains under study.

The colour of the apple ranged from red to yellow. Some apples were not clearly red or yellow and were taken as orange. The form of the apple was divided into four categories: conical (with a cone-shape), cylindrical (when the diameters at top and bottom of the apple are equal), oblong (when the sides of the apple bulge out and the length and the thickest diameter are equal) and finally pyriform (with a pear-shape). Most of the selected strains had an orange apple with pyriform shape. Only 11 strains had yellow colour and 22 had red apples.

The length of the matured apples ranged between 32 and 70 mm with a mean of 51 mm and the width of the thickest part of the apples varied from 25 to 55 mm, with a mean of 40 mm. The maximum weight was found in F4-45 with a weight of 82.85 g, followed by G17 (80.54 g). MZ75 had the smallest apple size with only 16.92 g.

4.1.4.2 Nut

Nut characteristics taken into consideration were length, width and weight. Table 4.17 contains the length and the width measured through the thickest part of the nuts for the studied strains.

The shell of the nuts was shiny and varied in shape, size and colour, from greyish to dark-brown (Figure 4.14). The length of the nuts varied between 25 mm (C5-44 and MZ32) and 49 mm (MZ75), with a mean of 37 mm. The width ranged from 17 mm (B1-17) to 38 mm (MZ75) with a mean of 28 mm. MZ75 seemed to have the longest nut with the biggest width.

Table 4.16 Apple characteristics

a) Zambia M/Unknown strains

Strains	*Colour*			*Shape*				*Average*		
	red	orange	yellow	conical	cylindrical	oblong	pyriform	length (mm)	diameter (mm)	weight (g)
M1	x						x	53	47	58
M2		x		x				53	49	64
M3			x				x	53	44	51
M4		x				x		55	47	56
M5		x			x			46	37	31
M6	x				x			51	42	40
M7		x					x	52	42	40
M9		x				x		51	38	29
M11		x					x	54	45	41
M14			x				x	55	43	40
M26		x				x		51	44	58
M27		x					x	54	48	61
M28	x						x	56	48	58
M30			x				x	57	48	61
M39			x	x				59	48	69
M40		x					x	53	40	33
G17		x					x	70	55	81
G24		x					x	54	41	37
G53		x					x	50	37	43
GJ1		x					x	51	37	39
GL15		x					x	52	40	41
MD6		x		x				49	37	42
MD18		x			x			46	35	39
MM16		x					x	50	35	41

Table 4.16 Apple characteristics (continued)

b) Zambian (MZ) strains

Strains	Colour			Shape				Average		
	red	orange	yellow	conical	cylindrical	oblong	pyriform	length (mm)	diameter (mm)	weight (g)
MZ7		x					x	47	41	39
MZ12		x					x	44	34	31
MZ17		x					x	47	44	45
MZ21		x					x	49	42	47
MZ22		x			x			42	36	29
MZ23	x						x	62	44	55
MZ24		x			x			39	31	38
MZ25	x				x			45	35	29
MZ26		x					x	54	48	51
MZ28		x					x	38	33	23
MZ29		x			x			37	36	24
MZ32		x					x	38	32	29
MZ35		x			x			36	26	26
MZ37		x					x	48	37	43
MZ38	x			x				45	40	37
MZ42		x				x		57	49	54
MZ44		x					x	50	43	46
MZ46		x					x	51	41	49
MZ47		x					x	49	42	60
MZ48		x		x				55	49	55
MZ50	x						x	54	45	48
MZ51		x		x				45	34	31
MZ54		x					x	50	37	34
MZ55		x					x	51	40	47
MZ57		x					x	60	45	61
MZ58		x					x	47	36	33
MZ59		x					x	54	43	59
MZ61		x					x	54	49	51
MZ64		x					x	43	33	23
MZ65		x				x		43	38	42
MZ69		x					x	45	33	34
MZ71		x				x		37	45	46
MZ73			x		x			55	44	60
MZ74	x						x	56	35	37
MZ75		x				x		32	28	17
MZ76		x					x	35	30	30
MZ80	x						x	38	33	23
MZ81		x					x	53	41	45
MZ82		x			x			50	38	46
MZ100		x					x	49	42	42
MZ101		x					x	46	40	44

Table 4.16 Apple characteristics (continued)

c) Zambian (NZ) strains

Strains	Colour			Shape				Average		
	red	orange	yellow	conical	cylindrical	oblong	pyriform	length (mm)	diameter (mm)	weight (g)
NZ1		x					x	53	43	53
NZ2		x			x			49	47	58
NZ7	x			x				49	43	53
NZ8		x				x		44	49	56
NZ9		x					x	60	48	73
NZ11		x		x				49	40	54
NZ12	x						x	51	41	46
NZ13		x				x		44	49	53
NZ14	x						x	45	36	45
NZ15		x					x	54	52	64
NZ18	x				x			49	45	54
NZ22		x		x				56	43	52
NZ23		x		x				54	51	65
NZ24		x		x				52	52	59
NZ25		x		x				46	42	46
NZ26	x						x	56	35	37
NZ27		x				x		53	44	50
NZ28		x					x	58	48	68
NZ29		x				x		56	54	48
NZ31		x					x	55	58	64
NZ32		x					x	48	36	27
NZ33		x			x			48	37	49
NZ34	x					x		53	49	64
NZ35		x		x				61	50	40
NZ36		x					x	36	25	23
NZ41			x	x				45	34	31
NZ42	x						x	29	29	20
NZ43		x					x	56	52	51
NZ45		x					x	38	33	23
NZ46		x				x		41	37	29
NZ52	x			x				34	38	30
NZ54		x					x	49	42	37
NZ55		x					x	52	43	50
NZ65	x						x	44	36	45

Table 4.16 Apple characteristics (continued)

d) Brazilian strains

Strains	Colour			Shape				Average		
	red	orange	yellow	conical	cylindrical	oblong	pyriform	length (mm)	diameter (mm)	weight (g)
A1-18		x				x		62	49	77
A1-32		x					x	67	48	66
A2-18	x						x	61	46	65
A3-42		x					x	50	41	51
A4-17	x				x			49	39	46
B1-17		x					x	46	38	35
B1-20		x					x	51	42	45
B1-28		x		x				52	38	40
B2-32		x			x			48	41	34
B5-17	x						x	36	27	26
C1-18		x					x	45	38	37
C1-45		x			x			54	50	53
C3-19		x			x			56	51	79
C3-46		x					x	53	51	57
C5-44		x					x	52	45	51
C5-5			x				x	44	36	30
D1-10		x			x			62	50	62
D1-26			x				x	57	41	41
D1-32		x					x	54	45	45
D1-42		x					x	47	36	35
D2-15	x						x	57	48	64
D2-40		x		x				66	46	60
D2-46		x			x			43	35	28
D4-36	x				x			46	45	50
D5-35		x					x	56	50	67
D5-46		x					x	50	40	41
E1-6	x						x	40	30	28
E3-41		x			x			47	49	56
F1-29		x			x			61	45	80
F4-1		x					x	55	43	55
F4-45	x					x		48	54	83

Figure 4.13 Cashew apple: variation in colour, shape and size

Figure 4.14 Cashew nut: variation in colour, shape and size

Table 4.17 Nut characteristics of the studied strains

a) Zambian M/Unknown strains

Strains	Average length (mm)	Average width (mm)
M1	33	27
M2	33	26
M3	32	25
M4	31	25
M5	32	28
M6	32	26
M7	31	24
M9	31	24
M11	37	31
M14	33	22
M26	31	25
M27	30	24

Strains	Average length (mm)	Average width (mm)
M28	30	25
M30	30	26
M39	29	24
M40	29	24
G17	36	30
G24	30	25
G53	31	29
GJ1	29	27
GL15	30	26
MD6	35	32
MD18	31	26
MM16	32	30

b) Zambian (MZ) strains

Strains	Average length (mm)	Average width (mm)
MZ7	34	25
MZ12		
MZ17	35	28
MZ21	31	26
MZ22	32	24
MZ23	33	23
MZ24	31	28
MZ25	36	26
MZ26	30	25
MZ28	32	30
MZ29	31	24
MZ32	25	20
MZ35	28	24
MZ37	40	32
MZ38	33	23
MZ42	35	28
MZ44	30	25
MZ46	38	33
MZ47	32	27
MZ48	36	29
MZ50	33	29

Strains	Average length (mm)	Average width (mm)
MZ51	33	26
MZ54	35	29
MZ55	32	22
MZ57	37	29
MZ58	35	31
MZ59	31	22
MZ61	37	31
MZ64	31	25
MZ65	32	24
MZ69	33	28
MZ71	40	30
MZ73	29	21
MZ74	34	27
MZ75	49	38
MZ76	31	24
MZ80	30	31
MZ81	31	24
MZ82	43	35
MZ100	28	21
MZ101	31	28

Table 4.17 Nut characteristics of the studied strains (Continued)

c) Zambian (NZ) strains)

Strains	Average length (mm)	Average width (mm)
NZ1	29	23
NZ2	34	25
NZ7	32	28
NZ8	31	26
NZ9	38	27
NZ11	31	24
NZ12	29	22
NZ13	31	22
NZ14	34	27
NZ15	37	31
NZ18	31	24
NZ22	33	26
NZ23	36	29
NZ24	34	26
NZ25	36	27
NZ26	30	30
NZ27	32	28

Strains	Average length (mm)	Average width (mm)
NZ28	43	35
NZ29	33	28
NZ31	37	34
NZ32	31	31
NZ33	31	25
NZ34	32	24
NZ35	32	26
NZ36	35	27
NZ41	37	27
NZ42	31	26
NZ43	30	25
NZ45	29	23
NZ46	34	29
NZ52	31	27
NZ54	28	19
NZ55	30	21
NZ65	31	25

d) Brazilian strains

Strains	Average length (mm)	Average width (mm)
A1-18	34	28
A1-32	29	16
A2-18	29	23
A3-42	38	27
A4-17	37	24
B1-17	33	17
B1-20	35	29
B1-28	30	28
B2-32	29	25
B5-17	32	26
C1-18	31	24
C1-45	31	25
C3-19	31	26
C3-46	32	25
C5-44	25	22
C5-5	29	25

Strains	Average length (mm)	Average width (mm)
D1-10	35	28
D1-26	34	28
D1-32	33	21
D1-42	31	24
D2-15	29	23
D2-40	30	23
D2-46	30	25
D4-36	30	21
D5-35	31	24
D5-46	29	25
E1-6	32	25
E3-41	26	25
F1-29	30	25
F4-1	33	25
F4-45	31	27

4.2 Yield

Yield of the cashew strains studied was measured during the growing seasons 1999-2000 and 2000-2001. The results were divided into three groups according to the number of trees per studied strain:

- group (a) strains, represented by ten trees per strain,
- group (b) strains, represented by five trees per strain,
- group (c) strains, represented by one tree per strains.

During the first season, all the trees included were 3 ½ years old and the selected ones during the second season were 4 ½ years old.

4.2.1 1999-2000 growing season

The yield characteristics were: the average number of fruit set per panicle, the average number of nuts that reached maturity, the percentage of fruit dropped per panicle, the average yield per tree and the average weight of a single nut.

4.2.1.1 Average number of panicles per tree

See section 4.1.3.1.

4.2.1.2 Average number of hermaphrodite flowers

See section 4.1.3.2 c

4.2.1.3 Average number of fruit set per panicle

The average number of fruit set per panicle per strain has been discussed in section 4.1.3.2 g, above. Fifty-eight strains had a fruit set of less than five, six had a fruit set between 12 and 14 and the majority had an average fruit set of eight.

4.2.1.4 Average number of nuts matured and percentage of fruit dropped per panicle

The number of nuts that matured indicated the final retention of fruits per panicle. The results in Table 4.18 and Figure 4.15 indicate that the mean number of matured nuts or nuts retained per panicle ranged from 0.00 to 6.75. Twelve strains did not retain any fruit. Six strains, MD6, A3-42, D2-40, N27, NZ71 and NZ35, had a very low number of matured nuts per panicle: 0.25. The maximum number of nuts that matured per panicle was found in NZ2: 6.75.

It is also apparent from Table 4.18 that the total fruit dropped varied from 34% to 100% with a mean of 66%. NZ2 had the lowest percentage of fruit drop and the twelve strains which had zero retention, had the highest percentage (100). MD6, A3-42, D2-40, NZ7, NZ71 and NZ35, with the same number of matured nuts, showed different percentages of nut drop of 97, 96.6, 93.8, 90, 83.3 and 80 percent respectively.

Fruit drop occurred at different stages of fruit development, from the smallest stage to the largest stage. The fruit drop at the later stages seems to be due to insect attack and disease.

Table 4.18 Average fruit set, nut matured and fruit dropped per panicle and their percentage (1999-2000)

a) Group of ten trees per strain

Strains	Average fruit set	Nut matured	Fruit dropped	% Fruit matured	% Fruit dropped
M1	7.08	2.58	4.50	36.40	63 60
M2	7.92	2.35	5.57	29.68	70.32
M3	6 50	2.48	4.03	38.08	61.92
M4	7.88	4.38	3.50	55 56	44.44
M5	9.75	1.23	8.53	12.56	87.44
M6	5.75	0 97	4 78	16.85	83.15
M7	2.58	1.44	1.13	56.09	43.91
M9	5.14	1.10	4.04	21.41	78.59
M11	2.95	2.20	0.75	74 58	25.42
M14	4.17	0.44	3.73	10.50	89.50
M26	2.75	1.28	1.47	46.59	53.41
M27	2.93	1.53	1.39	52.35	47 65
M28	4.95	1.66	3.29	33 46	66.54
M30	4.97	1.00	3.97	20.11	79.89
M39	3.15	0.50	2.65	15.87	84.13
M40	2.97	2.00	0.97	67.29	32.71

c) Group of one tree per strain

Strains	Average fruit set	Nut matured	Fruit dropped	% Fruit matured	% Fruit dropped
NZ7	2.50	0.25	2.25	10.00	90.00
NZ9	6.25	5.00	1.25	80.00	20.00
NZ11	4.50	0.50	4 00	11.11	88.89
NZ12	4.50	1.00	3.50	22.22	77.78
NZ18	3.13	0.63	2.50	20.00	80.00
NZ24	5.00	2.00	3.00	40.00	60.00
NZ26	9.25	4 00	5.25	43.24	56.76
NZ27	4.75	3.25	1.50	68.42	31.58
NZ29	7.50	2.50	5.00	33.33	66 67
NZ31	5.75	1.50	4.25	26.09	73.91
NZ42	12.75	5.00	7.75	39.22	60.78
NZ46	8 25	4.25	4.00	51.52	48.48
NZ52	2.00	1.00	1.00	50.00	50 00
NZ54	2.00	0.50	1.50	25.00	75.00
NZ55	1.50	1.25	0.25	83.33	16.67
NZ65	3 00	0.00	3.00	0.00	100.00
MZ21	10 25	5 50	4 75	53 66	46.34
MZ23	3 75	2.75	1.00	73.33	26 67
MZ26	18.50	4.50	14 00	24.32	75.68
MZ28	8.25	4.00	4.25	48.48	51.52
MZ35	11.00	4 00	7 00	36.36	63.64
MZ46	2.25	1.75	0 50	77.78	22.22
MZ58	1.00	0.00	1.00	0.00	100 00
MZ75	4.75	0.50	4 25	10.53	89.47
MZ80	14 00	6.00	8 00	42.86	57.14
MZ100	14 00	3.25	10.75	23.21	76 79
MZ101	7.50	0.00	7.50	0.00	100.00

Table 4.18 Average fruit set, nut matured and fruit dropped per panicle and their percentage (1999-2000) (continued)

b) Group of five trees per strain

Strains	Average *fruit set*	Nut *matured*	Fruit *dropped*	% Fruit *matured*	% Fruit *dropped*
A1-18	3.25	2.38	0 88	73.08	26.92
A1-32	7.50	0.38	7.13	5.00	95.00
A2-18	8.55	3.70	4.85	43 27	56.73
A3-42	7.25	0.25	7.00	3.45	96.55
A4-17	4.00	1.25	2.75	31.25	68.75
B1-17	3.19	0.75	2.44	23.53	76.47
B1-20	13.75	1.75	12.00	12.73	87.27
B1-28	3 50	0.00	3 50	0.00	100.00
B2-32	8.25	0.00	8 25	0.00	100.00
B5-17	5.35	2.85	2.50	53 27	46.73
C1-18	6.40	2.75	3.65	42.97	57.03
C1-45	13.00	3.90	9.10	30.00	70.00
C3-19	5.75	1.50	4.25	26.09	73 91
C3-46	7.60	2.60	5.00	34.21	65.79
C5-44	1.88	0.50	1.38	26.67	73.33
C5-5	7.40	1.00	6 40	13.51	86.49
D1-10	5.75	0.85	4.90	14.78	85.22
D1-26	6.19	1.13	5.06	18.18	81.82
D1-32	6.25	2.60	3.65	41.60	58.40
D1-42	5.25	2.50	2.75	47.62	52.38
D2-15	6 38	1.94	4.44	30.39	69.61
D2-40	3 92	0 25	3.67	6 38	93.62
D2-46	3.88	0.88	3.00	22.58	77.42
D4-36	6.65	2.90	3.75	43.61	56.39
D5-35	4.44	0.88	3.56	19.72	80.28
D5-46	1.38	0.00	1.38	0.00	100 00
E1-6	5 00	3.63	1.38	72.50	27.50
E3-41	6.08	5.82	0.27	95.60	4.40
F1-29	4.81	1.17	3.65	24.24	75.76
F4-1	3.25	1.75	1.50	53.85	46.15
F4-45	7.35	3.15	4.20	42.86	57.14
MZ7	2.25	0.75	1 50	33.33	66 67
MZ12	10.50	2.63	7.88	25.00	75 00
MZ17	10.38	2.59	7.78	25.00	75.00
MZ22	8.38	2.09	6.28	25.00	75 00
MZ24	8.25	2.06	6.19	25.00	75.00
MZ25	2.13	0.53	1.59	25.00	75.00
MZ29	8.00	3.50	4 50	43.75	56.25
MZ32	5.50	1.38	4.13	25 00	75.00
MZ37	3 50	0.88	2.63	25.00	75.00
MZ38	7.38	1.84	5.53	25.00	75.00
MZ42	11.70	2.93	8.78	25 00	75.00
MZ44	8.60	2.15	6.45	25.00	75.00
MZ47	13.25	3.31	9.94	25.00	75 00

Table 4.18 Average fruit set, nut matured and fruit dropped per panicle and their percentage (1999-2000) (continued)

b) Group of five trees per strain (Continued)

Strains	Average fruit set	Nut matured	Fruit dropped	% Fruit matured	% Fruit dropped
MZ48	6.63	1.66	4.97	25.00	75.00
MZ50	1.63	0.41	1.22	25.00	75.00
MZ51	6.00	1.50	4.50	25.00	75.00
MZ54	8.15	2.04	6.11	25.00	75.00
MZ55	5.75	1.44	4.31	25.00	75.00
MZ57	6.94	1.73	5.20	25.00	75.00
MZ61	8.10	2.03	6.08	25.00	75.00
MZ64	6.50	1.63	4.88	25.00	75.00
MZ65	9.50	2.38	7.13	25.00	75.00
MZ69	3.38	0.84	2.53	25.00	75.00
MZ71	1.50	0.38	1.13	25.00	75.00
MZ73	3.88	0.97	2.91	25.00	75.00
MZ74	7.40	1.85	5.55	25.00	75.00
MZ76	5.38	1.34	4.03	25.00	75.00
MZ81	7.88	1.97	5.91	25.00	75.00
MZ82	3.50	0.88	2.63	25.00	75.00
NZ1	3.25	1.38	1.88	42.31	57.69
NZ2	10.13	6.63	3.50	65.43	34.57
NZ8	7.50	1.75	5.75	23.33	76.67
NZ13	1.75	1.00	0.75	57.14	42.86
NZ14	10.75	3.75	7.00	34.88	65.12
NZ15	8.38	3.50	4.88	41.79	58.21
NZ22	2.13	1.00	1.13	47.06	52.94
NZ23	6.10	1.53	4.58	25.00	75.00
NZ25	5.00	1.25	3.75	25.00	75.00
NZ28	8.25	1.75	6.50	21.21	78.79
NZ32	4.88	0.88	4.00	17.95	82.05
NZ33	4.50	1.69	2.81	37.50	62.50
NZ34	5.75	3.10	2.65	53.91	46.09
NZ35	1.25	0.25	1.00	20.00	80.00
NZ36	4.25	1.25	3.00	29.41	70.59
NZ41	1.50	0.63	0.88	41.67	58.33
NZ43	3.55	2.44	1.11	68.66	31.34
NZ45	5.75	2.50	3.25	43.48	56.52
G17	4.38	0.38	4.00	8.57	91.43
G24	4.25	2.63	1.63	61.76	38.24
G53	0.00	0.00	0.00	0.00	0.00
GJ1	3.00	0.00	3.00	0.00	100.00
GL15	1.63	0.00	1.63	0.00	100.00
MD6	8.25	0.25	8.00	3.03	96.97
MD18	0.00	0.00	0.00	0.00	0.00
MM16	0.00	0.00	0.00	0.00	0.00

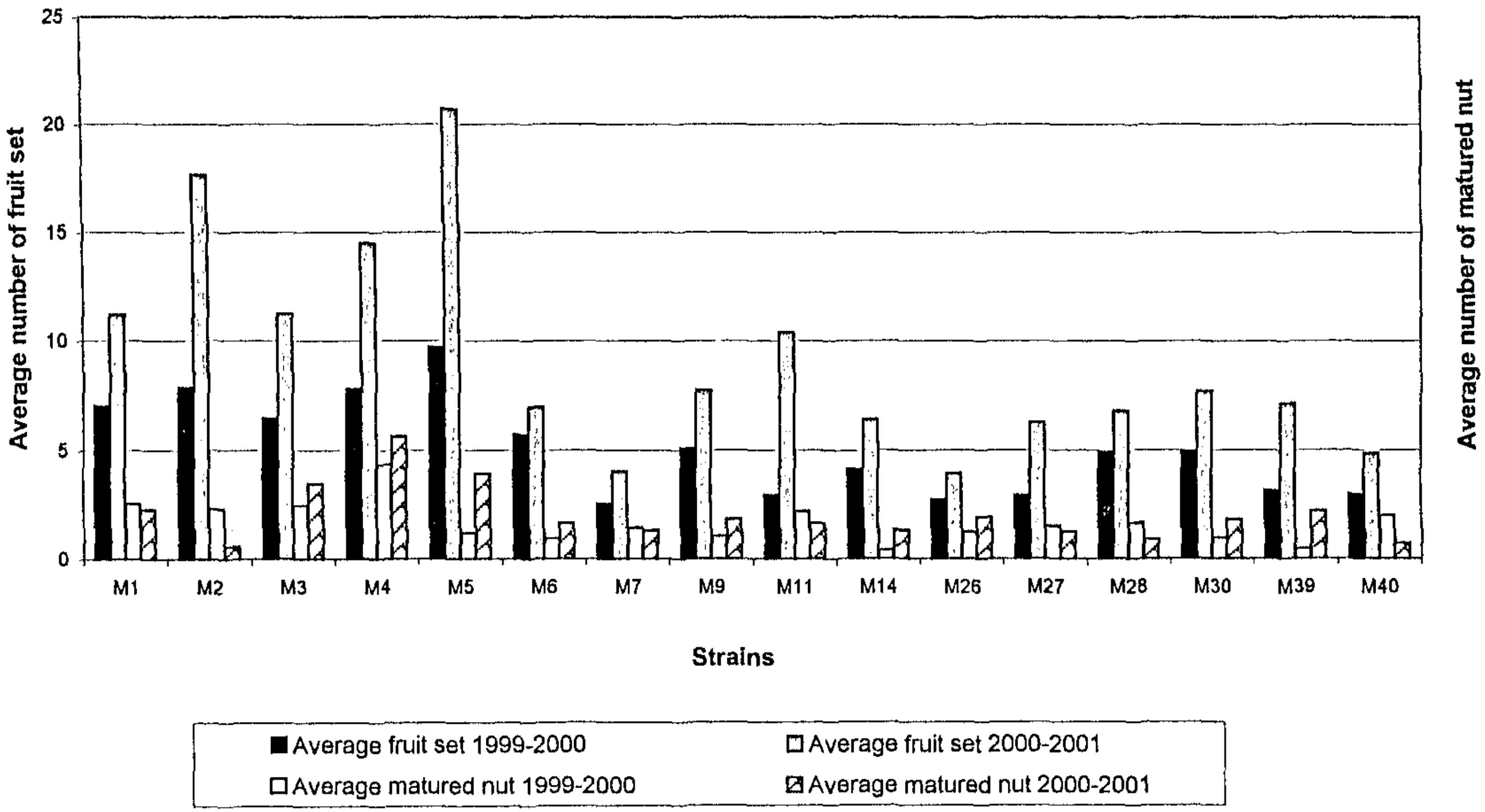


Figure 4.15a Average fruit set and matured nuts per panicle (Strains based on average of ten trees)

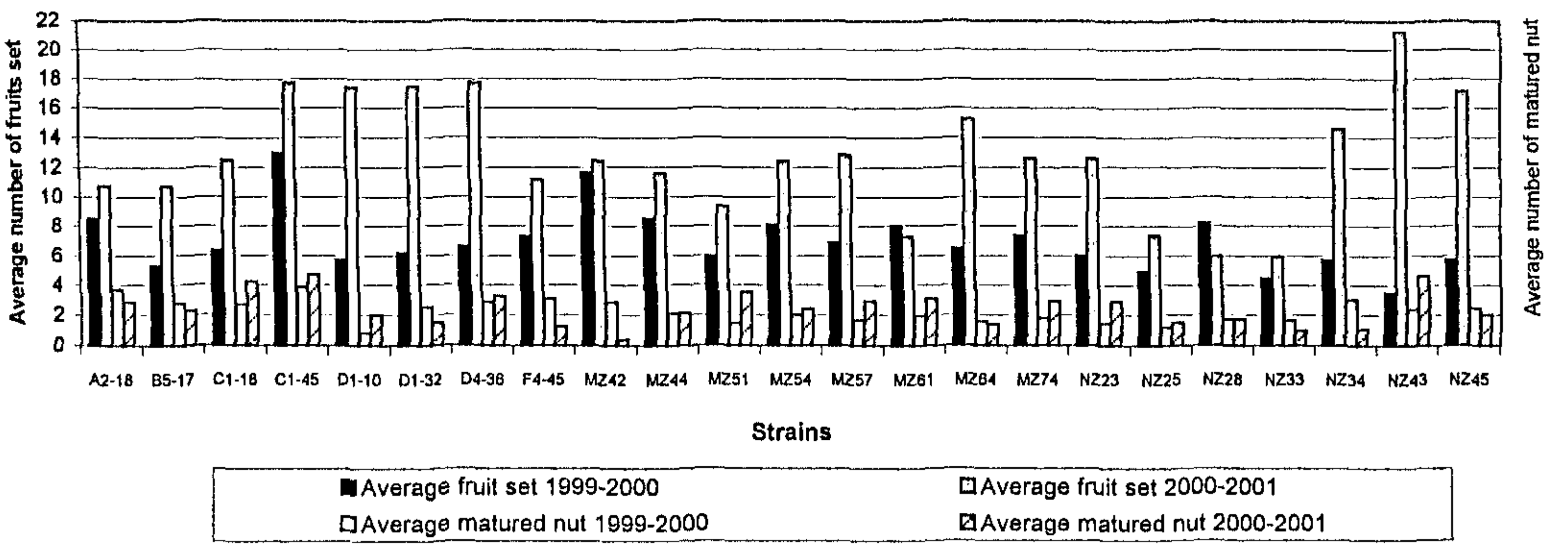


Figure 4.15b Average fruit set and matured nuts per panicle (Strains based on average of five trees)

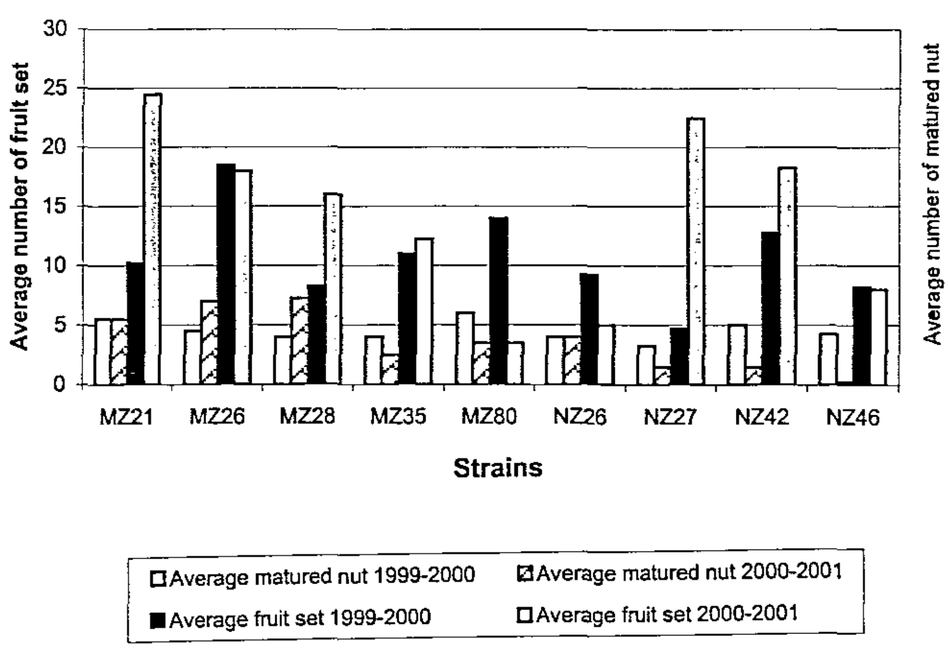


Figure 4.15c Average fruit set and matured nuts per panicle (Strains based on average of one tree)

4.2.1.5 Average yield per tree

The average yield of nuts in kilogram per tree per strain was calculated from the measured weight of matured nuts produced per panicle and the number of panicles produced per tree (see section 4.1.3.1). Table 4.19 contains the results.

The average yield for each strain varied from 0.07 to 14.82 kg. High yielding strains included NZ9, MZ80, MZ21, MZ26 and MZ35 for which 14.82, 12.14, 10.29, 9.51 and 9.01 kg of nuts were recorded from a single tree for each strain, respectively. The lowest yield recorded was 0.07 kg, found in MZ6 and D2-40. The yield during 1999-2000 was estimated from the matured nuts of the four panicles per tree studied. Because of nil nut retention, no yield was calculated for the following strains: B1-28, B2-32, D5-46, M12, MZ50, MZ58, MZ101, G53, GJ11, GJ1, GL15, MD18 and MM16.

4.2.1.6 Average nut weight

The average weight of nuts indicates the nut size (Table 4.19). The average weight of nuts ranged between 2.87 and 10.71 g. The highest nut weight of 10.71 g was found in MZ71, followed by MZ75 (9.73 g), G17 (9.70 g) and MZ25 (9.43 g). The lowest nut weight of 2.87 g was recorded for NZ55. In the majority of the strains, the average nut weight was about 5 g.

The 1999-2000 growing season was characterised by an abnormally heavy rainfall. These conditions could have contributed to the low retention of nuts.

Table 4.19 Average nut weight and yield per strain (1999-2000)

a) Group based on ten trees

Strains	Average weight *nut in g*	Average yield *in kg*
M1	5.91	0.72
M2	6.16	0.71
M3	6.03	0.58
M4	4.83	0.67
M5	6.31	1.25
M6	5.63	0.23
M7	5.33	0.16
M9	5.06	0 34

Strains	Average weight *nut in g*	Average yield *in kg*
M11	6.21	0.36
M14	4.90	0.29
M26	5.17	0.07
M27	5.57	0.29
M28	5.33	0.23
M30	5.49	0.26
M39	4 82	0.19
M40	5.93	0.14

c) Group based on one tree

Strains	Average *weight* nut in g	Average *yield* in kg
NZ7	8.40	0 63
NZ9	6.92	14.82
NZ11	5.47	0.88
NZ12	7.08	2.75
NZ18	5.10	0.57
NZ24	7.06	5.30
NZ26	4.45	5.36
NZ27	5.04	6.53
NZ29	4.54	3.97
NZ31	6.01	3.34
NZ42	4.33	1.70
NZ46	6.68	0.00
NZ52	7.06	2.75
NZ54	5.20	1.20

Strains	Average *weight* nut in g	Average *yield* in kg
NZ55	2 87	1.62
NZ65	5.28	1.84
MZ21	4.91	10.29
MZ26	4.91	9 51
MZ28	4.84	5 02
MZ35	4.93	9 01
MZ80	4 98	12.14
MZ46	5 99	3.79
MZ58	5.21	0.61
MZ75	9.73	2.24
MZ80	4.98	12.14
MZ100	4.98	7.31
MZ101	5.02	0.40

Table 4.19 Average nut weight and yield per strain (1999-2000) (continued)

b) Group based on five tree

Strains	Average weight nut in g	Average yield in kg
A1-18	7.86	3.11
A1-32	3.98	0.18
A2-18	5.08	1.56
A3-42	9.43	0.18
A4-17	6.86	0.71
B1-17	5.74	0.36
B1-20	6.21	2.31
B1-28	4.53	0.41
B2-32	4.82	0.44
B5-17	5.66	1.17
C 1-18	6.89	1.30
C 1-45	5.70	1.44
C3-19	4.96	0.79
C3-46	6.29	1.18
C5-44	5.77	0.39
C 5-5	4.45	0.26
D 1-10	7.30	0.43
D 1-25	7.13	0.99
D 1-32	7.06	1.28
D 1-42	5.66	1.79
D 2-15	4.37	0.65
D 2-40	4.80	0.07
D 2-46	6.21	0.94
D 4-36	5.91	1.48
D 5-35	5.15	0.45
D 5-46	5.04	0.50
E 1-6	6.84	4.52
E 3-41	5.45	1.51
F 1-29	4.15	0.40
F 4-1	8.32	2.63
F 4-45	5.70	1.37
MZ7	8.22	0.49
MZ12	5.24	0.42
MZ17	5.54	5.35
MZ22	5.78	2.31
MZ24	6.25	2.33
MZ25	9.43	0.75
MZ29	5.87	4.12
MZ32	4.85	0.45
MZ37	7.95	1.13
MZ38	5.63	3.36
MZ42	7.11	1.07
MZ44	6.04	1.23
MZ47	7.94	6.34

Strains	Average weight nut in g	Average yield in kg
MZ48	7.01	4.24
MZ50	5.14	0.46
MZ51	6.69	1.04
MZ54	7.64	1.50
MZ55	5.99	0.31
MZ57	8.30	0.72
MZ59	4.69	1.19
MZ61	7.73	0.62
MZ64	6.36	0.89
MZ65	6.66	4.07
MZ69	7.45	2.10
MZ71	10.71	0.28
MZ73	5.52	1.34
MZ74	7.07	1.17
MZ76	5.33	3.40
MZ81	4.97	1.81
MZ82	7.99	2.61
NZ1	4.16	0.96
NZ2	5.96	6.33
NZ8	3.71	1.25
NZ13	5.03	0.91
NZ14	5.55	3.50
NZ15	5.39	3.61
NZ22	7.08	1.46
NZ23	5.76	0.94
NZ25	5.50	6.12
NZ28	8.90	8.71
NZ32	8.72	1.28
NZ33	5.55	0.65
NZ34	5.85	1.69
NZ35	6.84	0.22
NZ36	7.45	2.61
NZ41	5.47	0.66
NZ43	5.90	0.90
NZ45	6.46	0.66
G17	9.70	0.80
G24	4.99	2.60
G53	5.34	0.44
GJ1	5.24	0.50
GL15	4.68	0.52
MD6	5.82	0.03
MD18	4.33	0.31
MM16	5.07	0.43

4.2.2 2000-2001 growing season

Newly selected strains for the 2000-2001 season are indicated in Table 3.1. Based on the previous results, 48 strains were selected for study. These include the high, intermediate and low yielding strains discussed in section 3.2.

Low and intermediate yielding strains were included because the abnormally wet weather conditions of 1999-2000 in the region could have had a detrimental effect on otherwise high yielding strains. Furthermore, for cross breeding programs, medium and low yielding strains could have adapted genetically to resist disease and to overcome detrimental environmental conditions.

In addition to the yield characteristics considered in section 4.2.1, the number of nuts per kilogram of nut in shell (NIS), the mass of kernel, as well as the shelling percentage of the nuts were included during 2000-2001 season.

4.2.2.1 Average number of hermaphrodite flowers per panicle

See section 4.1.3.2 c.

4.2.2.2 Average number of fruit set per panicle

The average number of fruit that set per panicle for the strains varied from 3.55 to 24.5 (Table 4.20 and Figure 4.15). The highest was found for MZ21 (21.5), followed by NZ7 (22.5) and NZ34 (21.3). The lowest was found for MZ80 (3.25), M26 (4) and M7 (4). The strains represented by one tree (MZ21, MZ26, MZ28, MZ35, MZ80, NZ26, NZ27 and NZ42) had high fruit set compared to the average for strains represented by ten or five trees.

4.2.2.3 Average number of nuts matured and percentage of fruit dropped per panicle

The average number of nuts matured per panicle is shown in Table 4.20 and Figure 4.15. It varied from 0.25 (NZ45) to 5.75 (M4). Three strains, MZ28, MZ26 and MZ21 seemed to have a good retention of nut with an average number of fruit set of 7.25, 7 and 5.5 respectively. Strains M2, M39, MZ42 and NZ45 had an average number of fruit set of less than one.

The percentage of fruit drop varied from 0% to 96.88%. MZ80 had no fruit drop (0): all the fruit that set reached maturity. The percentage of fruit drop was very high for most of the strains: more than 50%, except for MZ80 (0%) and NZ26 (20%). Seven strains had more than 90% fruit drop with the maximum for NZ45 (96,88%).

4.2.2.4 Average yield per tree

The average yield in kilogram per tree is shown in Tables 4.21, 4.22 and Figure 4.16. It varied from less than 1 to 4.4 kg. The minimum yield was found in NZ45 (0.20), followed by NZ42 (0.35) and M30 (0.39 kg). MZ21, MZ26 and NZ7 had the maximum yield of 4.40, 4.30 and 4.22 kg respectively but these results were based on one tree per strain. MZ61, with an average of 4.13 kg per tree, seems to be the most promising strain, followed by NZ34 (3.96), M3 (3.78), M5 (3.42) and C1-45 (3.24 kg).

In comparison to the previous season (1999-2000), these five strains producing more than 3 kg nuts per tree had an average percentage increase of 66, 13, 65, 175 and 125% respectively. M3, M5 and NZ34 were amongst the high yielding strains during the 1999-2000 season, but MZ61 and C1-45 were amongst the low yielding strains. A number of strains studied during both seasons (M9, M14, M30, M6, M39, M11, M27 and M26) had an increase in yield of even greater than 600%, compared to the 1999-2000 season.

The average yield in kilogram per tree for D1-32, M2, MZ45, NZ28 and NZ25 decreased from 1999-2000 to 2000-2001. A possible explanation for this decrease could have been the different climatic conditions such as the drier 2000-2001 season, or the strong winds experienced towards the end of 2000, or perhaps the higher incidence of pest and/or disease attack. Also, according to the results in Tables 4.12 and 4.14, the above strains had a high male to hermaphrodite flower ratio and they reached their peak or close to peak period earlier in the flowering season for 2000-2001.

4.2.2.5 Average nut weight

The average weight of a single nut is shown in Table 4.21 and Figures 4.16a-c. It varied between 3.54 and about 8.50 g. The maximum weight was found in MZ61 (8.52 g), which was the top yielding strain. The minimum nut weight was recorded in MZ28 (3.54 g), followed by NZ26 (3.57 g) and MZ26 (3.81 g). The majority of the strains had an average nut weight of 5.5 g.

4.2.2.6 Average number of nuts per kilogram

The average number of nuts per kilogram varied from 114 (MZ61) to 250 (NZ26) with a mean of 182. MZ61 had the highest yield (4.13 kg), the biggest nut size (8.52 g) but low nut retention.

4.2.2.7 Kernel weight and shelling percentage

For each strain studied during 2000-2001, the kernel weight is shown in Table 4.21. It varied from 0.58 (NZ26) to 2.10 g (MZ61). The shelling percentage ranged from 67% (MZ21, NZ34 and D1-32) to 87% (NZ33) with an average of 77%. According to the results, large nuts did not necessarily have heavy kernels, except for MZ61 with nut weight of 8.52 g.

The results in Table 4.23 show that after 6 hours drying at 90°C, the weight of kernels of the studied strains varied from 9.96 g (NZ33) to 29.86 g (M27). The kernel lost, on average, approximately 10-20 % moisture. The majority of the strains had an average kernel weight of 20,72 g but six had more than 25 g. These were M1 (25.8), MZ80 (25.81), MZ51 (26.5), D1-32 (26.98), NZ43 (27.2) and M27 (29.86g).

For the processing industry, which pays for the nuts by the total weight, the kernel percentage is the most important characteristic of the nut, as the kernel is the most valuable part of the cashew.

Table 4.20 Average fruit set, nut matured and fruit dropped per panicle (2000 - 2001)

a) Group based on ten trees per strain

Strains	Fruit set per panicle	Nut matured per panicle	Fruit dropped	% Fruit dropped
M1	11.19	2.30	8.89	79.45
M2	17.70	0.63	17.08	96.47
M3	11.25	3.48	7.78	69.11
M4	14.55	5.65	8.90	61.17
M5	20.75	3.50	16.80	80.96
M6	7.00	1.65	5.35	76.43
M7	4.05	1.35	2.70	66.67
M9	7.78	1.85	5.93	76.21
M11	10.40	1.65	8.75	84.13
M14	6.43	1.35	5.08	78.99
M26	3.95	1.93	2.03	51.27
M27	6.30	0.28	5.03	79.76
M28	6.83	0.93	5.90	86.45
M30	7.73	1.83	5.90	76.38
M39	7.15	2.20	4.95	69.23
M40	4.88	0.75	4.13	84.62

c) Group based on one tree per strain

Strains	Fruit set per panicle	Nut matured per panicle	Fruit dropped	% Fruit dropped
MZ21	24.50	5.50	19.00	77.55
MZ26	18.00	7.00	11.00	61.11
MZ28	16.00	7.25	8.75	54.69
MZ35	12.25	2.50	9.75	79.59
MZ80	3.50	3.50	0.00	0.00
NZ26	5.00	4.00	1.00	20.00
NZ27	22.50	1.50	21.00	93.33
NZ42	18.25	1.50	16.75	91.78

Table 4.20 Average fruit set, nut matured and fruit dropped per panicle (2000 - 2001) (continued)

b) Group based on five trees per strain

Strains	Fruit set per panicle	Nut matured per panicle	Fruit dropped	% Fruit dropped
A2-18	10.80	2.90	7.90	73.15
B5-17	10.75	2.30	8.45	78.60
C1-18	12.50	4.25	8.25	66.00
C1-45	17.75	4.75	13.00	73.24
D1-10	17.45	2.05	15.40	88.25
D1-32	17.55	1.55	16.00	91.17
D4-36	17.75	3.30	14.45	81.41
F4-45	11.25	1.30	9.95	88.44
MZ42	12.50	0.45	12.05	96.40
MZ44	11.65	2.15	9.50	81.55
MZ51	9.45	3.55	5.90	62.43
MZ54	12.45	2.45	10.00	80.32
MZ57	12.90	3.00	9.90	76.74
MZ61	7.35	3.15	4.20	57.14
MZ64	15.25	1.45	13.80	90.49
MZ74	12.65	2.98	9.70	76.68
NZ23	7.40	1.55	5.85	79.05
NZ25	6.00	1.75	4.25	70.83
NZ28	6.00	1.00	5.00	83.33
NZ33	14.65	1.10	13.55	92.49
NZ34	21.30	4.65	16.65	78.17
NZ43	17.15	2.05	15.10	88.05
NZ45	8.00	0.25	7.75	96.88

Table 4.21 Average nut weight and yield per strains (2000-2001)

a) Group based on ten trees per strain

Strains	Nut weight in grams	yield in kg/tree
M1	5.44	2.09
M2	5.31	0.57
M3	6.10	3.78
M4	4.86	2.56
M5	5.81	3.42
M6	5.56	1.58
M7	5.14	0.53
M9	5.58	2.09

Strains	Nut weight in grams	yield in kg/tree
M11	5.64	2.17
M14	5.68	1.92
M26	5.90	1.71
M27	4.10	1.19
M28	5.12	0.90
M30	4.91	1.51
M39	5 60	1.46
M40	4.42	0.39

b) Group based on five trees per strain

Strains	Nut weight in grams	yield in kg/tree
MZ42	4.41	1.61
MZ44	4 53	2.78
MZ51	4.39	1.38
MZ54	5.69	2.09
MZ57	5.38	2.00
MZ61	8.52	4.13
MZ64	5.70	1.79
MZ74	6 50	1.50
NZ23	6.55	1.14
NZ25	6.59	1.70
NZ28	6.28	2.20
NZ33	4.31	1.68

Strains	Nut weight in grams	yield in kg/tree
NZ34	4 80	3.96
NZ43	5.04	2.00
NZ45	7.28	0 20
A2-18	5.46	1.97
B5-17	5.01	2.05
C1-18	4.82	1.80
C1-45	5.69	3.24
D1-10	4 34	1.65
D1-32	6.03	0.61
D4-36	5.49	2.44
F4-45	5 83	2.12

c) Group based on one tree per strain

Strains	Nut weight in grams	yield in kg/tree
MZ21	5.40	4.40
MZ26	3.81	4.30
MZ28	3.54	3.39
MZ35	4.19	2.49
MZ80	3.99	0 83
NZ26	3.57	2.96
NZ27	7.29	4.22
NZ42	7.56	0.35

Table 4.22: Cashew strains studied during 2000-2001 ranked according to yield

Strains	Average number panicle/tree	Average number nut/1 kg	Weight single nut (g)	Weight kernel (g)	Shelling %	Average yield/tree (kg)
MZ61	416	114	8.52	2.10	75	4.13
NZ34	409	220	4.80	1.56	67	3.96
M3	419	161	6.10	1.76	71	3.78
M5	534	162	5.81	1.64	72	3.42
C1-45	419	178	5.69	1.62	72	3.24
MZ44	360	194	4.53	0.96	79	2.78
M4	501	172	4.86	1.46	70	2.56
D4-36	453	166	5.49	1.06	81	2.44
NZ28	559	152	6.28	1.63	74	2.20
M11	544	180	5.64	1.44	75	2.17
F4-45	410	162	5.83	1.75	70	2.12
MZ54	355	166	5.69	1.38	76	2.09
M9	514	183	5.58	1.26	77	2.09
M1	402	166	5.44	1.66	69	2.09
B5-17	369	192	5.01	1.05	79	2.05
MZ57	372	174	5.38	1.04	81	2.00
NZ43	393	190	5.04	1.47	71	2.00
A2-18	428	170	5.46	0.85	85	1.97
M14	450	167	5.68	1.24	78	1.92
C1-18	376	206	4.82	1.15	76	1.80
MZ64	243	166	5.70	1.48	74	1.79
M26	435	152	5.90	1.39	76	1.71
NZ25	495	160	6.59	1.17	82	1.70
NZ33	421	212	4.31	0.58	87	1.68
D1-10	389	180	4.34	1.07	75	1.65
MZ42	415	146	4.41	1.07	76	1.61
M6	400	173	5.56	1.44	74	1.58
M30	416	174	4.91	1.30	73	1.51
MZ74	349	168	6.50	1.92	70	1.50
M39	406	186	5.60	1.47	74	1.46
MZ51	281	186	4.39	1.30	68	1.38
M27	438	182	4.10	1.30	70	1.19
NZ23	267	126	6.55	1.97	77	1.14
M28	390	185	5.12	1.20	67	0.90
D1-32	320	172	6.03	1.98	73	0.61
M2	419	169	5.31	1.44	81	0.57
M7	401	189	5.14	0.99	76	0.53
M40	472	172	4.42	1.05	75	0.39
NZ45	442	190	7.28	1.82	75	0.20

Based on one tree per strain

MZ21	381	200	5.40	1.80	67	4.40
MZ26	430	240	3.81	1.09	71	4.30
NZ27	398	140	7.29	1.50	79	4.22
MZ28	260	130	3.54	0.86	76	3.39
NZ26	301	250	3.57	1.07	70	2.96
MZ35	457	220	4.19	1.27	70	2.49
MZ80	460	210	3.99	1.22	69	0.83
NZ42	492	120	7.56	1.94	74	0.35

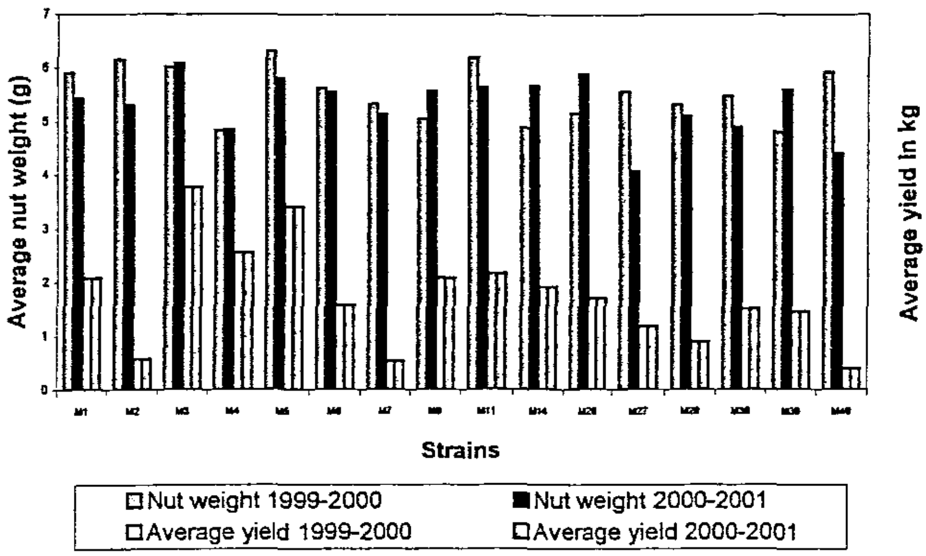


Figure 4.16a Average yield and nut weight (Strains based on average of ten trees)

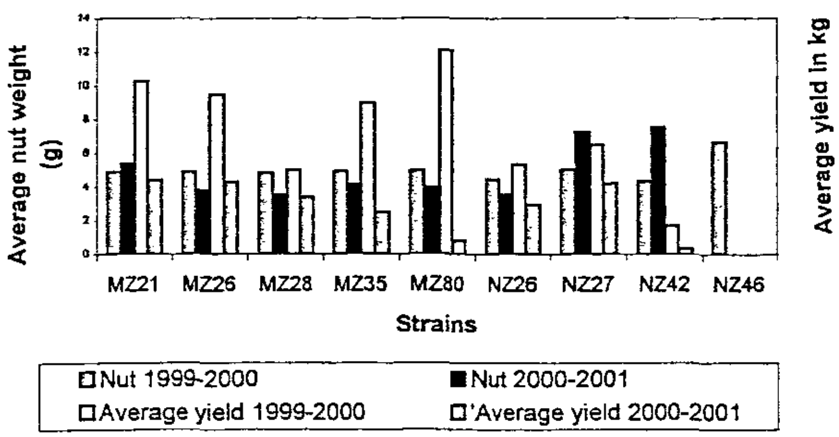


Figure 4.16c Average yield and nut weight (Strains based on average of one tree)

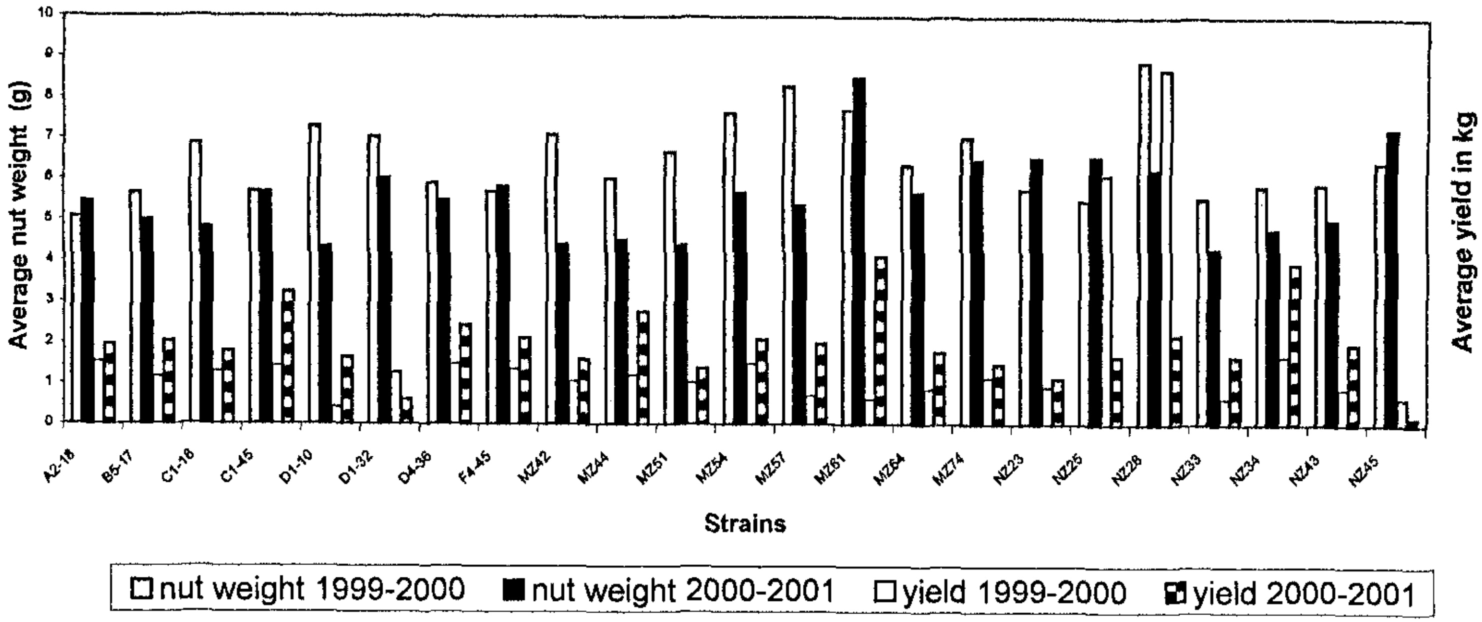


Figure 4.16b Average yield and nut weight (Strains based on average of five trees)

Table 4.23 Fresh weight of kernel from 100g nut in shell of the 2000-2001 strains and dried at 90°C for 6 hours

Strains	0 hour	1 hour	2 hour	3 hour	4 hour	5 hour	6 hour
M1	30.53	26.60	26.32	26.12	26.20	25.90	25.80
M2	27.20	25.30	24.70	24.50	24.30	24.10	23.30
M3	28.82	27.45	26.75	25.77	23.75	23.30	23.08
M4	30.10	23.55	23.10	22.84	22.90	22.60	22.50
M5	28.30	22.30	17.80	17.40	17.04	16.89	16.77
M6	25.88	22.97	22.15	20.50	20.40	19.24	19.06
M7	19.30	17.20	16.20	16.10	15.97	15.92	15.82
M9	22.67	21.75	21.37	21.12	20.99	20.97	20.95
M11	25.43	23.82	20.90	20.40	20.25	19.70	19.54
M14	21.83	20.59	20.90	19.62	19.76	19.20	19.04
M26	23.56	20.09	19.53	19.21	19.20	18.80	17.53
M27	31.64	31.37	31.26	30.27	30.1	29.99	29.86
M28	23.50	19.90	18.30	18.10	30.1	17.64	17.53
M30	26.58	24.55	21.23	20.80	20.64	20.20	20.06
M39	26.30	19.86	19.19	18.94	19.00	18.70	18.60
M40	23.73	21.90	21.30	20.52	20.30	20.19	20.02
A2-18	15.49	15.18	14.40	14.36	14.25	14.30	14.17
B5-17	20.89	19.95	18.85	18.60	18.28	18.20	18.12
C1-18	23.85	22.29	19.80	18.91	18.80	18.70	18.55
C1-45	28.48	22.27	20.64	20.08	20.00	19.80	19.50
D1-10	24.53	22.07	21.64	21.50	21.60	21.30	21.20
D1-32	32.79	29.60	28.26	27.37	27.18	27.08	26.98
D4-36	19.23	18.84	18.65	18.40	18.02	17.50	17.37
F4-45	30.06	26.28	25.58	25.32	25.00	24.70	24.50
MZ21	33.44	29.54	28.24	25.54	24.19	23.67	23.61
MZ26	28.61	23.20	22.00	21.08	20.40	20.36	20.31
MZ28	24.20	22.78	19.41	18.80	18.77	18.65	18.58
MZ35	30.23	26.20	24.70	24.10	22.70	22.40	22.43
MZ42	24.35	22.41	21.43	21.07	20.88	20.85	20.77
MZ44	21.11	20.17	19.84	19.20	19.07	18.80	18.66
MZ51	29.56	28.26	27.54	27.08	26.87	26.66	26.57
MZ54	24.32	19.27	18.47	18.17	18.90	18.70	18.60
MZ57	19.29	15.90	14.37	14.01	13.86	13.07	13.02
MZ61	24.59	22.28	21.45	21.20	21.08	20.06	20.47
MZ64	26.04	24.96	23.54	22.74	22.52	22.43	22.38
MZ74	29.57	24.90	24.10	23.78	23.70	23.40	23.40
MZ80	30.60	29.43	26.22	25.80	25.39	25.52	25.31
NZ23	30.01	26.29	25.70	25.43	25.40	25.10	25.00
NZ25	17.75	17.65	17.42	17.26	17.04	16.80	16.74
NZ26	30.01	24.30	23.25	22.52	22.39	22.24	22.04
NZ27	20.60	20.03	17.09	16.80	16.75	16.64	16.58
NZ28	26.01	24 62	24.00	23.17	23.33	22.00	21.76
NZ33	13.40	12.10	11.70	11.20	10.50	10.00	9 96
NZ34	32.62	30.08	12.84	12.30	12.05	11.90	11.57
NZ42	25.60	23.20	21.88	21.21	20.93	20.77	20.66
NZ43	29.06	28.36	28.94	28.15	28.04	27.50	27.20
NZ45	24.99	22.06	19.10	19.02	18 94	18.30	18.14

4.3 Multiple regression

A multiple regression analysis was performed with various variables linked to yield. The eight independent variables included: number of panicles per tree, number of male flowers per panicle, number of hermaphrodite flowers per panicle, ratio hermaphrodite to male flowers, number of fruit set per panicle, ratio of fruit set to hermaphrodite flowers, number of matured nuts per panicle and nut weight. The dependent variable was yield (Y). A summary of the analysis is shown in Table 4.24. It was found that 345 cases had enough data to be included in the analysis. The resulting model is:

$$\mathbf{Y = -8.65621 + 0.726532(X1) + 0.632648(X2)}$$

- Y = *yield in kg per tree*
- X1 = number of panicles per tree
- X2 = number of hermaphrodite flowers per panicle

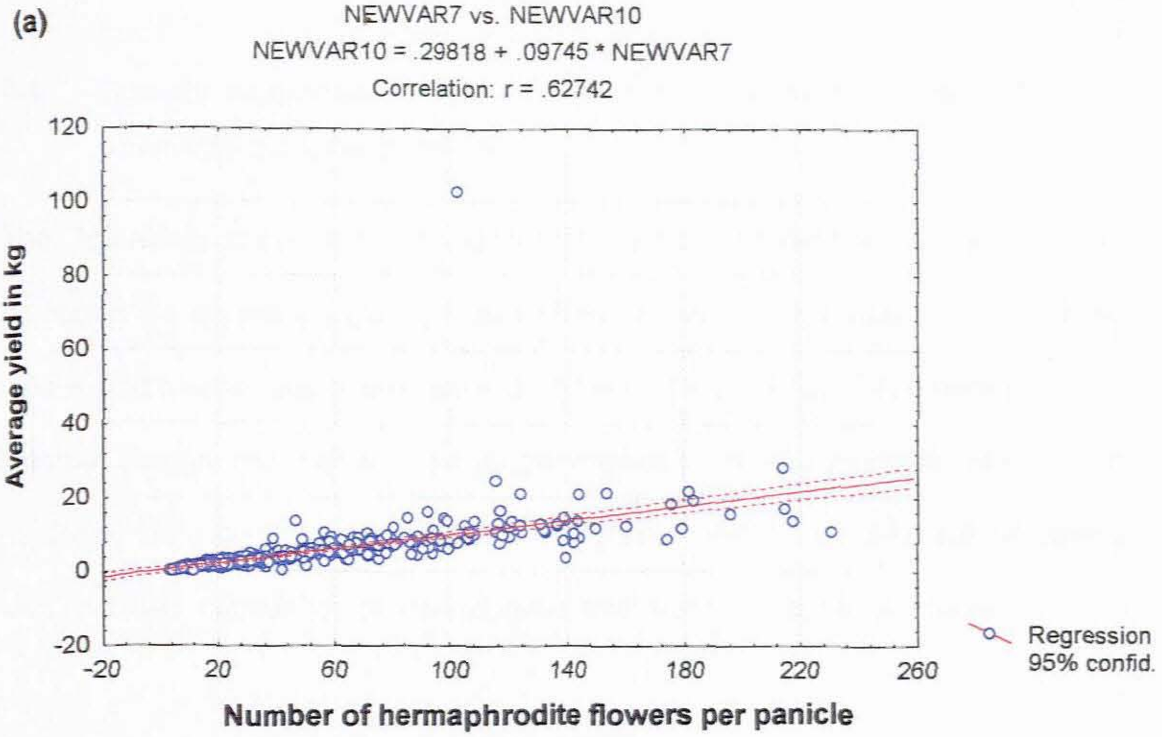
Table 5.24 Summary of regression analysis

STAT. MULTIPLE REGRESS.	Regression Summary for dependent Variable: Yield (NEWVAR10 R= .96179725 R^2= .92525395 Adjusted R^2 = .92439460 F (3,341) = 1403,0 p<0.0000 Std.Error of estimate: 1.9222					
N = 345	BETA	St. Err. OF BETA	B	St. Err. of B	t (341)	p – level
Intercpt			-8.65621	.276155	-31.3454	0.000000
NEWVAR9	.726532	.014827	.02196	.000448	49.0006	0.000000
NEWVAR7	.632648	.015129	.09946	.002375	41.8719	0.000000

NEWVAR9 = number of panicles per tree NEWVAR7 = number of hermaphrodite flowers per panicle

The best predictor variable for yield (NEWVAR10) is shown in the Figure 4.17 and was found to be the number of panicles per tree (NEWVAR9), followed by the number of hermaphrodite (perfect) flowers per panicle (NEWVAR7).

(a)



(b)

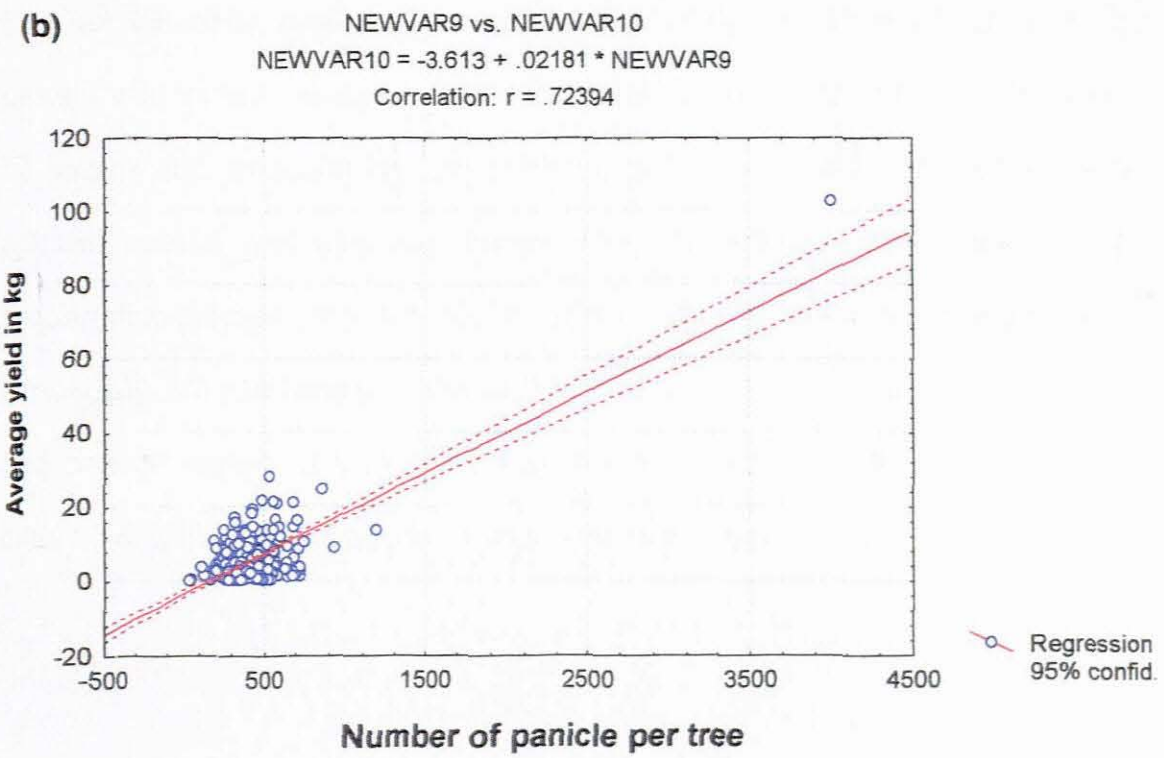


Figure 4.17 Best predictor variable for yield

(a) Number of hermaphrodite flowers per panicle

(b) Number of panicle per tree

4.4 Genetic relationships between the various strains according to their phenotypic characteristics

The following phenotypic characteristics were included in an analyse to establish the possible genetic relationships between the various strains: apple colour and shape, leaf shape, apex and base (Figure 4.3). Three apple colours (yellow, orange and red) and four apple shapes (conical, cylindrical, oblong and pyriform) were distinguished (Figure 4.13). Leaf shape was elliptical or oblong with rounded, notched or pointed apexes and attenuate or obtuse bases.

According to the results (Table 4.25), 20 strains were completely separated from all the other strains. Eight groups containing two strains each and 18 groups with three or more strains were identified. The largest group contained 17 strains and produced orange, pyriform apples and had oblong leaves with pointed apexes and attenuate bases. The five strains recommended for a propagation program, M3, M5, NZ34, C1-45 and MZ61 were not closely related genetically. M3 had yellow apples and NZ34 red apples. The other three strains had orange apples. The closest relation was found for C1-45 and M5, which differed only because of attenuate or obtuse leaf bases.

Table 4.25 Genetic relationship between various strains

Number of strains	Apple colour	Apple shape	Leaf shape	leaf apex	Leaf base	Strains
11	Yellow	Conical	elliptic	rounded	attenuate	MZ39
				notched	obtuse	NZ41
		Cylindrical	elliptic	rounded	attenuate	MZ73
				notched	attenuate	D4-36
		Oblong	elliptic	notched	attenuate	F4-45
		Pyriform	elliptic	pointed	obtuse	D1-26
				rounded	obtuse	M3, MZ74
				notched	attenuate	M14, M30, C5-5
22	Red	Conical	elliptic	rounded	attenuate	MZ38, NZ7
					obtuse	NZ52
		Cylindrical	elliptic	rounded	attenuate	M6, MZ25, A4-17
					obtuse	NZ18
		Oblong	elliptic	notched	obtuse	NZ34
		Pyriform	oblong	rounded	obtuse	NZ14
				notched	attenuate	B5-17
			elliptic	rounded	attenuate	D2-15, A2-18, NZ65
					obtuse	M28, MZ23
				notched	attenuate	M1, E1-6, MZ80, NZ26, NZ42, MZ50
					obtuse	NZ12

Table 4.25 Genetic relationship between various strains (continued)

Number of strains	Apple colour	Apple shape	Leaf shape	leaf apex	Leaf base	Strains
28	Orange	Conical	oblong	rounded	attenuate	MZ48
				notched	obtuse	MZ51
			elliptic	rounded	attenuate	NZ11, NZ22, NZ23, NZ24,B1-28
					obtuse	NZ25
				notched	attenuate	M2, MD6, NZ35
					obtuse	D2-40
		Cylindrical	oblong	rounded	attenuate	C1-45, D2-46, MZ22, NZ2
					obtuse	M5, C3-19
				notched	attenuate	B2-32, E3,41
			elliptic	pointed	attenuate	MZ29
				rounded	attenuate	D1-10, MZ24, MZ82
				notched	attenuate	F1-29, MZ35, MD8, NZ33

Table 4.25 Genetic relationship between various strains (continued)

Number of strains	Apple colour	Apple shape	Leaf shape	leaf apex	Leaf base	Strains
69	**Orange**	Oblong	oblong	rounded	obtuse	NZ46, A1-18, NZ13
				notched	attenuate	NZ8
			elliptic	rounded	attenuate	M4, MZ42, NZ29
					obtuse	M9, NZ27, MZ65, MZ71, MZ75
				notched	obtuse	M26
		Pyriform	oblong	rounded	attenuate	C1-18, MZ54, MZ37
					obtuse	D5-35, MZ17
				notched	attenuate	MZ46, NZ31
					obtuse	G17, MZ44, NZ1, NZ32
				pointed	attenuate	MZ12, MZ21
					obtuse	NZ45
			elliptic	rounded	attenuate	M27, GL15, G24, GJ1, MM16, D1-32, MZ32, MZ47, MZ69, MZ100, B1-20, MZ101, NZ9, NZ15, NZ43, F4-1, MZ7
					obtuse	A3-42, D1-42, D4-36, MZ28, MZ58, MZ61, MZ64, MZ76, NZ28, NZ55
				notched	attenuate	C5-44, MZ26, MZ55, NZ36, M7, M40, A1-32, C3-46,
					obtuse	M11, G53, B1-17, MZ57, MZ59, MZ81, NZ54

CHAPTER FIVE

5 DISCUSSION AND CONCLUSION

5.1 Discussion

During the 1999-2000 season, the majority of the trees were damaged by powdery mildew (*Oidium anarcardii*), possibly because of the abnormally heavy rainfall in the Maputaland region throughout the flowering period. During the 2000-2001 season, the trees were exposed to drier conditions with strong winds towards the end of 2000 and a pest and/or disease attack, viz., anthracnose (*Colletotrichum gloeosporioides*), powdery mildew and the tea mosquito (*Helopeltis antonii*). At the age of 3 to 3½ years, the cashew strains at Coastal Cashew produced economically but there were some early bearing trees.

The flowering pattern was uniform for most of the studied strains: a mix phase of male and hermaphrodite flowers followed by a male phase. This pattern was similar to that observed in some Indian, Tanzanian and Australian strains (Bigger, 1960; Northwood, 1966; Pavithran and Ravindra, 1974; Ghosh, 1988; Reddy *et al.*, 1988 and Heard *et al.*, 1990).

The peak flowering period of the majority of the studied strains was seen to be uniform, having one peak. Eight strains were found with two peaks during the 1999-2000 season compared to four during the 2000-2001 season. Only MZ51 had two flowering peaks during both seasons. This sequence of two flowering peaks was found across the world, viz. Australia, India, Senegal and Tanzania, by several authors (Bigger, 1960; Northwood, 1966; Reddy *et al.*, 1986; Wunnachit *et al.*, 1992 and Behrens, 1996).

The total number of flowers per panicle varied from one season to the next within and between strains. The difference within strains would be due to the difference in age of the trees and the difference between strains would be due to the type and source of plant materials and the climatic conditions.

In this study, it was found that the number of male and hermaphrodite flowers per panicle varied from 1999 -2000 to 2000 -2001. A high percentage of male flowers are desirable for high pollen production, which may contribute to increased fruit set. A high number of hermaphrodite flowers are required for high yield.

The ratio of hermaphrodite to male flowers was low during the two growing seasons for the majority of the studied strains. This low ratio can account for low yield in cashew under Coastal Cashews conditions.

In order to increase fruit set, strains should be selected that produce high numbers of hermaphrodite flowers. Observations made in West and East India (Rao, 1956; Murthy *et al.*, 1975; Nawale *et al.*, 1984 and Patnaik *et al.*, 1985) indicated that the number of fruit that set was also very low compared to the number of hermaphrodite flowers produced. The reason for the poor fruit set might be due to insufficient pollination and fertilization and other unknown factors (such as nutrition) that could be investigated during further studies.

The higher ratio of hermaphrodite to male flowers in some strains did not always go hand in hand with high fruit and nut retention. The number of nuts that matured per panicle varied considerably but the majority of the studied strains had very low nut retention. Heavy fruit drop before maturity occurred at different stages for the majority of the strains during the two seasons. The inefficiency of pollinating insects, the extreme temperatures, the coincidence of flowering with the rainy season and insect attack and disease, especially at the latest stage of fruit development, could all contribute to fruit drop.

For successful cashew production, the cultivation of high yielding strains is very important. Data based on strains with a single tree were not taken into consideration for the final recommendations from this study. Based on the 2000-2001 results, five of the forty-seven strains had high yields and could be considered for selection. The results of this study show increases in nut yield between seasons. It must be remembered that these trees are still young and developing. Yield usually increases up to the twentieth year. When selecting cashew strains, the economic aim should be remembered: if yield potential is important, nut characteristics should be considered, but if harvesting economy is important, morphological characteristics such as tree appearance should also be considered. Biotechnological development could contribute to the improvement of cashew strains for high yield or for resistance against pests and diseases. Trees should, however, be continuously studied for several years before they can be included in propagation programs.

Using morphological and phenotypic features to support the selection of high yielding cashew strains suitable for the environmental conditions of Coastal Cashews and Maputaland can thus be considered essential. A model to assist in the prediction of future yield is shown in Table 5.1.

Various authors (Northwood, 1966; Ohler, 1979; Directorate, 1985; Reddy *et al.*, 1985) stated that trees producing more than 3 kg nuts are considered as high yielding trees. Five high yielding strains, MZ61, NZ34, M3, M5 and C1-45 could be used by Coastal Cashews.

5.2 Conclusion

In conclusion, it was suggested that Coastal Cashews selects a smaller number of strains for their propagation program in order to optimize yield, number of hermaphrodite flowers per panicle, and number of panicles per tree. Furthermore, it was suggested that certain selected strains be included in the strain mix for the purpose of sufficient pollen production. It is therefore concluded that:

a) the best tree to facilitate harvesting should have a decumbent habit and dwarf size but if for high yield, the tree should have an ascending or intermediate habit and a medium to tall size,

b) the five best strains suggested for a high yield are: MZ61, NZ34, M3, M5 and C1-45,

c) the five best strains suggested for a high number of panicles per tree are: NZ28, NZ25, NZ34, MZ35 and D4-36,

d) *the five best strains suggested for a high number of hermaphrodite* flowers per panicle are: D1-10, F4-45, MZ61, C1-45 and NZ28,

e) the five best strains suggested for high pollen production are: NZ26, D4-36, MZ61, NZ45 and NZ33,

f) the five best strains suggested for a high nut weight are: MZ61, NZ42, NZ27, NZ45 and NZ33, and

g) the five best trees suggested for bigger apples are: F4-45, G17, F1-29, C3-19 and A1-16.

Table 5.1 Description of cashew strains selected
(Adapted from Kumar and Hedge, 1994)

Characteristics	**Selected high yielding strains**				
	MZ61	**NZ34**	**M3**	**M5**	**C1-45**
Age	4.5	4.5	4.5	4.5	4.5
Plant habit	ascending	decumbent	ascending	intermediate	ascending
Plant height (m)	2.24	2.59	2.91	2.28	3.14
Canopy diameter (m)	3.25	3.54	2.91	3.7	3.42
Trunk diameter (cm)	15	17.1	14.6	17.4	15.2
Leaf parameters					
shape	elliptic	elliptic	elliptic	oblong	oblong
apex	rounded	notched	rounded	rounded	rounded
base	obtuse	obtuse	obtuse	obtuse	attenuate
margin	wavy	smooth	wavy	smooth	smooth
Leaf length (cm)	14.7	15.1	15.2	14.7	14.7
Leaf width (cm)	8.9	8.9	7.9	9.5	8.6
Leaf surface area (cm^2)	81.06	74	101.5	113.5	59.5
Number of veins (pairs)	13	10	13	13	10
Yield parameters					
Peak flowering time	23/12-22/01	23/12-12/01	02/01-22/01	02/01-11/02	23/12-12/01 01/02-21/02
Average number of panicle per tree	416	409	419	534	419
Average number of male flowers per panicle	600.4	490.6	254.6	428.5	320.6
Average number of perfect flowers per panicle	404.8	204.4	272.6	269.2	333.2
Ratio perfect to male	0.67	0.42	1.07	0.63	1.04
Average number of fruit set per panicle	7.35	21.3	11.25	20.75	17.75
Ratio fruit set to perfect flowers	0.07	0.42	0.17	0.31	0.21
Average number of mature nuts per panicle	3.1	0.65	3.48	3.95	4.75
Average yield (kg) per tree per year	4.13	3.96	3.78	3.42	3.24
Nut weight (g)	8.52	4.8	6.1	5.81	5.69
Number of nuts per kilogram	114	220	161	162	178
Kernel weight (g)	2.1	1.56	1.76	1.64	1.62
Shelling percentage	75	67	71	72	72
Apple colour	orange	red	yellow	orange	orange
Apple shape	pyriform	oblong	pyriform	cylindrical	cylindrical
Average apple weight (g)	51	64	51	31	53

SUMMARY

Maputaland, where Coastal Cashews estate has been established, is probably the closest to a tropical climate in South Africa. A tropical climate is required for growth of cashew trees.

This study on the morphology and selection of high yielding cashew strains at Coastal Cashews was carried out on one hundred and thirty strains during the 1999-2000 season. Based on these results, forty-seven strains were selected for further investigation during 2000-2001.

The existing plant material was originally imported over a number of years from various sources such as Zambia and Brazil. Trees selected for this study were all 3-3½ years old. Morphological and yield characteristics were studied for the selected strains.

The morphological study revealed that the trees ranged in height between 1.5 to 3 m. The tree habit ranged from ascending to decumbent with a conical to an umbrella-shaped canopy. The leaves had oblong to elliptical shapes, pointed/rounded to retuse apex and attenuate to obtuse bases. The leaf margins varied from wavy to smooth, the leaf length ranged from 8 to 22 cm and the width from 5 to 17 cm with coriace texture. The leaves had 9 to 18 pairs of veins, which were visible on both sides. Petioles were up to 30 mm long, basifixed and glabrous.

Cashew apples, or "pseudo-fruit", had various shapes (conical, cylindrical, oblong and pyriform) and colours (red, yellow and orange). Apples were 32 to 70 mm long and weighed between 17 and 85 g. True nuts with different shapes and colours with an average weight of about 4.5 g grew at the base of the cashew apple.

The flowering season at Coastal Cashews was between November to March, with the peak flowering period during December and January. The majority of the strains followed a specific flowering pattern, during which a mixed phase occurred first (male and hermaphrodite flowers opened at the same time), followed by a male phase where only male flowers opened.

Most of the studied strains had very low ratios of hermaphrodite to male flowers during both seasons. Fruit set during both seasons was low in comparison to the number of hermaphrodite flowers. Nut retention was generally low due to high nut drop. Fruit drop occurred at different stages of fruit development.

The yield studies revealed that the average yield between strains varied tremendously. Strains represented by only one tree need to be studied further before definite conclusions can be drawn. Most of the strains increased yield from 1999-2000 to 2001, although a few strains did show a decrease. A possible explanation of this decrease could be the different climatic conditions and perhaps the high incidence of pest and/or disease attacks. The majority of *the strains had a medium nut size with an average weight between 4.5 and 5.5* grams.

For future study, five strains were suggested for a propagation program to establish the South African cashew industry. Furthermore, it has been suggested that the strain mix should also include strains having high male flower production to ensure efficient pollination.

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APPENDIX I NUTRIENTS' VALUE OF CASHEW NUT

NUTRIENTS IN 100 g OF TREE NUTS[*]								
NUTRIENT	Units	Almonds	Cashews[ɪ]	Hazelnuts	Macadamias	Pecans	Pistachios	Walnuts
CALORIES	kcal	578	574	628	716	691	567	654
PROTEIN	g*	21	15	15	8	9	21	15
TOTAL FAT	g	51	46	61	76	72	46	65
CARBOHYDRATE	g	20	33	17	13	14	27	14
FIBER	g	12	3	10	8	10	10	7
SUGARS	g	5	NA	4	4	4	8	3
CALCIUM	mg**	248	45	114	70	70	108	104
IRON	mg	4	6	5	3	3	4	3
MAGNESIUM	mg	275	260	163	118	121	120	158
PHOSPHORUS	mg	474	490	290	198	277	485	346
POTASSIUM	mg	728	565	680	363	410	1033	441
SODIUM	mg	1	16	0	5	0	1	2
ZINC	mg	3	6	2	1	5	2	3
COPPER	mg	1	2	2	1	1	1	2
MANGANESE	mg	3	1	6	3	4	1	3
SELENIUM	mcg***	8	12	4	4	6	8	5
VITAMIN C	mg	0	0	6	1	1	2	1
THIAMIN	mg	0.2	0.2	0.6	0.7	0.7	0.8	0.3
RIBOFLAVIN	mg	0.8	0.2	0.1	0.1	0.1	0.1	0.1
NIACIN	mg	4	1	2	2	1	1	2
PANTOTHENIC ACID	mg	0	1	1	1	1	1	1
VITAMIN B6	mg	0.1	0.3	0.6	0.4	0.2	1.7	0.5
FOLATE	mcg	29	69	113	10	22	50	98
VITAMIN B12	mcg	0	0	0	0	0	0	0
VITAMIN A	IU****	10	0	40	0	77	533	41
VITAMIN A	mcg RE*****	1	0	4	0	8	64	4
VITAMIN E	mg ATE	26	1	15	1	4	4	3
CHOLESTEROL	mg	0	0	0	0	0	0	0
SATURATED FAT	g	4	9	4	12	6	4	6
MONOUNSATURATED FAT	g	32	27	46	59	41	25	9
POLYUNSATURATED FAT	g	12	8	8	1	22	14	47
LINOLEIC ACID (18:2)	g	12	8	8	1	21	14	38
LINOLENIC ACID (18:3)	g	0	0	0	0	1	0	9
PHYTOSTEROLS	mg	120	158	96	114	102	214	72
AMINO ACIDS								
TRYPTOPHAN	g	0.19	0.24	0.19	0.07	0.09	0.29	0.17
THREONINE	g	0.68	0.59	0.50	0.36	0.31	0.71	0.60
ISOLEUCINE	g	0.69	0.73	0.55	0.31	0.34	0.94	0.63
LEUCINE	g	1.47	1.28	1.06	0.59	0.60	1.63	1.17
LYSINE	g	0.60	0.82	0.42	0.02	0.29	1.21	0.42
METHIONINE	g	0.19	0.27	0.22	0.02	0.18	0.35	0.24
CYSTINE	g	0.28	0.28	0.28	0.00	0.15	0.38	0.21
PHENYLALANINE	g	1.15	0.79	0.66	0.65	0.43	1.11	0.71
TYROSINE	g	0.53	0.49	0.36	0.50	0.22	0.44	0.41
VALINE	g	0.80	1.04	0.70	0.36	0.41	1.30	0.85
ARGININE	g	2.47	1.74	2.21	1.38	1.18	2.13	2.28
HISTIDINE	g	0.59	0.40	0.43	0.19	0.26	0.53	0.39
ALANINE	g	1.00	0.70	0.73	0.38	0.40	0.97	0.70
ASPARTIC ACID	g	2.73	1.50	1.68	1.08	0.93	1.90	1.83
GLUTAMIC ACID	g	5.17	3.62	3.71	2.23	1.83	4.00	2.82
GLYCINE	g	1.47	0.80	0.72	0.45	0.45	1.00	0 82
PROLINE	g	0.97	0 69	0.56	0.46	0.36	0.85	0.71
SERINE	g	1.00	0.85	0.74	0.41	0.47	1.28	0.93

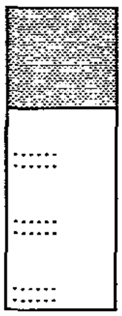
*g = grams **mg = milligrams ***mcg = micrograms ****IU = International Units *****RE = Retinol Equivalent

[*] = All tree nuts are unsalted

[ɪ] = Cashew data from the USDA Nutrient Database for Standard References, Release 12 (Marck 1998).

All other data from the USDA Nutrient Database for STandard Reference, Release 13 (Fall 1999).

APPENDIX II SOIL PROFILES AND PROPERTIES OF STUDY SITES



Thickness range (cm)	Diagnostic horizons	Description
10 - 30	Orthic A	Black, fine to medium sand with low organic matter
> 200	Regic sand	Grey, greenish gre white, medium to fine grained sand

	FERNWOOD FORM
SOIL PROPERTY	FERNWOOD SERIES
CLAY CONTENT (%) Topsoil Subsoil	 < 6 < 6
ORGANIC CARBON (%) Topsoil	 < 2
APPROX. PLANT AVAILABLE WATER ($mm.m^{-1}$) Topsoil Subsoil	 60 30
APPROX. FIELD WATER CAPACITY ($mm.m^{-1}$) Topsoil Subsoil	 100 70
EROSION HAZARD Water Wind	 Low / Moderate Very high
INFILTRATION RATE (cm/hr)	32 - 71
EXPANSION POTENTIAL	none
SOIL STABILITY	Low
GENERAL FERTILITY	Very low
pH CLASS	Strongly acid
POSSIBLE MICRONUTRIENT DEFICIENCY	High

APPENDIX III WEATHER SUMMARY OF COASTAL CASHEWS (Jan. 1996 - Sept. 1999)

From	01-Jan-96											
TOTAL	30-Sep-99											
DATE	MAX AIR Temp (^{0}C)	MIN AIR TEMP (^{0}C)	AVE AIR TEMP (^{0}C)	AVE WET BULB TEMP (^{0}C)	MAX RH (%)	MIN RH (%)	TOTAL RAIN (mm)	EVAP (mm)	SOLAR RAD. (MJ/m/d)	AVE WIND SPEED (km/hr)	MAX WIND SPEED (km/hr)	WIND DIRECTION
Minimum	14	6.6	13	12	87	32	0	0	1	4	6	NNE
Average	29	17	22	20	97	72	2	5	7	12	21	SE
Maximum	40 6	26	29	29	100	97	185	18	14	36	15	WSW
Total							2530	6325				
Days	1245						742	1854				
Hours	16											
below 7^0C												
January	30	22	25	23	96%	75%	4	5	9	13	21	ENE
February	30	21	25	23	97%	75%	5	5	9	11	19	ENE
March	30	20	24	22	96%	75%	2	6	8	11	21	ENE
April	28	17	22	20	98%	74%	2	6	7	10	18	ESE
May	27	15	20	18	96%	69%	1	4	6	10	20	ESE
June	26	11	18	16	98%	66%	1	4	6	11	19	E
July	24	12	17	15	98%	71%	1	4	6	12	21	E
August	28	14	20	17	67%	45%	1	5	7	13	24	E
September	28	16	21	18	98%	70%	1	6	7	14	24	E
October	28	17	22	19	96%	73%	2	6	7	14	24	E
November	30	19	24	21	97%	73%	3	6	8	14	13	E
December	30	20	25	22	96%	73%	2	4	9	13	22	E