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ORIGIN, DOMESTICATION, TAXONOMY, BOTANICAL DESCRIPTION, GENETICS AND CYTOGENETICS, GENETC DIVERSITY AND BREEDING OF CASHEW (*Anacardium occidentale* L.)

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ABSTRACT

Cashew belongs to the family Anacardiaceae, the genus *Anacardium* and species *A. occidentale*. Cashew is considered native of tropical America, not-withstanding the uncertainty in defining its natural distribu-tion, due to its long association with man. It was suggested that it originated in the restinga, meaning the low vegetation found in the sandy soil along the coast of Eastern and Northeastern Brazil. Anacardiaceae is a moderately large family consisting of Ca 74 genera and 600 species. It is subdivided into five tribes, namely Anacardieae, Spondiadeae, Semecarpeae, Rhoeae, and Dobineae. The tribe Anacardieae consists of 8 genera, namely, *Androtium, Buchanania, Bouea, Gluta, Swintonia, Mangifera, Fegimanra* and *Anacardium.* Within Central and South America as many as 20 species of *Anacardium* are known to exist. *Anacardium* L. is a small genus of trees, shrubs and sub-shrubs indigenous to the tropics. Some authors report 10 species and others until 20 species. It is native to Latin America, having a primary center of diversity in Amazon and a secondary center in the Planalto of Brazil. Of all, only cashew (*A. occidentale*) is of economic importance because of its edible apple and nutritious kernel. The cashew tree (*Anacardium occidentale* L.) is indigenous to Brazil and is an evergreen nut-bearing tropical plant that grows in latitude 15° north and south of the equator. There is a fact that not everyone knows about cashew fruit, this is a dry, non-self-opening fruit, kidney-shaped, about 2 to 3 cm long, hard outer shell, sunken face. The tree produces a long, fleshy stalk, called a cashew apple, which resembles a small pear. The color may be red, yellow or mixture of colors. The mature cashew apple can be eaten fresh as well as cooked. At the end of this stalk grows the kidney-shaped cashew nut that many know and love. Because of that, we often assume that the bulging stem is the fruit, and the "cashew nut" is the seed. Cashew is a source of food, income, industrial raw materials and foreign exchange for many countries of Africa, Asia and Latin America. Morphologically, the architecture of cashew tree makes it a foremost tree crop for reclaiming land area to enhanced productivity, through the prevention of desertification and soil erosion. The drought resistant, evergreen cashew tree is economically grown for its nut, apple and wood. Products derived from the nuts include the world's highly delighted roasted kernel snacks, kernel oil, cashew nut shell liquid, and from the apple: juice, jam and alcohol among others. Cashew wood is also used for furniture and fishing boats. Of all, cashew nut is the most economic part of the cashew tree providing foreign exchange earnings for producer countries. Cultivation and processing activities in cashew provides employment and income generation for women and smallholder farmers. Women are particularly involved in the cashew sub-sector more than in any other cash crop. So far 61 varieties in India have been released for cultivation as a result of evaluation of germplasm collection and hybridization and selection. These varieties have been released from different research centers of SAUs and DCR (formerly NRCC). Among them 34 are selections and 27 are hybrids. Soft wood grafting technique has been found to be the best method of propagation and it is recommended for commercial multiplication of cashew varieties. In this review article Origin, Domestication, Taxonomy, Botanical Description, Genetics and Cytogenetics, Genetc Diversity, Breeding, Uses, Nutritional Value, Health Benefits of Cashew are discussed.

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INTRODUCTION

Cashew is widely cultivated throughout the tropics for its nuts and is a native of tropical American country: Brazil. It was one of the first fruit trees from the New World to be widely distributed throughout the tropics by the early Portuguese and Spanish adventurers (Purseglove, 1988). At the time of the first Portuguese colonization, the name used by local populations (Tupi Natives of Brazil) for the cashew was "acaju" (nut), which turned into "caju", in Portuguese spelling and "cashew" in English. Most of the names for cashew in Indian languages are also derived from the Portuguese name "caju"

(Johnson, 1973). The common Indian names for cashew are, kajubadam (Assamese), hijli badam, kaju (Bengali), hijlibadam, kaajuu, kaju, kajubadam (Hindi), geru, gerumara, godambi (Kannada), kashukavu, kasumav (kasumavu), parangi mavu, paringi maavu (Malayalam), kaju, kajugola (Marathi), Lanka badam, Lanka beej (Oriya), kaju (Punjabi), agnikrita, batada, bhallataka, guchhapuspha, hijli badam, kajutaka, parvati, venamrah, vrkkabijah, vrkkaphalah (Sanskrit), andima, andimankottai, kallārmā, kolamavu, kolamaavutam, matumancam (nut), mundhiri paruppu, mundiri, munthiri, muntirikkottai munthiriparuppu, saram, tirikai (nut), tirigai, virai-muntirikai (Tamil), grabijamu, (jidi chettu, jidi kaaya, Jidimamidi, Jeedimamidi, Jidi mamidi, munthamamidi (Telugu) and kaajuu (Urdu).

The Maconde tribe in Mozambique call it the Devil's nut. It was offered at wedding banquets as a token of fertility. The cashew has a long history as a useful plant but only in the twentieth century it has become an important tropical tree crop. Small-scale local exploitation of the cashew for its nuts and cashew apples appears to have been the pattern for more than 300 years in Asia and Africa. Cashew belongs to the family Anacardiaceae, the genus Anacardium and species A. occidentale. A. occidentale is considered native of tropical America, not-withstanding the uncertainty in defining its natural distribu-tion, due to its long association with man. Johnson (1973) suggested that it originated in the restinga, meaning the low vegetation found in the sandy soil along the coast of eastern and northeastern Brazil. Anacardiaceae is a moderately large family consisting of Ca 74 genera and 600 species. It is subdivided into five tribes, namely Anacardieae, Spondiadeae, Semecarpeae, Rhoeae, and Dobineae. The tribe Anacardieae consists of 8 genera, namely, Androtium, Buchanania, Bouea, Gluta, Swintonia, Mangifera, Fegimanra and Anacardium (Mitchell and Mori, 1987). Within Central and South America as many as 20 species of Anacardium are known to exist (Nair et al. 1979). Anacardium L. is a small genus of trees, shrubs and sub-shrubs indigenous to the tropics. Some authors report 10 species and others until 20 species. It is native to Latin America, having a primary center of diversity in Amazon and a secondary center in the Planalto of Brazil. Only one species is an incipient domesticate commonly known as cashew (CGIAR, 2015). Of all, only cashew is of economic importance because of its edible apple and nutritious kernel

The cashew tree (*Anacardium occidentale* L.) is indigenous to Brazil and is an evergreen nut-bearing tropical plant that grows in latitude 15° north and south of the equator. It is a multipurpose tree crop with great economic importance to third world countries including Benin Republic, Brazil,Cote d'Ivore, Guinea Bissau, Ghana, India, Mozambique, Nigeria, Philippines, Sri Lanka, Tanzania and Vietnam. Cashew is a source of food, income, industrial raw materials and foreign exchange for many countries of Africa, Asia and Latin America. Morphologically, the architecture of cashew tree makes it a foremost tree crop for reclaiming land area to enhanced productivity, through the prevention of desertification and soil erosion. The drought resistant, evergreen cashew tree is economically grown for its nut, apple and wood. Products derived from the nuts include the world's highly delighted roasted kernel snacks, kernel oil, cashew nut shell liquid, and from the apple: juice, jam and alcohol among others. Cashew wood is also used for furniture and fishing boats. Of all, cashew nut is the most economic part of the cashew tree providing foreign exchange earnings for producer countries. Cultivation and processing activities in cashew provides employment and income generation for women and smallholder farmers in Nigeria. Women are particularly involved in the cashew sub-sector more than in any other cash crop of the nation. There is a fact that not everyone knows about cashew fruit, this is a dry, non-self-opening fruit, kidney-shaped, about 2 to 3 cm long, hard outer shell, sunken face. The tree produces a long, fleshy stalk, called a cashew apple, which resembles a small pear. The color may be red, yellow or mixture of colors. The mature cashew apple can be eaten fresh as well as cooked. At the end of this stalk grows the kidney-shaped cashew nut that many know and love. Because of that, we often assume that the bulging stem is the fruit, and the "cashew nut" is the seed.

The cashew tree, *Anacardium* occidentale, of the family Anacardiaceae, is short-trunked, up to 13 m high and normally with a very broad crown, although it is often stunted and bushy on coasts. There is an enormous, very old, wild cashew tree in Natal, Brazil, that covers 0.75 ha and is a great tourist attraction. Its leathery, evergreen leaves are clustered at the branch tips. The small, yellow-and-red flowers are borne in open sprays. The true fruit of the tree is the kidney-shaped, hard-shelled nut that is at first green, later turning an ashy brown; it grows to 3 cm or more in length and develops at the tip of a fleshy stalk. As the 'nut' matures, the stalk inflates to form a showy, pear-shaped, smooth-skinned, succulent, juicy pseudofruit (false fruit), which is bright-red, orange, yellow, or two-tone and is usually viewed, and utilized, as a fruit. The weight of the expanded pseudofruit causes the nut to fall to the ground at its peak of maturity. A caustic oil in the honeycomblike cells within the double-layered shell of the 'nut' protects it from being destroyed by foragers that feed on the 'apple.' However, the oil seriously complicates the processing of the 'nut' and extraction of its kernel for food use (Morton, 2003). Considerable variation was noticed among the collections for some economic characters, viz., the season of flowering, duration of flowering, apple colour, apple shape , apple weight, nut weight (2.4-18.0 g), kernel to whole nut ratio (19.0-32.0%) etc. In addition, different ideotypes like dwarf and bushy habit, erect/tall types ; compact /loose canopy etc have been classified. The germplasm accessions evaluated exhibited a considerable amount of diversity for some of the economic characters (Swamy and Thimmappaiah, 1991). So far 61 varieties in India have been released for cultivation as a result of evaluation of germplasm collection and hybridization and selection. These varieties have been released from different research centers of SAUs and DCR (formerly NRCC). Among them 34 are selections and 27 are hybrids (Eradasappa, 2022). Soft wood grafting technique has been found to be the best method of propagation and it is recommended for commercial multiplication of cashew varieties (Swamy *et al*., 1998). Cashew kernels are roasted, fried, spiced, or honey coated and sold in different packages and sizes as snacks. Oil has been mechanically extracted from the cashew kernel which has higher stability at 80 degrees centigrade compared with other commercial oils like palm oil, groundnut oil, corn oil, or cocoa butter. The cashew kernel oil is promising for food and industrial uses. There has been development of improved technique for processing cashew apples into wine, jam, and non-alcoholic beverage of a high nutritional value with vitamin C content of 170-180 mg/100 ml juice. In this review article Origin, Domestication, Taxonomy, Botanical Description, Genetics and Cytogenetics, Genetc Diversity, Breeding, Uses, Nutritional Value, Health Benefits of Cashew are discussed.

ORIGIN AND DOMESTICATION

A. occidentale is considered native of tropical America, not-withstanding the uncertainty in defining its natural distribu-tion, due to its long association with man. Johnson (1973) suggested that it originated in the restinga, meaning the low vegetation found in the sandy soil along the coast of eastern and northeastern Brazil. The similarity between the form of cultivated A. occidentale and the native trees found in resting vegetation is high (Johnson 1973). A. occidentale was also found to be an indigenous element of the savannahs of Colombia, Venezuela and the Guyanas, as well as occasionally a dominant feature of the savannah-like vegetation, also known as cerrados, of central and Amazonian Brazil (Nair 2010). Therefore, it is believed that A. occidentale originally evolved in the cerrados of Central Brazil and later spread in the restingas of the coast. However, recent findings shed further light on the origin of cashew. Archeological data from 47 million-year-old lake sediment in Germany provided evidence of distribution of cashew in Europe during the Tertiary period: such a discovery suggests a bio-geographic link between the American and European continents in terms of the distribution of genus Anacardium (Manchester *et al.* 2007). What is known for sure is the role of European explorers in spreading cashew throughout the world: it is well documented that the Portuguese discovered cashew in Brazil and thereafter introduced it to Mozambique and later India during the sixteenth and seventeenth

centuries. After coming to the east coast of Africa in the second half of the sixteenth century, cashew then spread to the west coast and finally to the islands. Following its introduction into India, the plant was taken to Southeast Asia and later it spread to Australia and parts of North America such as Florida (Nair 2010). The genus *Anacardium* is a native to latin America and has a primary centre of diversity in Amazonia and secondary one in the Planalto of Brazil. Behrens (1998) described the crop as a tropical tree species that originated from South America. Natural occurrences of cashew have been reported for Mexico to Peru and in the West Indies. The crop was introduced into India, the East Indies and Africa by the Portuguese explorer in the 16th century. Thereafter, exploitation of cashew for its fruits (nut and apple) among local people appears to have been the pattern for more than 400 years in Asia and Africa (Mitchell and Mori, 1987). *Anacardium* includes ten species which are naturally distributed from Honduras south to Parana, Brazil and eastern Paraguay. The genus is found west of the Andes in South America only in Venezuela, Colombia, and Ecuador. Cashew originated in Latin America, specifically North-eastern Brazil (Ohler, 1979). *Anacardium occidentale* is cultivated or adventive throughout the New and Old World tropics. The genus has two centres of diversity –Central Amazonia and the Planalto of Brazil. This is illustrated by the occurrence of four species in the vicinity of Manaus and by three species occupying the same habitat in the Federal District, Brazil. The following five distribution patterns of *Anacardium* were reported by Mitchell and Mori (1987):

1) *A. excelsum* is isolated taxonomically and geographically from its congeners (species within the same genus) by the Andes. The uplift of the Andes was probably the driving force in the early differentiation of *A. excelsum* from the rest of the genus.
2) *A. giganteum* and *A. spruceanum* have Amazonian-Guyanan distributions.
3) *A. occidentale*, which is the most widespread species in the genus, has disjunct populations in the Planalto of Brazil, the *restingas* of eastern Brazil, the savannas of the Amazon basin, and the Llanos grasslands of Colombia and Venezuela. It should be kept in mind, however, that the natural distribution of this species is obscured by its widespread cultivation in both the Old and New World.
4) Three closely related species, *A humile, A. nanum* and *A. corymbosum*, are restricted to the Planalto of central Brazil.
5) Two species of *Anacardium* are narrow endemics. *A. corymbosum*, which is restricted to south-central Mato Grosso of Brazil is an allospecies (geographically separated species that constitute a superspecies) of *A. nanum* and *A. fruticosum* (a new species) is endemic to the upper Mazaruni River basin in Guyana. It is closely related to the Amazonian *A. parvifolium.*

*A. occidentale i*s native to tropical America where its natural distribution is unclear because of its long and intimate association with man. The problem of its origin and distribution has been investigated by Johnson (1973) who suggested that it originated in the *restinga* found in sandy soil along the Eastern Brazil of Northeastern Brazil. *Restinga* is a spit and a distinct type of coastal tropical and subtropical moist broadleaf forest found in Eastern Brazil. *Restingas* form on sandy, acidic, and nutrient-poor soils, and are characterized by medium sized trees and shrubs adapted to the drier and nutrient-poor conditions. Johnson is probably correct in assuming that the cultivated form of *A. occidentale* came from Eastern Brazil, because cashew trees cultivated in the Old and New Worlds are identical in appearance to native trees found in *restinga* vegetation. In particular, cultivated and wild populations of cashew from Eastern Brazil share chartaceous (resembling paper) leaf blades and long petioles. *A. occidentale* is probably an indigenous element of the savannas of Colombia, Venezuela and the Guyanas. **A** savanna or savannah is a grassland ecosystem characterised by the trees being sufficiently widely spaced so that the canopy does not close. It is clearly a native, and occasionally a dominant feature of the *cerrados* (savanna-like vegetation) of central and Amazonian Brazil. The *cerrado* populations of *A. occidentale* differ from the restinga populations by having undulate, thickly coriaceous leaves with short, stout petioles. The hypocarps (cashew apples) of *cerrado* trees are usually smaller and sometimes have a more acidic flavour than those of the *restinga*. The natural distribution of *A. occidentale* extends from northern South America south to Sao Paulo, Brazil. It is probably not native to Central America, the West Indies, or South America west of the Andes. It is believed that *A. occidentale* originally evolved in the *cerrados* of Central Brazil and later colonized the more recent *restingas* of the coast. Central Brazil is a center of diversity for *Anacardium* where the distribution of *A. occidentale* overlaps the ranges of *A. humile, A. nanum* and *A. corymbosum. A. humile*, the closest relative of the cultivated cashew, is closer morphologically to the *cerrado* ecotype than it is to the *restinga* and cultivated populations of *A. occidentale* (Mitchell and Mori, 1987).

The earliest reports of cashew are from Brazil coming from French, Portuguese and Dutch observers (Johnson, 1973). The French naturalist and monk, Andre Thevet was the first to describe, in 1557, a wild plant extremely common in Brazil, the cashew tree and its fruits. He recounted that cashew apples and their juice were consumed and that the nuts were roasted in fires and the kernels eaten. Andre Thevet provided the first drawing of the cashew showing the local people harvesting fruits and squeezing juice from the cashew apples into a large jar (Johnson, 1973; NOMISMA, 1994) (Fig. 1). There are indications that the local Tupi Indians had used cashew fruits for centuries. They probably played a major role in the species dispersion in their temporary migrations towards the coast of north-eastern Brazil, where a considerable intraspecific variation has been recorded (Ascenso, 1986). The entire cashew fruit, nut and peduncle, will float when mature. This could account, in Brazil, for coastward dispersal of the species by rivers draining north and east. Fruit bats may also have been involved in seed movement. Within the Amazon forests fruit bats are the most important agents of seed dispersal of tree species (Johnson, 1973). From its origin in Northeastern Brazil, cashew spread into South and Central America (Van Eijnatten, 1991).

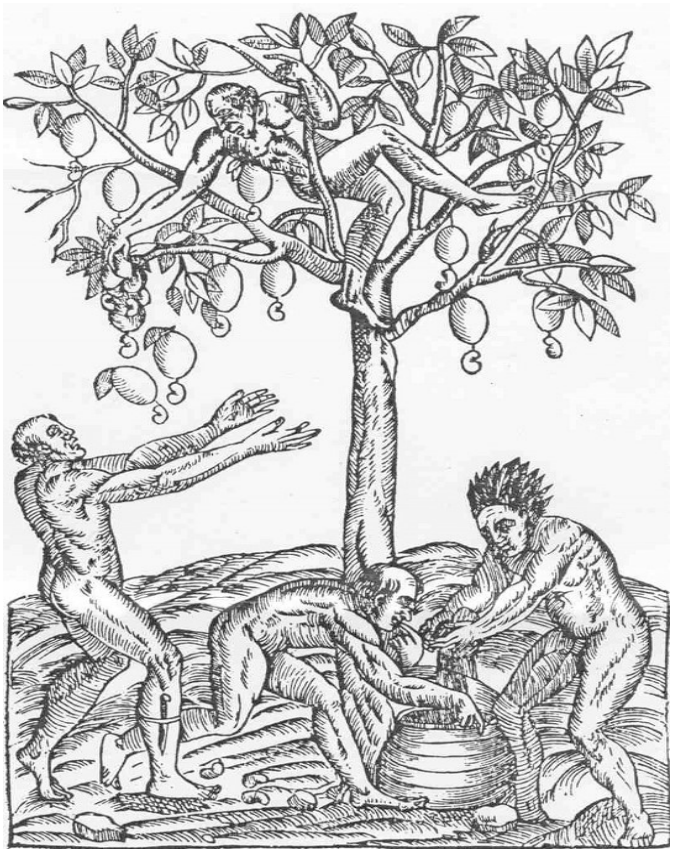


Fig. 1. Engraving of Tupí Indians harvesting cashew apples and sqeezing juice from cashew apples (Paris, 1557)

The Eastern portion of the Amazon river figures prominently in distributions of many plants and animals, many of which are found either exclusively to the North or South of the river. However, in the

case of *Anacardium*, all Amazonian species are found on both sides of the Amazon river. The reason for this is probably the ease with which bats, large birds, and water (in the case of *A. microsepalum*) carry fruits across water barriers (Mitchell and Mori, 1987). *A. occidentale* is cultivated and adventive throughout the Old and New World Tropics where the geographical limits of its cultivation are latitudes 27°N and 28°S, respectively (Nambiar, 1977).

The presence of cashew in other continents is to be attributed to man's intervention (Johnson 1973). The Portuguese discovered cashew in Brazil and spread first to Mozambique (Africa) and later into India between sixteenth and seventeenth centuries (De Castro, 1994). According to Agnoloni and Giuliani (1977), it arrived in Africa during the second half of the sixteenth century, first on the east coast and then on the west and lastly in the islands. In Africa, although it can be guessed that the cashew was introduced at an early period by the Portuguese, there are no records which provide specific dates. Dispersal of the cashew in east Africa may in part be due to the elephant, whose fondness for fruits is well known (Johnson, 1973). Attracted by the colour of the false fruit (apple), they swallowed this together with the nut which was too hard to be digested. This was then expelled with their droppings, a natural manure, and trodden far enough into the ground by the animals following along behind to root and grow into a seedling first and then a tree. This is how the cashew was spread along the East coast of Africa facing the Indian Ocean (Massari, 1994). The spreading of the cashew within the South American continent was gradual and spontaneous (NOMISMA, 1994). It is believed that the Portuguese brought the cashew to India, between 1563 and 1578. It was first described in gardens in Cochin on the Malabar coast. Following its introduction into Southwestern India, the cashew probably diffused throughout the Indian subcontinent to some degree by means of birds, bats, but most importantly, human elements. Cochin served as a dispersal point for the cashew in India, and perhaps for Southeast Asia as well (Johnson, 1973). According to Johnson (1973) the reason for the introduction is not documented, although the popular explanation is that it was for the purpose of checking soil erosion in the coastal areas of India. This interpretation, however, smacks of a twentieth century concept being applied to a 16th century event. Portuguese learned of the reported medicinal properties of the cashew and also that the juice of the cashew apple could be fermented into a good wine. It seems plausible, therefore, that they visualized the cashew as a crop of potential value to India. After India, it was introduced into Southeast Asia (NOMISMA, 1994). Dispersal in Southeast Asia appears to have been aided by monkeys. Whether the cashew reached the Philippines via India is uncertain. It may have come directly from the New World on the Manila Galleons (Johnson, 1973). The cashew later spread to Australia and some parts of the North American continent, such as Florida. Finally, its present diffusion can be geographically located between 31° North latitude and 31° South latitude, both as a wild species and under cultivation (NOMISMA, 1994). At present cashew is cultivated in many tropical countries, mainly in coastal areas (Ascenso, 1986; Van Eijnatten, 1991). In the 19th century, proper plantations were established and the tree then spread to a number of other countries in Africa, Asia and Latin America (Massari, 1994). Though cashew is indigenous to Brazil, India is the country that nourished this crop and made it a commodity of international trade and acclaim. Even today, India is the largest producer, processor, exporter and second largest consumer of cashew kernels in the world (Nayar, 1998).

Recent History: It was not until the early years of the 20th century that international trade in cashew kernels began with the first exports from India. A very slow beginning, but recent decades have seen the cashew become an important commercial tree crop (Johnson, 1973). Cashew production takes place mainly in the Central and South American zone, Asia and Oceanic zone and African zone. The Asiatic zone includes India as the major producer besides China, Indonesia, Malaysia, Philippines, Thailand, Vietnam, Sri Lanka and Myanmar. In the African Zone, Mozambique, Tanzania and Kenya are the major producers, besides, minor countries such as Benin, Guinea Bissau, Ivory Coast, Madagascar, Nigeria, Ghana, Senegal and Togo. In the Latin American Zone, the primary producers of cashew comprises of Brazil., Columbia, Costa Rica, Honduras, Salvador, Gautemala, Panama and Venezuela. Traditionally cashew has been cultivated on commercial scale in Brazil, India, Tanzania, Mozambique, Kenya and Madagascar, while in the recent years plantations are also raised in South East Asian countries like Vietnam, Myanmar, Thailand, on commercial scale. In India cashew is grown mainly in Maharashtra, Goa, Karnataka and Kerala along the west coast and Tamil Nadu, Andhra Pradesh, Orissa and West Bengal along the east coast. To a limited extent it is grown in Manipur, Meghalaya, Tripura, Andaman and Nicobar Islands and Chhattisgarh. Portuguese explorers introduced it to the tropics of Asia and Africa from where it spread into other parts of the world. At present, cashew is produced in 32 countries of the world with sufficient warm and humid climate. The main producers however are Brazil, Benin Republic, Cote d'Ivore, Ghana, Guinea Bissau, India, Mozambique, Nigeria, Philippines, Srilanka, Tanzania and Vietnam.

TAXONOMY

Cashew belongs to the family Anacardiaceae, the genus *Anacardium* and species *occidentale*. A taxonomic treatment of *Anacardium* (Anacardiaceae; Anacardieae), a Latin American genus of trees, shrubs and geoxylic subshrubs, is provided by Mitchell and Mori (1987). Anacardiaceae Lindl., the cashew family, is an economically important, primarily pantropically distributed family of 82 genera and over 700 species. This family is well known for its cultivated edible fruits and seeds (mangos, pistachios, and cashews), dermatitis causing taxa (*e.g*., *Comocladia, Metopium, Semecarpus, Toxicodendron*, *etc*.), and lacquer plants (*Toxicodendron* and *Gluta* spp.). Two genera, *Anacardium* L. and *Semecarpus* L. f., have an enlarged edible hypocarp subtending the drupe. One species of *Anacardium, A. microsepalum* Loesener, lacks the hypocarp and grows in the flooded forests of the Amazon where it may be fish dispersed (Mitchell and Mori, 1987; Pell, 2004). Anacardiaceae is a moderately large family consisting of Ca 74 genera and 600 species. It is subdivided into five tribes, namely Anacardieae , Spondiadeae, Semecarpeae, Rhoeae, and Dobineae. The tribe Anacardieae consists of 8 genera, namely, *Androtium, Buchanania, Bouea, Gluta, Swintonia, Mangifera, Fegimanra* and *Anacardium* (Mitchell and Mori, 1987).

Anacardium is one of the most economically important genera in the Anacardiaceae. This is due to *Anacardium occidentale* (the cashew of commerce), which yields: roasted cashew nuts (seeds), which are a major third world export to industrialized nations; cashew apples (hypocarps), which are consumed locally or used to make a widely marketed juice in South America, especially Brazil; and cashew nut shell liquid, which has medical and industrial applications. Some of the other species have economic potential but they are currently under-utilized. *A. excelsum* is used for construction and as a shade tree for coffee and cocoa plantations. *A. giganteum* is a locally important timber, and its hypocarps are relished by local people. The spectacular white leaves associated with the inflorescences of *A. spruceanum* make it a tree with excellent ornamental potential. *A. humile*, a subshrub closely related to *A. occidentale*, possess edible hypocarps and seeds. Selective breeding for higher quality hypocarps and seeds, and hybridizations with *A. occidentale*, could yield subshrubs with fruits that could be mechanically harvested. The economic potential of the other two subshrubs, *A. nanum* and *A. corymbosum* also should be investigated. (Mitchell and Mori, 1987)

Species of *Anacardium*

According to Bailey (1958) *Anacardium* is a small genus of eight species indigenous to South America. However, Agnoloni and Giuliani (1977) and Johnson (1973) have recognised eleven and sixteen species, respectively. Valeriano (1972) names five different species, namely, *A. occidentale* L., *A. pumilum* St Hilaire, *A. giganteum* Hanca, *A. rhinocarpus* and *A. spruceanum* Benth. He also suggests recognition of only two species namely *A. nanum* and *A. giganteum* which can further be sub-divided based on the colour (yellow or red), and shape (round, pear-shaped or elongated) of the pseudo-fruit. He also considers the

division into dwarf and giant species to be the only way to classify cashew in a rational and practical way. His arguments are based on the characteristics of pseudo fruits. However the description provided by Peixoto (1960) separates recognition of more than two species. It appears from the published accounts that *A. occidentale* L. is the only species which has been introduced outside the New World. Within Central and South America as many as 20 species of *Anacardium* are known to exist (Nair *et al.* 1979). *Anacardium* L. is a small genus of trees, shrubs and sub-shrubs indigenous to the tropics. Some authors report 10 species and others until 20 species.

However, 20 accepted species of *Anacardium* are reported by TPL (2023) and Wikipedia (2023) as given below

Species in *Anacardium*

Anacardium amapaense J.D.Mitch.
Anacardium amilcarianum Machado
Anacardium brasiliense Barb.Rodr.
Anacardium caracolii Mutis ex Alba
Anacardium corymbosum Barb.Rodr.
Anacardium curatellifolium A.St.-Hil.
Anacardium excelsum (Bertero ex Kunth) Skeels
Anacardium fruticosum J.Mitch. & S.A.Mori
Anacardium giganteum Hancock ex Engl.
Anacardium humile A.St.-Hil.
Anacardium kuhlmannianum Machado
Anacardium microsepalum Loes.
Anacardium nanum A.St.-Hil.
Anacardium negrense Pires & Fróes
Anacardium occidentale L.
Anacardium othonianum Rizzini
Anacardium parvifolium Ducke
Anacardium rondonianum Machado
Anacardium spruceanum Benth. ex Engl.
Anacardium tenuifolium Ducke

It is native to Latin America, having a primary center of diversity in Amazon and a secondary center in the Planalto of Brazil. Only one species is an incipient domesticate commonly known as cashew, (*Anacardium occidentale* L.) (CGIAR, 2015). Of all, only cashew (A. occidentale) is of economic importance because of its edible apple and nutritious kernel.

Anacardium species names and synonyms are as under (MMPND, 2001):

1. Anacardium corymbosum Barbosa Rodriguez
2. Anacardium excelsum (Bertero & Balbis ex Kunth) Skeels
3. Anacardium giganteum Hancock ex Engler
4. Anacardium humile St. Hilaire
5. Anacardium latifolium Lam. -> *Semecarpus anacardium* L.f.
6. Anacardium longifolium Lam. -> *Semecarpus cuneiformis* Blanco
7. Anacardium macrocarpa Engler
8. Anacardium microcarpum Ducke -> *Anacardium occidentale* L.
9. Anacardium nanum St. Hilaire
10. Anacardium negrense Pires & Fróes
11. Anacardium occidentale L.
12. Anacardium officinarum Gaertn. -> Semecarpus anacardium L.f.
13. Anacardium orientale auct. ex Steud. -> Semecarpus anacardium L.f.
14. Anacardium pumilum St. Hilaire
15. Anacardium rhinocarpus (Bertero & Balb. ex Kunth) DC.
16. Anacardium spruceanum Bentham ex Engler

However, Mitchell and Mori (1987) recognise ten species in the genus *Anacardium*, one of which, *A. fruticosum*, is described as new. The species of *Anacardium* and there synonyms are presented in Table 1. The genus has a primary centre of diversity in Amazonia and a secondary centre in the Planalto of Brazil. All known species of the *Anacardium* genus can be found in the American continent, only four of them (*A. coracoli, A. encardium, A. excelsum, A. rhinocarpus*) do not exist in Brazil. There, the high number of wild species suggests that the Northeast is the site of origin for *Anacardium* genus and namely for *Ancardium occidentale* L. In fact, here different forms of cashew can be found with a high variability for local populations, namely along the coast and dune areas. Now-a-days most species belonging to the *Anacardium* genus are found everywhere in Brazil (NOMISMA, 1994). Ascenso (1986) reported that cashew (*A. occidentale* L.) is the only species in the genus which attained economic importance. The *Anacardium* genus appeared to have originated in the Amazon region of Brazil and hence speciation followed different geographic patterns. Although of tremendous economic importance, no work has been done with the intraspecific classification of *A. occidentale*. Few cultivars have been named and the only major distinction established is that between yellow and red hypocarp cultivars. Some trees have been selected for nut quality, whereas others have been selected for hypocarp size, colour, succulence and flavour (Mitchell and Mori, 1987).

Brief Description of Species of *Anacadium*

A brief description of ten species of *Anacadium* genus recognised by Mitchell and Mori (1987) are detailed below:

***1) Anacardium occidentale* Linnaeus (Cashew; caju):** *A. occidentale* is probably an indigenous element of the savannas of Colombia, Venezuela, and the Guianas. It is clearly a native and occasionally a dominant feature, of the *cerrados* (savanna-like vegetation) of central and Amazonian Brazil. The *cerrado* populations of *A. occidentale* differ from the *restinga* populations by having undulate, thickly coriaceous leaves with short, stout petioles. The hypocarps (cashew apples) of *cerrdo* tress are usually smaller and sometimes have a more acidic flavour than those of the *restinga*. The natural distribution of *A. occidentale* extends from northern South America, the West Indies, or South America west of the Andes. *A. occidentale* originally evolved in the *cerrados* of Central Brazil and later colonized the more recent *restingas* of the coat. Central Brazil is a center of diversity for *Anacardium* where the distribution of *A. occidentale* overlaps the ranges for *A. humile, A. nanum*, and *A. corymbosum, A. humile*, the closest relative of the cultivated cashew, is closer morphologically to the *cerrado* ecotype than it is to the *restinga* and cultivated populations of *A. occidentale*. *A. occidentale* grows in the coastal *restinga* of eastern Brazil, the thorny *caatinga* of north eastern Brazil, and the *cerrados* of Central and Amazonian Brazil. It is also present in the savannas of the Guianas, Venezuela and Colombia. In India, East Africa, and Malaysia, where *A. occidentale* is an introduced cultivar, it readily invades and becomes established in native vegetation. Ecologically the cashew is very adaptable as it can tolerate extended periods of drought and poor soils (pH 4.5 – 6.5). The most important limiting factors in its growth are water-logged or calcareous soils and frosts. Cold has the most severe effect on young trees and this probably limits the species to less than 1500 m above seas level. In the Greater Antilles, *A. occidentale* flowers from December to August with peak flowering from February to Aril. A secondary flowering peak occurs in August. Fruits usually are produced from February to August. In the Lesser Antilles, flowering occurs from November to August with peak flowering from February to May. The Central American populations generally flower from January to April and fruiting from December to July. In Colombia and Venezuela flowering and fruiting is either distributed throughout the year or varies regionally, and, in the Guianas, flowering and fruiting occurs throughout the year with peaks in April to July and from September to November. The eastern Amazonian populations of *A. occidentale* flower from December to February and from May to September. In western Amazonia, flowering occurs though out the year with peaks from February to June and from August to October.

Table 1. Species of *Anacardium* and their synonyms

Sl. No.	Species	Synonym (s)
1.	*A.occidentale* Linnaeus	*Cassuvium pomiferum* Lamarck
		Acajuba occidentale (L) Gartner
		Anacardium occidentale var. *americanum* de Candole
		A. occidentale var. *indicum* de Candole
		A. mediterraneum Vellozo
		A. curatellifolium A. St. Hilaire
		Cassuvium reniforme Blanco
		A. occidentale var. *longifolium* Presl
		A. occidentale var. *gardneri* Engler
		A. subcardatum Presl
		A. microcarpum Ducke
		A. rondonianum Machado
		A. amilcarianum Machado
		A. Kuhlmannianum Machado
		A. othonianum Rizzini
2.	*A. giganteum Hancock ex Engler*	*A. giganteum.* Loudon ex Steudel.
3.	*A. humile* St. Hilaire	*Monodynamus humilus* Pohl
		A. subterraneum Liais
		A. pumilum St. Hilaire ex Engler
		A. pumilum var. *petiolata* Engler
		A. humile var *subacutum* Engler
		A. humile Martius
4.	*A. microsepalum* Loesener	*A. negrense* Pires & Froes
5.	*A. excelsum* (Bertero & Balbis ex Kunth Skeels)	*Rhinocarpus exceelsa* Bertero & Balbis ex Kunth
		Anacardium rhinocarpus de Candole
		Anacardia rhinocarpa St. Lager
		Anacardium caracoli Mutis
6.	*A. parvifolium* Ducke	*A. tenuifolium* Ducke
7.	*A. corymbosum* Barbosa Rodrignes	--
8.	*A. spruceanum* Bentham ex Engler.	*Anacardium brasiliense* Barbosa Rodrigues
9.	*A.nanum* St.Hilaire	A. pumila Walpers
10.	*A. fruticosum* Mitchell & Mori	--

In northeastern Brazil flowering occurs throughout the year with peak from June to December. In southeastern Brazil, flowering is throughout the year with peaks in January and February and September and October. Fruiting is primarily from November to April. In Central Brazil, flowering mostly occurs from June to October with the majority of the fruits produced in October. In general, throughout its range *A. occidentale* flowers most profusely during the dry season. In many areas, two fruits crops are produced yearly. Flowering is controlled by several environmental mental cues,. An increase in sunshine and moisture stress concomitant with a decrease in relative humidity following the end of the rainy season induces bud break. Then a new flush of leaves produced which is directly followed by flowering. Low temperatures, however, delay flowering . Staminate flowers open before bisexual ones. Most cashew flowers open between 0600 and 1800 with peak anthesis occurring between 1100 to 1230. The stigmas are receptive as soon as the flowers open and the anthers dehisce one to five hours later. *A. occidentale* is highly out-crossed. Experiments have shown that maximum fruits set (80%) is obtained by crossing emasculated flowers with pollen from another plants, whereas self pollinated flowers gave a much lower fruit set (40%). The flowers are pollinated by bees, wasps, ants, flies, and possibly humming birds. In cashew plantations, most of the pollinations is accomplished by honey bees. Natural populations of *A. occidentale* are pollinated by bees and butterflies. The primary dispersal agents of the fruits of *A. occidentale* are probably frugivorous bats. Bats fly into a tree or shrub, seize the fruit, eat the fleshy hypocarp, and then discard the poisonous drupe. Bat dispersal also has been reported for *A. excelsum* and bats are probably the primary dispersal agents for most species of the genus. However, water has been suggested as a secondary means of dispersal. Acaju, derived from the Tupi Indians of Brazil, became caju in Portuguese and variants of caju in tropical Asian aand African countries. The English name cashew is clearly derieved from the Portuguese caju. In Brazil the cashew nut is called castanha and the hypocarp is frequently referred to as caju manso. In India cashew is also known as Agnikrita, guchapushpa, hajli badam, jidi-mamadi, kaju, kaju kalinga, kajutaka, kere-mara, parangimaru, prithagabija, xophahara, vrittapatra. *A. occidentale* is a polymorphic speices. The *restinga* ecotype of *A. occidentale* of eastern coastal Brazil is easily differentiated from *A. humile*. However, the cerrado ecotype of *A. occidentale* sometimes overlaps in leaf morphology with *A. humile*. The principal difference between *A. occidentale* and *A. humile* is that the former is always a tree and the latter is a subshrub with a massive underground root system and rigidly ascending branches. The *cerrado* ecotype of *A. occidentale* frequently has broadly obovate leaves with an obtuse or slightly auriculate base, whereas the leaves of *A. humile* are generally oblanceolate with attenuate bases. Moreover, the majority of flowers of *A. occidentale* have 9-10 stamens while the majority of flowers of *A. humile* have 7-8 stamens. The types of *A. curatellaefolium* St. Hil., *A. rondonianum* Machado, *A. kuhlamannianum* Machado, and *A. othonianum* Rizzini exemplify the *cerado* ecotype of *A. occidentale*. Hypocarp pyriform, much larger in cultivated forms than in wild populations, 5-20 x 2-8 cm, yellow, orange, or red. Drupe subreniform, 2-3.5 x 1-2 cm, gray or brown at maturity. The mature hypocarp is often glabrous. Drupe symmetry bilateral, fruit wall (pericarp), 3-4 mm thick, pericarp consists of exocarp, mesocarp and endoscarp. The exocarp uniseriate, the cell walls thick, lignified, the cuticle thin. Mesocarp is the thickest part of pericarp. Secretary cavities dominant feature of mature pericarp which contain yellow, caustic liquid (cashew nut shell liquid) consisting of phenols such as anacardiol and cardol. Endocarp mostly of mechanical tissue. Seeds edible, 2-4.5 x 0.9-3.7 cm. Endosperm scanty or poorly developed. Testa with thick layer of crushed, lignified parenchyma. Cotyledons with very thin cuticle.

Some authors say that *A. microcarpum* is synonym of *A. occidentale. A. microcarpum* is a wild cashew relative featuring 1-1 1/2" fruits that are smaller than the more common cashew apple. As with other cashew species, the fruit is the hard nut, with the bulbous pseudofruit (the apple) ripening to red and having an acidic sweet flavor. A small tree, usually growing to 10-25 feet. Fruits form in large clusters, with well-sized panicles. Overall appearance is much like the cashew apple

tree. Fruits and nuts are used much like the regular cashew. Fresh pseudofruits are edible and the roasted nuts are edible and quite tasty. The pseudofruits are harvested and sold in local markets. Native to scrublands and non flood plain zones of the lower Amazon region of Brazil.

2) Anacardium giganteum **Hancock ex Engler (caju):** Trees, to 40 m x 300 cm. Trunk cylindrical, bark very thick, gray, moderately coarse with vertical fissures, the inner bark pinkish-brown. Hypocarp pyriform, 1.3 x 1-5 cm, red. Drupe subreniform, black, 27 x 18 mm. The distribution is from the Pacific coast of Colombia and Loreto, Peru south to northern Mato Grosso and east to Surinam and Maranhao, Brazil. A large tree growing in moist, *terra firme* forests. It flowers from November to January and in June and August. In the state of Para, Brazil it normally flowers at the beginning of the wet season (December – January) and the fruits mature in the middle of the wet season (March). Individual trees will frequently flower every other year. The flowers of *A. giganteum* change colour after pollination from yellow to white to dark red. The single fertile stamen is only 0.5 mm long in unpollinated bisexual flowers, but it increases to 4.5 – 5 mm long and dehisces after pollination (*i.e.,* in flowers with red corollas). This suggests that self pollination is inhibited by protogyny. The hypocarp is eaten by spider and capuchin monkeys. The seed is sometimes dispersed endozoochorously by tortoises. The wood is easily worked and finishes smoothly. The ripe hypocarp is edible and a fine red wine can be prepared from its juice. However, the quality of the ripe hypocarp varies from very sweet and tasty to extremely acidic and usually they are too sour for eating. *A. giganteum* is abundant in the forests of Parque Nacional do Tumucumaque and Amapa, Brazil where it is an important item in the diet of the native Indians. They consume the hypocarps mixed with the flour of mandioca (*Manihot esculenta* Crantz). The seeds are toxic when raw but edible when roasted, and are said to be as delicious as those of the commercial cashew.

3) Anacardium humile **St. Hilaire (caju anao):** Subshrub 30 to 150 cm tall, with large underground trunk and rigidly ascending braches. Hypocarp obconical to pyriform, 1-3 x 1-2 cm, red or yellow when ripe. Drupe subreniform, 1.3 – 2.3 x 1.-1.7 cm, green gray, or dark brown at maturity. The distribution extends from Santa Cruz, Bolivia south to eastern Paraguay and in Brazil from southeastern Rondonia and northern Goias to Parana. A very common subshrub of savanna like vegetation (*campo* and *cerrado*) between 100 and 1200 m alt. It often grows in very dense patches usually 40 to 75 cm in height. The patches are the result of an extensive lateral branch system. *A. humile* has a very long and thick tap root that penetrates deeply though the very hard soil of the *cerrado* to reach the low water table, especially during the dry season. Radiating from the central subterranean axis are large plagiotropic branches from which are produced orthotropic shoots that emerge above the ground. The above ground parts of *A. humile* consist of short, rigidly ascending branches, tight clusters of leaves and terminal or axillay inflorescences. The prostrate form of *A. humile* is well adapted to the frequent and severe fires, seasonally dry environment, poor soils, and the low water table of the *cerrado*. The majority of the underground parts of *A. humile* represent a subterranean trunk of stem, not root. Flowering occurs primarily between July and October, and peak fruiting takes place in October and November at the beginning of the wet season. *A. humile* is pollinated by bees and butterflies. The hypocarps are eaten by parakeets, bats, and terrestrial mammals. The hypocarp is eaten raw by natives. It is also made into preserves, candies, juice, liquors and wine in the same ways as that of *A. occidentale*. The roasted seed ('nut') is edible.

4) Anacardium microsepalum **Loesener:** Trees, to 20 m x 50 cm. Bark smooth with scattered lenticels, the inner bark reddish-brown, forming a resinous exudate when cut. A lenticel is a porous tissue consisting of cells with large intercellular spaces in the periderm of the secondarily thickened organs and the bark of woody stems. Hypocarp absent. Drupe reniform, 20-30 x 19-26 mm, glabrous, green at maturity, Pedicel not accrescent. The distribution extends in Central Amazonian Brazil from the upper Rio Negro south to Rondonia and east to Borba and Manaus. A medium-sized to large tree in seasonally inundated forests. Its fruits may be dispersed by water. The seeds of *A. microsepalum* are eaten by fish. The flowers appear from December to June and the fruits are present from December to June. The roasted cashew seeds ('nuts') are eaten in Northwestern Amazonia. *A. microsepalum* is the only species of the genus without a fleshy hypocarp (Fig. 2).

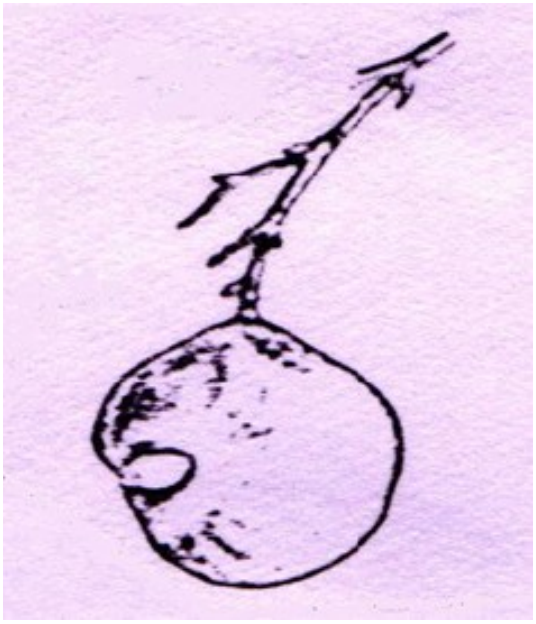


Fig. 2. ***Anacardium microsepalum*** **(Note absence of hypocarp)**

5) Anacardium excelsum **(Bertero & Balbis ex Kunth) Skeels (Wild cashew):** Tree, to 50 m x 30 cm, with cylindrical trunk, *slightly swollen at base. Hypocarp slender, sigmoid,* 2-4 x 1.5 – 2 cm, green. Drupe reniform, 23-34 x 14-20 mm, glabrous, green at maturity (Fig. 3). The distribution is from southern Honduras south to Los Rios, Ecuador and east to Aragua, Venenzuela. This is one of the largest trees in tropical America, *A. excelsum* grows in moist upland forests and in gallery forests adjacent to dry forests generally below 1000 m alt. It is frequently a dominant species in primary and secondary forests. *A. excelsum* usually drops its leaves in the early dry season. The flower appear from January to April (May) shortly after the new leaves are flushed and the fruits mature from March to May. On Barro Colorado Island peak flowering is in late February and the seeds generally mature in April. *A. excelsum* is pollinated primarily by settling moths. The hybpcarps are eaten by coatis, white-faced and howler monkeys; the bat *Micronycteris hirsute* and other bats. The hypocarps dropped to the ground by howler monkeys are eaten by basilisk lizards (*Basilisicus basiliscus*). Neither the monkeys nor the lizards eat the drupes and further it washypothesized that the "toxic fruits and edible pedicels may be an evolutionary response of *Anacardium* to insure the dispersal of fruits without injury to the fruit". However, it is reported that the monkeys and lizards never carry the fruit far from the parent tree and suggested that birds and bats may be the primary dispersal agents. The hypocarp of *Anacardium* is carried by bats to feeding roosts, where the untouched seeds are dropped after the frugivorous bat eats the receptacle. Exudates from the trunk of *A. exelsum* are an important items in the diet of the Panamanian tamarin (*Saguinus oedipus geofrooyi*). The macerated bark is used as barbasco (fish poison) in Panama and the wood is employed for bridge boards, fence posts, concrete forms, rough construction, general carpentry, boxes and crates. However, the wood is susceptible to dry rot and termite attack and is hard to work. *A. excelsum* has potential as a plantation crop. The seeds (nuts) are toxic when raw but edible when roasted and the hypocarps are edible. *A. excelsum* is cultivated in Cuba and Ecuador.

6) ***Anacardium parvifolium*** **Ducke:** Large trees, 22 to 40 m x 100 cm, Bark smooth. Hypocarp pyriform. 2 x 1.4 cm, red. Drupe reniform, 13 x 10 mm. The distribution extends in Amazonian Brazil

from extreme western Amazonas east to Maranhao and Amapa. A large tree of moist primary forests growing in flood plains and upland sites. It flowers from May to November and fruits have been collected in June.

Fig.3a: *Anacardium excelsum* (Note slender, sigmoid hypocarp)

Fig.3b: *Anacardium excelsum* (Note slightly swollen trunk at base)

***7) Anacardium corymbosum* Barbosa Rodrigues:** Subshrub 50 to 150 cm tall, with large underground trunk and rigidly ascending branches. Hypocarp subreniform, 1.5 – 2 x 1 – 1.7 cm, dark brown at maturity. The distribution is endemic to south central Mato Grosso, Brazil. A subshrub of savannas (*campo* and *cerrado*) between 100 and 800 m alt. Flowering occurs from June through October and fruiting commences in October. The hypocarps, according to local informants, are eaten by birds and mammals. The hypocarp is eaten raw by local people in Brazil.

***8) Anacardiuim spruceanum* Bentham ex Engler (Forest cashew; caju assu):** Tree to 35 m x 100 cm, with cylindrical trunk slightly swollen at base. Bark smooth. Hypocarp obconical or pyriform, 100 x 6-15 mm, very juicy, white, red, or yellow, with strong resinous smell. Drupe reniform, 14-15 x 13-20 mm, black at maturity. The distribution is from Bolivar, Venezuela south to Rondonia, Brazil and Pando, Bolivia and east through the Guianas to eastern Para, Brazil. A large tree in moist primary and old secondary forests growing in flood plains and on upland sites. *A. spruceanum* is a relatively uncommon tree. Out of 1000 trees sampled in Camaipi, Amapa, only five individuals of *A. spruceanum* were encountered, and in Saul, French Guiana not one tree was found in a survey of 800 tress. Scattered large individuals of *A. spruceanum* were found outside of the transect in the Saul study. *A. spruceanum* flowers from April to September and from November to January with peak flowering in July and August. Mature fruits appear at the beginning of the wet season. This species is probably dispersed by bats. The green and white foliage of the outer branches associated with the inflorescences give the tree a magnificent appearance when in flower and therefore *A. spruceanum* has been recommended as an ornamental for tropical climates. Populations of *A. spruceanum* with white hypocarps appear to be concentrated in French Guiana and Amapa, Brazil, whereas specimens with red hypocarps have been colleted from the area around Manaus, Brazil. *A. brasiliense* is treated here as a synonym of *A. spruceanum* because of Barbosa Rodrigues reference to the leaves as being of a different colour than in other species of the genus. Certainly, he was referring to the showy white leaves and foliaceous bracts subtending the rachises of the inflorescence of *A. spruceanum*, a feature unique to this species.

***9) Anacardium nanum* St. Hilaire:** Subsrub, 30 to 150 cm tall, with large underground trunk, 35 to 65 cm diam. The distribution extends in Brazil from central Goias and the Distrito Federal south to central and western Minas Gerais. A subshurb of savannas (*campos* and *cerrados*) between 700 and 900 m alt. It flowers from May to August and is pollinated by bees and butterflies.

***10) Anacardium fruticosum* Mitchell and Mori:** Low spreading tree, 2-3 m tall. The distribution is known only from the upper Mazaruni river basin, Guyana. A shrub to low spreading tree in savannas from 460 to 1250 m alt. It flowers from June to October. The fruits have not yet been collected. This species is very similar to *A. parvifolium*, differing primarily in being a shrub or low spreading tree 2-3 m tall growing in savannas and bearing relatively large, coriaceous leaves. *A. parvifolium*, on the other hand, is a tall rain forest tree with chartaceous, smaller leaves.

Synonyms of *Anacardium occidentale* L: IBP (2023) has reported the following 9 synonyms of *Anacardium occidentale* L.:

Acajuba occidentalis (L.) Gaert.
Anacardium amilcarianum Machado
Anacardium kuhlmannianum Machado
Anacardium microcarpum Ducke
Anacardium othonianum Rizzini
Anacardium rondonianum Machado
Cassuvium pomiferum Lam.
Cassuvium reniforme Blanco
Cassuvium solitarium Stokes

Botanical Discription

Cashew (*A. occidentale* L.) is an evergreen perennial tree plant belonging to the family Anacardiaceae. This family is considered to encompass 60–74 genera consisting of 400–600 species, depending on the classification adopted. Among the eight species in the genus *Anacardium*, only cashew (*occidentale*) is of economic value, due to its edible hypocarp and nutritious kernel. Plant height varies considerably, ranging from 5 to 14 m. The canopy size also varies up to a width of 20 m. The root system is usually deep and widespread. The root distribution pattern depends on soil type, planting material and method, age, level of crop nutrition, and irrigation. Upon germination of the nut, the radicle develops rapidly into a tap root, which further produces laterals. As the lateral roots elongate, fibrous roots develop on the tap root. The early developed tap root system gradually takes up a complex structure of extensive roots with considerable lateral and vertical spread, with most of the feeding roots residing in the surface layer of the soil. In shallow laterite soils, typical of tropical areas where cashew is probably native, cashew tree roots can extend up to 300 cm laterally around the tree and 100 cm vertically (Abdul Salam and Peter 2010). When propagated by transplantation, the level of development of root system determines the establishment of cashew planting material. (Abdul Salam and Peter 2010). The trunk is usually irregular and rather short, as the initial branches grow close to the ground. Leaves are green, elliptic to obovate, with smooth margins and sometimes a notched tip; they are arranged in a spiral pattern toward the end of the stem with a short stalk. Usually, there are 3 to 14 leaves on each terminal stem, which become fully mature after 20–25 days after emerging (Ohler 1979). Flowers are gathered in a panicle which is up to 26 cm long and bears 5 to 11 laterals. The panicles predominantly constitute of male and hermaphrodite flowers in varying proportion. Both of them present a single large stamen and five to nine smaller ones. Overall, there may be 200 to 1,600 flowers per panicle (Northwood 1966). Flowering occurs at the end of new shoots in the periphery of the tree canopy over a 30- to 60-day period during the vegetative flush that usually follows dry periods (Martin *et al*. 1997). Individual flowers are small, consisting of a small crown of five yellowish-green sepals and five white to reddish petals. When open, flowers are receptive to pollen for several days. The stigma becomes immediately receptive, even though the release of pollen occurs later. This favours cross-pollination by insects, which largely predominates on self-pollination due to the sticky nature of the pollen (Northwood 1966). The fruit of the cashew tree consists of an accessory fruit and the true fruit itself. The former is an oval or, alternatively, pear-shaped hypocarp deriving from the enlargement of the pedicel and the receptacle of the flower.

It is known as the "cashew apple" and, when fully ripened, is a yellow and/or red structure 5 to 11 cm long. The latter is a kidney-shaped drupe that develops at the bottom of the apple. This is the first part to ripen on the cashew tree, followed by the cashew apple (Lim 2012). Within this fruit, there is a single seed, the cashew nut, which is surrounded by a double shell containing anacardic acid, an allergenic phenolic compound (Lim 2012) (Fig. 4).

Cashew orchard

Cashew tree

Cashew young shoot

Cashew panical

Cashew flowers

Cashew immature fruits

Cashew immature fruits

Cashew mature fruits

Cashew mature fruits

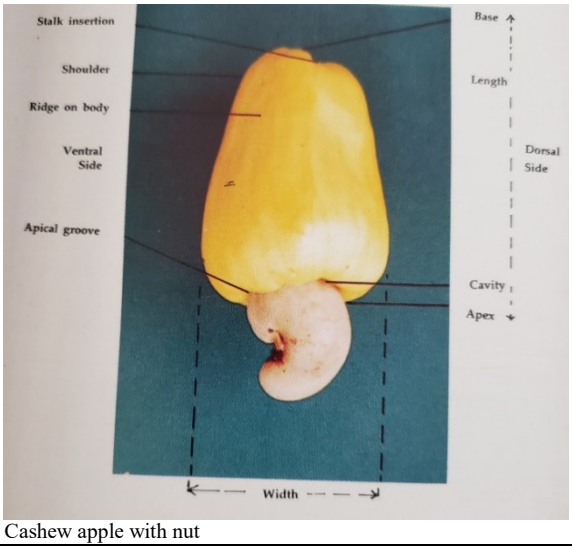
Cashew immature kernels

Cashew kernels

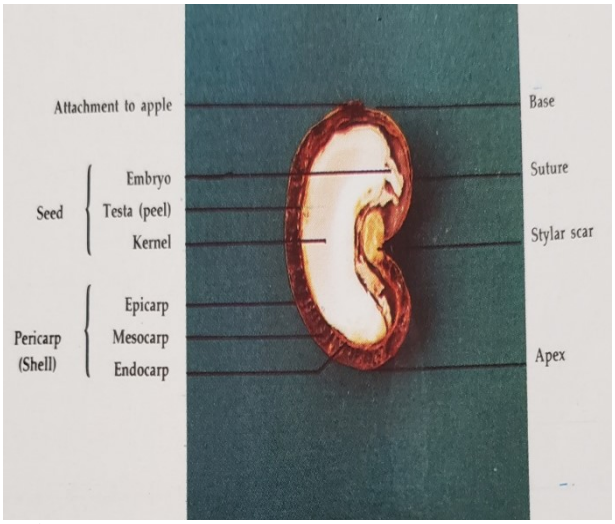
Fig. 4. Botanical description

Apart from the above-listed common features, there are two distinct morphological groups within the *A. occidentale* species that differ from one another in terms of size: the common type and the dwarf type. The former is bigger and generally more vigorous. Adult plants grow from 8 to 14 m in height and develop a crown span that reaches up to 20 m (Ohler 1979). They generally flower in their third year from planting, but the minimum age for stable production is usually 8 years and more commonly between 12 and 14. The individual production capacity varies considerably, with plants producing less than 1 kg up to more than 100 kg of nuts per year. Similarly, a nut's weight can vary between 3 and 33 g, with the pseudo-fruit ranging from 20 to 500 g. The dwarf type generally reaches no more than 5 m in height, with a homogenous canopy 5–6.5 m wide. These plants have a notably shorter juvenile phase as they start flowering within 6 months so that they have a marketable production in their second or third year from planting (Barros et al. 2002). These traits, for which dwarf clones were selected both in Brazil and India, significantly affect production performance; at the optimum planting density, within the reference period 1959–1995, the mean yield per hectare was found to be 1,200 kg for the dwarf type and 379 kg for

the common type (Barros et al. 2002). Other characteristics that differentiate dwarf clones from common types include smaller and lighter green leaves, a smaller stem diameter, initial branches closer to the ground, smaller nuts, and larger peduncles (Barros 1995). In India, use of cashew apples and nuts was adopted by local peoples, and accounts from Africa are similar; making cashew wine appears to have been a common practice in both Asia and Africa (Johnson, 1973). It was offered at wedding banquets as a token of fertility by the Maconde tribe in Mozambique (Massari, 1994). Cashew tree bears numerous, edible, pear shaped false fruits or pseudo fruits or "accessory fruits" called "cashew apples." A small bean shaped, grey color "true fruit" is firmly adhering to lower end of these apples appearing like a clapper in the bell. This true fruit is actually a drupe, featuring hard outer shell (cashew nut shell) enclosing a single edible seed or the "cashew kernel". The outer shell is green and leathery and turns an orange red when mature. The inner shell is hard, similar to other nut shells, and contains the edible cashew kernel. The oil enclosed in the nut's shell (cashew nut shell liquid or CNSL) (anacardic acid)) is toxic and can burn the skin. It is used in producing plastics and as a lubricant and insecticide. It is, therefore, the outer shell which is roasted in the processing unit and then, the edible kernel is extracted. Parts of raw cashew apple and nut are shown in Fig. 5.



Cashew apple with nut



Cashew nut

Fig. 5. Parts of cashew apple and nut

The cashew tree, *Anacardium* occidentale, of the family Anacardiaceae, is short-trunked, up to 13 m high and normally with a very broad crown, although it is often stunted and bushy on coasts. There is an enormous, very old, wild cashew tree in Natal, Brazil, that covers 0.75 ha and is a great tourist attraction. Its leathery, evergreen leaves are clustered at the branch tips. The small, yellow-and-red flowers are borne in open sprays. The true fruit of the tree is the kidney-shaped, hard-shelled nut that is at first green, later turning an ashy brown; it grows to 3 cm or more in length and develops at the tip of a fleshy stalk. As the 'nut' matures, the stalk inflates to form a showy, pear-shaped, smooth-skinned, succulent, juicy pseudofruit (false fruit), which is bright-red, orange, yellow, or two-tone and is usually viewed, and utilized, as a fruit. The weight of the expanded pseudofruit causes the nut to fall to the ground at its peak of maturity. A caustic oil in the honeycomblike cells within the double-layered shell of the 'nut' protects it from being destroyed by foragers that feed on the 'apple.' However, the oil seriously complicates the processing of the 'nut' and extraction of its kernel for food use (Morton, 2003). *Anacardium occidentale* is a medium-sized tree, spreading, evergreen, much branched; grows to a height of 12 m. When grown on lateritic, gravelly, coastal sandy areas, it rarely exceeds 6 m and develops a spreading habit and globose shape with crown diameter to 12 m. Grown inland on loams, it reaches 15 m and is much branched, with a smaller (4-6 m) crown diameter. The root system of a mature *A. occidentale*, when grown from the seed, consists of a very prominent taproot and a well-developed and extensive network of lateral and sinker roots. Leaves simple, alternate, coriaceus, glabrous, obovate, rounded at ends, 10-18 x 8-15 cm, with short petiole, pale green or reddish when young and dark green when mature. The inflorescence is a terminal panicle-like cluster commonly bearing male and hermaphroditic flowers. The male flowers are the most numerous and usually bear 1 exserted stamen and 9 small inserted ones. *A. occidentale* normally comes into flowering in 3 to 5 years. The nut, which is the true fruit, dries and does not split open. Inside the poisonous shell is a large curved seed, nearly 2.5 cm long, the edible cashew nut. As the nut matures, the stalk (receptacle) at the base enlarges rapidly within a few days into the fleshy fruitlike structure, broadest at the apex, popularly known as the fruit. This thin-skinned edible cashew fruit has a light yellow spongy flesh, which is very juicy, pleasantly acidic and slightly astringent when eaten raw and highly astringent when green (Orwa *et al*., 2009). The cashew (*Anacardium occidentale*, Linn.) is a member of the Anacardium genus of the Anacardiaceae family. It is a small tree, with leaves that are alternate, simple, entire, obtuse, and borne on short leaf stalks. The flowers are abundant, small, and fragrant, and are produced in terminal, loose panicles. The enlarged juicy peduncle that bears the nut is known as the "cashew apple."

When ripe, it is of a golden-yellow color, obovate in shape, has a pleasant, acid flavor, and is somewhat astringent. The cashew nut hangs from the end of the cashew apple, and is kidney-shaped and about 2.5 cm long. It consists of an edible kernel, surrounded by two shells. The outer shell is smooth and of a bright brown color. Between the two shells, there is a very caustic oily substance. The cashew kernel is considered to be of high nutritive quality, and is covered with a thin reddish brown skin or testa (Rajini, 2011).

Pollination: Flies, bees and ants as well as wind carry out pollination. Bees promote greater pollination because scented flowers and sticky pollen grains attract them. Bagged inflorescence does not produce nuts unless it is hand pollination or insects are allowed inside. Self-pollination is also possible, as nuts have developed from hand-pollinated, bagged inflorescence (Orwa *et al.,* 2009).

Genetics and Cytogenetics: A clear example of the lack of clarity in the genetic background of cashew is the disagreement still persisting over the chromosome number and ploidy level of the species. Whereas there is a broad consensus that the crop is probably diploid, with a haploid count of n=21 (Aliyu and Awopetu 2007), lower counts of n=15 and n=12 have been reported (Khosla *et al.* 1973). Cytology of *Anacardium occidentale* L. has not been studied in detail. The chromosome number is reported only for *A. occidentale.* This morphologically polymorphic species also exhibits choromosome

polymorphism (Mitchell and Mori, 1987). Chromosome numbers reported in the literature range from 2n=24 (Khosla *et al.,* 1973; Goldblatt, 1984), 2n=30 (Machado, 1944), 2n=40, (Simmonds, 1954; Goldblatt, 1984) to 2n=42 (Darlington and Janaki Ammal, 1945; Khosla *et al.,* 1973; Goldblatt, 1984; Purseglove, 1988). Such chromosome polymorphism is well known in many domesticated trees (Khosla *et al.,* 1973). By comparison with other tropical industrial crops as oil palm, coffee, cacao and tea, very little cashew-improvement research has been done, owing to lack of adequate knowledge of cytology and genetics of the crop. The importance of cytological information to crop improvement cannot be overemphasized. Cytological studies have a lot to help in resolving the origin and evolution of plant species. Since the basis of improvement is based on variation, and variation has both genetic and non-genetic components, comparative work should provide useful data for solving the problems of low fertility, incompatibility *etc,* which are key components in tree crop breeding. These two variations bring about changes in the chromosome either structurally or morphologically are bound to affect the DNA components and therefore have genetic consequence. It has also been known that chromosomal or cytological studies help in determining the path of evolution of new species. Cytogenetics has been employed in agriculture for the development of improved cultivars especially in identifying the cause(s) of infertility in organism. Cytological and breeding investigations in cashew are few compared with other crops.

Hutchinson and Dalziel (1954) reported diploid chromosome number of 2n = 42 in cashew. Aliyu, and Awopetu (2007) quoted Deckers *et al.*(2001) that Cashew is a dicotyledonous evergreen tree with a morphologically polymorphous species that has been reported with polymorphic chromosome number 2n = 24, 30, 40, 42. Two major populations of cashew (Brazilian and Indian) were studied by Aliyu, and Awopetu (2007). The study revealed that Indian accessions are potentially prolific and consistent in fruiting, but with characteristic small-medium sized nuts and low-premium kernels. Meanwhile, Brazilian accessions produce large nuts with potentially good quality kernels, but very low and inconsistent in fruit yield. Based on the report of this diversity work, a recurrent selection breeding strategy has been developed that will involve the use of hybridization of identifiable promising genotypes as parents. The wide variability in germplasm collections of cashew offers opportunities for the exploitation of useful genes for improvement of the crop. However, to achieve the desired improvement through this breeding strategy, knowledge of basic cytology (number, structure and behaviour of chromosomes and pollen grain fertility) of these selections is very essential. The mitotic chromosomes of the studied accessions are presented in Fig. 6-8 with their corresponding schematic drawings. Diploid chromosome number of 2n = 42 was recorded among the two selected cashew populations. The karyotypic observations on the chromosomes were recorded among the Indian and Brazilian populations comprising mostly of medium and large jumbo sized nuts. The total length of the homologous chromosomes recorded for the Indian cashew population was found to be 51.10 µm, and chromosomes were designated 1 - 21, according to decreasing lengths. Karyotyping was based on the absolute length of the chromosome and ratio of chromosome short arms to long arms (centromeric location). The chromosome compliment gave a karyotypic formulae of 6Asm + 1Am + 4Bsm + 5Bm + 5Cm, while A represent chromosome >3.00 µm, B = 1.50 - 2.99 µm and C < 1.49 µm. Meanwhile, the chromosome lengths ranged between 1.00 and 4.20 µm for the shortest and the longest respectively.

Based on the morphology of the chromosomes, the complement comprises of 6 long submetacentric, 1 long metacentric, 4 intermediate submetacentric, 5 intermediate metacentric and 5 small metacentric chromosomes with regular mitotic division. The mitotic metaphase chromosome of Brazilian cashew population is presented in Fig. The total length of the homologous chromosomes recorded for the Brazilian cashew population was found to be 56.00 µm. Individual chromosome length ranged between 1.00 and 4.50 µm. The chromosome karyotype was very similar to that of Indian population comprising, 6Asm + 1Am + 1Ast +9Bm+ 2Bsm + 2Cm. It however shows that the complement includes, 6 long submetacentric, 1 long metacentric, 1 long subtelocentric 9 intermediate metacentric, 2 intermediate submetacentric and 2 small metacentric chromosomes with regular mitotic division. Apart from the slight variation in the chromosome length observed between the two populations, the chromosome stainability and behaviour during different stages of cell division was quite similar and regular divisions were recorded in their anaphase phases (Fig. 9 and 10). Regular meiotic divisions of 21 bivalents were commonly recorded among the two studied population with common occurrence tetrads in their pollen mother cells. This observation is an indication of potential high fertility of the pollen grain of cashew acession in these two populations. Few triads signifying iregularities during meiosis (microsporogenesis) was obtained in the pollen mother cells of three Brazilian accessions (Fig. 11 and 12). The occurrence of triads in the pollen mother cells of these three accessions would probably have implication on the fertility of their pollens. The chromosome lengths recorded in haploid set in this study tends to group into 3 sets (A B and C of karyotypic formulae), probably corroborating the 7x basic chromosome number. Mabberley (1997) reported basic chromosome number of between 7 and 16 in *Anacardiaceae.* The relative similarity to previous findings probably suggests that the crop species is relatively stable, with very little changes in the chromosomes. The similarity in chromosome number of the accessions in the two evaluated cashew populations also suggest that the materials are morphologically and genomically close, and probably have a common progenitor. The chromosome morphology of these two populations was very similar with respect to the range and gradation of chromosome length and the position of centromere. The chromosomes are mostly metacentric and submetacentric with regular mitotic cell division. Although the chromosomes are relatively small, slight differences in their size and morphology were detected. Most of the accessions analysed for the two populations have symmetric karyotypes, composed mainly of metacentric pairs with several submetacentrics.

The presence of a pair of subtelocentric chromosome in the Brazilian population would seem to be exceptional in the cashew cultivars. This fact probably suggests intraspecies variation, accompanied by few changes in the karyotype constitiution of the species. Degree of genomic closeness observed suggests that gene exchange among the accessions could be possible. Regularity of the chromosome behaviour during meiotic division and free flow of gene exchange observed in the fruit set study attest to the commonness of the progenitor of these accessions. Close similarity in the chromosome number, behaviour and structure of these accessions corroborate high degree of similarity in the tree morphological appearance. Regularity of chromosome behavior during meiotic cell division probably attests to the high pollen grain fertility recorded among the selections. It is concluded that despite the increased cultivation of cashew as a commodity crop in sub-Saharan Africa, Asia and South America there are few chromosome studies on it. The present study investigates number, structure and behavior of chromosome in cashew populations growing in Nigeria. Cytological examination of these populations revealed a diploid and haploid chromosomes of 2n = 42 and n = 21 respectively.

The karyotypes were mostly symmetric, composed mainly of metacentric pairs and several submetacentrics. Similarity in the morphology, number and behavior of the chromosomes in the accessions from different populations or origin attests to the degree of genetic closeness of the selections. This probably indicates high potential for use as parents in the breeding and improvement of cashew with very limited cross-incompatibility barriers (free gene exchange). Polymorphism in chromosome number was not recorded among these cashew selections. The diploid chromosome number of 2n = 42 and haploid of n = 21 obtained in this study agrees with Hutchinson and Dalziel (1954), but disagree with the polymorphism of 2n = 24, 30, 40, and 42 reported by Deckers *et al.* (2001). Archack *et al*. (2003b) quoted Purseglove (1988) that cashew has a chromosome number of 2n = 42; however, the ploidy is unclear. The accessions are probably polyploids with basic chromosome number x = 7.

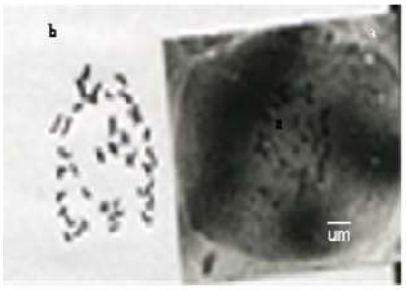


Fig. 6. (a): Mitotic chromosomes of Indian cashew accession. (b): The corresponding schematic drawings. Magnification: x400

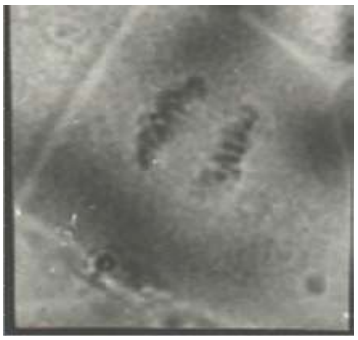


Fig. 7: Late anaphase of Indian cashew accession showing regular mitotic chromosome division. Magnification: x400

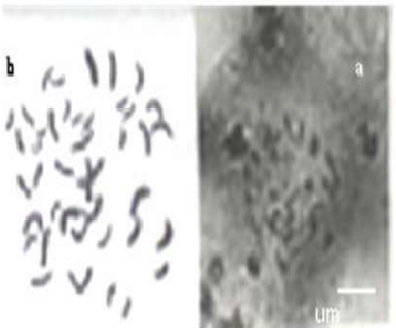


Fig. 8: (a): Mitotic metaphase chromosomes of Brazilian cashew accession. (b): The corresponding schematic drawings. Magnification: x400

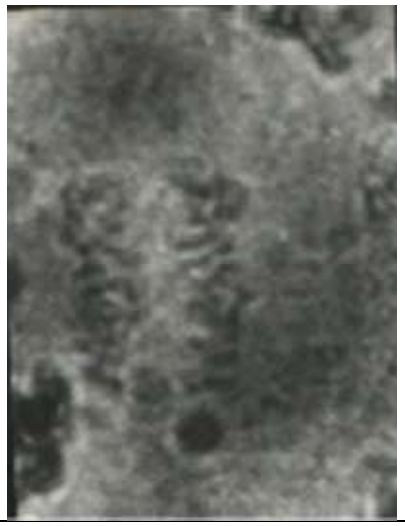


Fig. 9. Late anaphase of Brazilian cashew accession showing regular mitotic chromosome division. Magnification: x400

Fig. 10. Mieotic cell division in Indian (a) and Brazilian

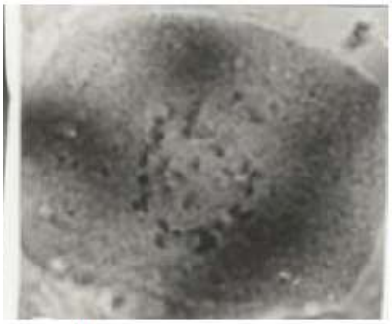


Fig. 10. Mieotic cell division in Indian (b) cashew accessions showing 21 bivalents

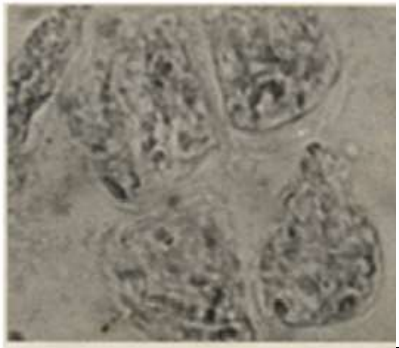


Fig. 11. Tetrads in pollen mother cell showing regular meiotic division. Magnification: x400

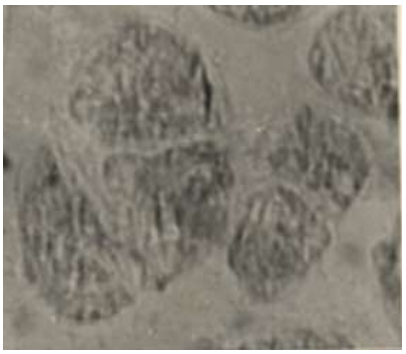


Fig. 12. Triads showing irregularities in microsporogenesis in Brazilian accessions. Magnification: x400

GENETIC DIVERSITY

A total collection of 292 accessions were systematically evaluated and characterized using IBPGR germplasm descriptor list at National Research Centre for Cashew, Puttur 574 202, Karnataka, India. Considerable variation was noticed among the collections for some economic characters, viz., the season of flowering, duration of flowering, apple colour, apple shape , apple weight, nut weight (2.4-18.0 g), kernel to whole nut ratio (19.0-32.0%) etc. In addition, different ideotypes like dwarf and bushy habit, erect/tall types; compact /loose canopy etc have been classified.

The germplasm accessions evaluated exhibited a considerable amount of diversity for some of the economic characters (Table 2) (Fig. 13). The data obtained revealed that the flowering season of all the accessions ranged from October- January. Early flowering genotypes are desirable as they escape from major pests like tea mosquito and there will be abundance of pollinators and the produce gets premium price in the market. The flowering period ranged from 40-127 days. Genotypes with short flowering period are desirable. Protracted flowering period contributes to high yields but the harvesting period will be long, resulting in more harvesting costs. Therefore, genotypes that complete flowering in one flush are good (Ohler 1979). The

harvesting period ranged from 30 to 105 days. However, the genotypes with short harvesting period are desirable, which will reduce the collection costs considerablyThe number of fruits borne on the panicles contributes to the yield. High yielding trees will have 5 to 10 fruits/panicle. The range was 1 to 8 fruits/panicle in most of the germplasm collections. The range of variability for apple weight was 30 to 150 gWhere apple is utilized for juice exploitation, increased weight of apple is important. The nut weight ranged from 2.4 to 1 8.0 g. Bold nuts yield big size kernels and hence ideal for export purpose. However, nuts having shell thickness more, the shelling per cent will be low. Apple to nut ratio ranged from 4:1 to 12:1. Where nut yield is important, using a genotype with a lower ratio and where apple yield is important selection of a genotype with higher ratio is desirable. The kernel weight, kernel count, shelling percentage and shell thickness are all interrelated. Kernel weight ranged from 0.5 to 4.5 g and kernel count from 1 00-900/lb. For export purposes, a kernel weight of more than 2g (Nair et al., 1979) with a kernel count of less than 210 wholes/lb is preferred. The shelling percentage ranged from 19.0 to 32.0 per cent and shell thickness ranged from 1.5 to 5.0 mm. Genotypes with thin shell and high shelling percentage are desirable. A genotype which is completely free from cashew nut shell liquid (CNSL) with a very thin shell is available in the germplasm collection. The production of such nuts might cause great changes in the processing industry, considerably reducing the costs. There would be no danger of CNSL contamination of the kernel and the kernel-to-whole nut ratio would be much higher. In the germplasm collection ideal genotypes with an yield potential of 8 kg and more /tree /year with a mean nut weight of more than 7 g per nut are available, which are ideal. Therefore, crop improvement through selection on the basis of individual tree yield appears to be promising. The plant habit varied from erect to bushy (dwarf) to spreading types. The dwarf genotypes exhibit two major advantages viz., smaller tree size and earlincss of bearing. Individual tree yields may be lower than those of common varieties. However, high density orchards of selected high yielding dwarf clones are considered to have the potential nut yield several times more than the common standard sized cashew trees. An erect genotype with upright growing branches suitable for the high density orchards and genotype which produces purple leaves are available in the present collection. The collections also include three related species viz., *A. microcarpum* (slow growing tree, 5-6g nut weight), *A. pumilum* (dwarf and slow growing tree. 1.0 g nut weight) and *A. orthonianum* (slower growing and erect tree, 2.0 -2.5 g nut weight), which are graft compatible with *A. occidentaie.* The variability observed in the accessions for some of the economic characters reveals its utilisation in the future crop improvement program (Swamy and Thimmappaiah, 1991).

Table 2. Variability recorded for some of the characters in the germplasm accessions

Character	Range
Flowering period	October–January
Flowering duration	40–127 days
Harvesting duration	30–105 days
No. of fruits/panicle	1-8
Apple weight	30-150 g.
Nut weight	2.4 - 18.0 g.
Apple: nut ratio	4:1 - 12:1
Kernel weight	0.5 - 4.5 g
Kernel count	100 – 900/lb.
Kernel: wholenut ratio (shelling %)	19.0 – 32.0%
Shell thickness	1.5 – 5.0 mm
Mean yield/plant/year (Mean of 10 years)	0.50 – 11.75 kg.
Plant habit	Erect/bushy/spreading
Canopy shape	Compact/medium sparse
Apple colour	Yellow/pink/red
Apple shape	Round/pear/long
Coherence of nut with apple	Loose/tight.

Nagaraja *et al*. (2007) have charecterizes 33 varieties and 79 germplasm accessions of cashew for biochemical composition of apple juice (tannin, flavonoids, sugars, ascorbic acid and organoleptic acceptability) and pomace (protein, carbohydrate, sugar, tannin and crude fibre). Based on the variability noted, quality indices have been developed and the varieties and accessions with desirable qualities identified. Among the varieties and accessions analysed, the variety Jhargram-1 and the accession NRC-190 were the best for cashew apple juice, while the varieties NRC Selection-1, BLA 139-1 and Bhubaneshwar-1 and the accessions NRC-160 and NRC-247 were found to have the best cashew apple pomace characteristics.

Fig. 13a. Variability for cashew apple color, shape and size

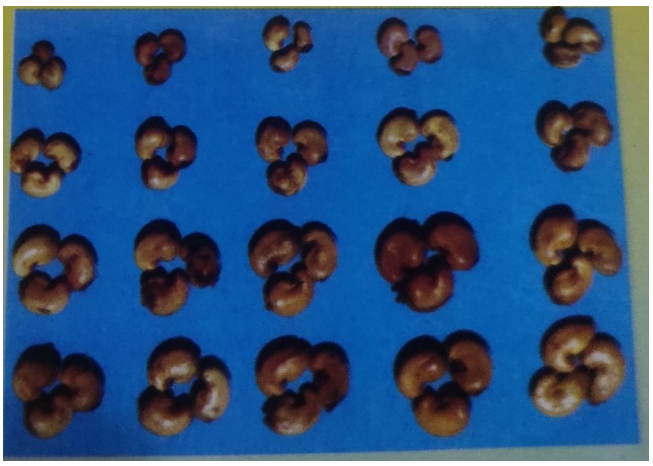


Fig. 13b: Variability for nut size

Fg. 13c: Variability for kernel size

Fig. 13. Genetic variability in cashew

Anik *et al.* (2002) have estimated the genetic diversity among 90 germplasm accessions of cashew using random amplified polymorphic DNA (RAPD) markers. A dendrogram was constructed using Ward's squared euclidean distance method which confirmed that the diversity of Indian cashew collection can be considered to be "moderate" to "high". A core collection has been identified based on the study which represents the same diversity as the entire population.

This could be the first step towards more efficient management of cashew germplasm in India.

For any meaningful genetic improvement programs, a vast understanding of the genetic diversity of existing germplasm is essentially important. DNA based markers in genetic analysis of cashew have been attempted in Brazil (Neto *et al.,* 1995), India (Karihaloo and Archak, 2000), and Tanzania (Mneney *et al*., 2001). Diversity studies undertaken in Tanzania and India revealed a narrow genetic base within geographic cashew variety groups (Mneney et al., 2001; Archak et al., 2003). Sika *et al.* (2015) characterized the genetic diversity of Benin's cashew accessions by SSR (simple sequence repeat) markers. Sixty cashew morphotypes from three regions of Benin, West Africa, were analyzed using eight SSR markers. A total of 146 polymorphic bands were produced. The polymorphic bands showed low genetic diversity (Shannon index = 0.04) that are relatively important for an imported species. Low diversity was found in North western regions compared to the other two regions (Center and North East). Genetic distance-based UPGMA dendrogram and Principal Coordinate Analysis (PCoA) showed a genetic differentiation between morphotypes. This genetic differentiation allowed us to cluster the samples into three clusters based on their genetic variations. This work further provides genetic information for the improvement of cashew production, conservation and better management of *A. occidentale* genetic resources in Benin.

Kambale *et al*. (2018) undertook a study to analyse the genetic diversity of 9 varieties of cashew obtainedfrom Regional Fruit Research Station (RFRS), Vengurle. The study indicated that ISSR markers are suitable for the assessment of genetic diversity among different varieties of cashew. Such information may be useful for selecting the diverse parents and monitoring the genetic diversity for improvement of cashew. Similarly, these varieties will be protected from commercial exploitation, since the genetic profile is available . Bhadra *et al.* (2019) observed a total of 33 reproducible bands and 74.12% polymorphism. Primers OPB-15 and OPK-03 yielded 100% polymorphism respectively. Cluster analysis revealed two main distinct groups, first group included GP-1 and the second consisted of five genotypes *viz.* GP-2, GP-3, GP-4, GP-5and GP-6 The major cluster- II was further subdivided into two minor clusters i.e. minor cluster- III and IV. The genetic distance between the groups was found low and varied from 0.002 to 0.0308. Maximum genetic distance was observed between GP-1 and GP-2 cashew germplasm and minimum between GP-5 and GP-6. In spite of having some limitations such as use of limited number of germplasm, the result of this study could be used as a guideline for future diversity assessment and genetic analysis of cashew in Bangladesh. The analysis of genetic relationships in cashew using RAPD bandingrevealed that the method is appropriate enough to evaluate the genetic relationships in cashew nut tree and thus the RAPD markers can generate wide array of polymorphism for varietal identification, study of genetic diversity and genetic conservation, and could be successfully used in cashew breeding program.

The characterization, variability/ genetic diversity as well as relationship among accessions determine its proper utilization in the breeding programmes. The present day breeding for the improvement of the cashew aims to enhance the quality cashew nut particularly the commercially important traits like nut size and its biochemical properties. Both traditional and molecular breeding approaches were exploited for cashew breeding as evident from the present reviews of previously published literature. Cashew breeding is mostly based on traditional methods of selection of useful traits, which is based on morphological and biochemical attributes which are not much reliable and sometimes misleading. Molecular markers are considerably efficient, robust, multiple allelic, co-dominant, highly polymorphic and reproducible. RAPD and ISSR endowed precisely for differentiating cashew cultivars when compared with morphological descriptors. The molecular markers like RAPD and ISSR have been exploited more in comparison to more reproducible SSR and AFLP markers. To accelerate conventional breeding QTLs that can be co-segregated with different useful traits have tobe exploited to introgress polygenic traits in desired background of Cashew genotypes (Das *et al.,* 2021). The Cashew is a flowering tree, native to northeastern Brazil, where it is called by its Portuguese name *Caju* (the fruit) or *Cajueiro* (the tree). It is now widely grown in tropical climates for its cashew "nuts" (and cashew apples. It is a small evergreen tree growing to 10-12 m tall, with a short, often irregularly-shaped trunk. The leaves are spirally arranged, leathery textured, elliptic to obovate, 4 to 22 cm long and 2 to 15 cm broad, with a smooth margin. The flowers are produced in a panicle or corymb up to 26 cm long, each flower small, pale green at first then turning reddish, with five slender, acute petals 7 to 15 mm long. What appears to be the fruit of the cashew tree is an oval or pear-shaped accessory fruit or false fruit that develops from the receptacle of the cashew flower. The true fruit of the cashew tree is a kidney or boxing-glove shaped drupe that grows at the end of the pseudofruit. Actually, the drupe develops first on the tree, and then the peduncle expands into the pseudofruit. Within the true fruit is a single seed, the cashew nut. Although a nut in the culinary sense, in the botanical sense the fruit of the cashew is a seed. However, the true fruit is classified as a nut by some botanists. The seed is surrounded by a double shell containing a caustic phenolic resin, urushiol, a potent skin irritant toxin also found in the related poison ivy. Some people are allergic to cashews, but cashews are a less frequent allergen than some other nuts (Anon., 2023).

BREEDING

Collection of Genetic Resources: Eventhough no reliable records of the introductions are available, it is presumed that the initial introductions in the Malabar Coast of Kerala were from only few trees and due to the hardy nature of the crop it has spread to all the coastal regions of India naturally. All these introductions were belonging to Anacardium occidentale. The initial empahsis was only on the establishment of plantations of seedling origin. As cashew is primarly a cross pollinated crop, it is highly heterozygous. Considerable segregation has resulted in large variation in the populations (Bhaskara Rao and Bhat, 1996). The early attempts for germplasm collections were made during the early 1950s with the sanctioning of Ad-hoc Schemes in the then composite States of Madras, Travancore, Cochin and Bombay. The research stations started under these Ad-hoc Schemes in Kerala (Kottarakkara), Karnataka (Ullal), Tamil Nadu (Vridhachalam), Anhdra Pradesh (Bapatla) and Maharashtra (Vengurla) took up the programme of collection of locally available elite plants for evaluation and further selection. These were the first attempts in collection of cashew germplasm in India. Many of the other research centres which were established subsequently have collected the seeds of germplasm from the centres, namely, Bapatla, Kottarakkara, Ullal, Vridhachalam and Vengurla. While making the initial collections of germplasm these centres have confined their survey mainly to the respective States and hence they represent the local germplasm available in the States . Since the inception of All India Coordinated Spices and Cashew Improvement Project in 1971, Central Plantation Crops Research Institute (CPCRI) Regional Station, Vittal, also took up the programme of cashew germplasm collection which mainly consisted of the seedling progenies of the collections which are available at Bapatla, Vridhachalam, Vengurla, Anakkayam and a few collections made locally from Karnataka (Swamy, 2011). Subsequent to the establishment of National Research Centre for Cashew (NRCC) at Puttur (presently, Directorate of Cashew Research-DCR), the germplasm collection through seeds has been discontinued and only the vegetative material (scion sticks) are being collected, the clones (softwood grafts) are prepared and conserved in the National Cashew Field Gene Bank (NCFGB). A coordinated approach was brought in the cashew gemplasm collection by organising joint survey teams consisting of scientists of NRCC/ DCR and the All India Coordinated Research Project on Cashew (AICRP on Cashew) centres of the respective States. Since 1986, cashew germplasm collection surveys are being under taken by NRCC/ DCR in collaboration with AICRP on cashew centres (9) and the cashew growing States, namely, Karnataka, Kerala, Maharashtra, Goa, Tamil Nadu, Andhra Pradesh, Orissa and West Bengal have been surveyed for germplasm collection (Swamy, 2011).

Conservation of Genetic Resources: *In situ* conservation of cashew germplasm is done only in the Amazon forests of Brazil (original home of cashew). However, *ex situ* conservation is generally being followed in cashew. Like in all other tree crops, the cashew germplasm is maintained as an active collection in the field gene bank which locks up the land for a long time. Further, field maintenance also has the inherent danger of losing the valuable collections during the natural calamities (as it often happens in the East Coast, especially at Bapatla centre due to cyclones). In order to overcome this danger as well as to effectively utilize the land for other field experiments, suitable *in vitro* preservation / cryo-preservation methods with the aid of biotechnology are to be developed. An effort in this direction is being made by establishing Biotechnology laboratory at DCR Puttur (Swamy, 2011). Presently a total of 1225 Cashew germplasm accessions have been collected and conserved in National Cashew Field Gene Bank (NCFGB) at DCR Puttur (527) and in Regional Cashew Field Gene Banks (RCFGBs) at various centres of AICRP on Cashew, namely, Bapatla (132), Bhubaneswar (98), Jhargram (119), Vridhachalam (208), Madakkathara (130), Pilicode (43), Vengurla (302), Chintamani (128), Jagdalpur (65) (Bhat *et al*., 2010; (Swamy, 2011).

Evaluation and Documentation of Genetic Resources: Germplasm evaluation, in the broad sense and in the context of genetic resources, is the description of the material in a collection. It covers the whole range of activities starting from the receipt of new samples by the curator and growing these, characterisation and preliminary evaluation and also further detailed evaluation and documentation. The evaluation of gemrplasm is an important part of a variety development programme designed to utilize germplasm resources. As new accessions become available, it is important to identify and characterize the new materials so that researchers may incorporate lines with desirable characters into utilization programmes. The first steps of this evaluation are (i) to compile the passport data and (ii) to characterize the accessions for easily recognised traits (minimum descriptors) (Swamy, 2011).

Characterization and Cataloguing of Germplasm: For systematic characterisation of cashew gemrplasm each accession was grown in the field gene bank (@6 grafts/accession; spacing 6 m x 6 m) at RCFGB, Puttur, Karnataka. Agronomic recommended practices were adopted. Observations were recorded on 3 selected plants in each accession after 10^{th} year of planting and after obtaining 6 annual harvests for 68 descriptors. For cashew germplasm, IPBGR (presently IPGRI) "Cashew Descriptors" (IBPGR, 1986) available were followed. Cashew germplasm collection in the NCFGB at NRCC/ DCR, Puttur has 527 Accessions. A total of 285 accessions have been characterized as per IPGRI descriptors. Three germplasm catalogues for 255 accessions have been brought out (Swamy *et al,* 1997, 1998 and 2000; Bhat *et al*., 2010). These are the first efforts made in characterisation of clonal accessions of cashew in the world. By adopting K-clustering algorithm using centroid distance method under Indostat Statistical package the 255 accessions were grouped into 22 clusters based on 19 descriptors. From each group a 10 per cent sample size was randomly selected as core entries.

Molecular Markers / DNA Fingerprinting: Molecular markers like DNA markers [randomly amplified polymorphic DNA (RAPD), inter simple sequence repeats (ISSR), restriction fragment length polymorphism (RFLP), amplified fragment length polymorphism AFLPs)] and biochemical markers (isozyme protein) can be used for characterization of germplasm and somaclonal variants. DNA fingerprinting of varieties using RAPD markers is being done at NRC for DNA fingerprinting, New Delhi and Department of Horticulture, UAS, Bangalore. DNA finger printing of cashew germplasm is being carried out in collaboration with Division of Horticulture, UAS, Bangalore under DST funded project. Leaf samples of 153 accessions (NRC 1 – 153) of cashew have been supplied from NCGB. RAPD markers generated by 7 selected operon primers (10 base-long) which produced 123 consistent, unambiguous, repeatable bands ranging from 400 bp to 3 Kbp were used to assess the diversity among 90 accessions. About 40 per cent of the samples were repeated to confirm the results. The analysis of the results (squared euclidean distance, Ward's clustering) revealed that the diversity in India cashew germplasm is moderate but not narrow as reported. Attempts have been made to fingerprint cashew genetic markers (Archak et al, 2003a, 2003b; Thimmappaiah et al., 2009a, 2009b).

Archak *et al*. (2003a) have developed the molecular profiles of 35 Indian accessions of cashew (24 varieties and 11 hybrids) with increased yield and excellent nut characters) using a combination of five RAPD and four ISSR primers pre-selected for maximum discrimination and repeatability. A total of 94 markers were generated which discriminated all the varieties with a probability of identical match by chance of $2.8 \times 10{-}11$. There was no correlation between the relationships based on molecular data and the pedigree of the varieties. Narrow range of average similarity values among major cashew breeding centres with only 3.6% of molecular variance partitioned between them was attributed to the exchange of genetic material in developing varieties. Difference in the average similarity coefficients between selections and hybrids was low indicating the need and scope for identification of more parental lines in enhancing the effectiveness of hybridisation programme. Archak *et al. (*2003b) have also analysed nineteen cashew accessions (8 varieties and 11 accessions) with 50 random primers, 12 ISSR primers and 6 AFLP primer pairs to compare the efficiency and utility of these techniques for detecting variation in cashew germplasm. Each marker system could discriminate between all of the accessions, albeit with varied efficiency of polymorphism detection. AFLP exhibited maximum discrimination efficiency with a genotype index of 1. The utility of each molecular marker technique, expressed as marker index, was estimated as a function of average band informativeness and effective multiplex ratio. Marker index was calculated to be more than 10 times higher in AFLP than in RAPD and ISSR. Similarity matrices were determined based on the data generated by molecular and morphometric analyses, and compared for congruency. AFLP displayed no correspondence with RAPD and ISSR. Correlation between ISSR and RAPD similarity matrices was low but significant ($r = 0.63$; $p < 0.005$). The similarity matrix based on morphometric markers exhibited no correlation with any of the molecular markers. AFLP, with its superior marker utility, was concluded to be the marker of choice for cashew genetic analysis. At DCR 239 accessions have been fingerprinted by Thimmappaiah *et al* (2009a). Low-level diversity has been observed in 40 elite varieties using RAPD, ISSR and SSR markers. Moderate diversity has been reported in cashew population using protein isoenzyme electrophoretic analysis (Thimmappaiah *et al.,* 2009a, and 2009b).

Assigning Indigenous Collection Numbers (IC No.) to Germplasm: In order to safeguard our national interest in the field of plant genetic resources, national identity numbers/ indigenous collection numbers (IC Nos) are being assigned to crop gemrplasm by the National Bureau of Plant Genetic Resources (NBPGR), New Delhi. In order to obtain IC numbers for the cashew germplasm holding in the country, the passport data for 1149 cashew accessions maintained at NCFGB and RCFGBs in the country have been compiled and submitted to NBPGR, New Delhi. IC Numbers have been assigned by NBPGR for 433 clonal accessions of cashew that are being conserved in NCFGB at Puttur and for the 716 accessions of cashew accessions which are being maintained at RCFGBs, namely, Chintamani (53), Vengurla (142), Pilicode (64), Madakkathara (73), Vridhachalam (250), Bapatla (80), Bhubaneswar (5) and Jhargram (49) (Swamy *et al.,* 2002; Swamy, 2011).

Registration of Unique Germplasm: Nine novel unique germplasm accessions of cashew maintained at DCR Puttur, namely NRC-59, 111, 116, 120, 121, 140, 142, 152, and 201, have been registered with the National Bureau of Plant Genetic Resources (NBPGR), New Delhi. These unique accessions have been assigned the INGR No. 03080 to 03088 by NBPGR (NBPGR, 2006; Swamy, 2011).

Utilization of Genetic Resources: By utilizing the existing cashew germplasm in the country, the following 40 high-yielding varieties of cashew have been developed and released by the Directorate of Cashew Research, Puttur, and various Agricultural Universities (Abdul Salam and Bhaskara Rao, 2001; Bhat *et al.* (2010): DCR Puttur (NRCC Selection-1, NRCC Selection-2 and Bhaskara); Bapatla

(BPP-1 to BPP-6 and BPP-8); Vridhachalam (VRI-1, VRI-2, VRI-3 and VRI- 5); Bhubaneswar (Bhubaneswar-1); Jhargram (Jhargram-1); Vengurla (Vengurla-1 to Vengurla-7); Goa (Goa-1 and Goa-2); Madakkathara [Anakkayam-1, Madak-1 (BLA-39-4), Madak-2 (NDR-2-1), K-22-1, Kanaka, Dhana, Priyanka and Amrutha]; Ullal (Ullal-1, Ullal-2, Ullal-3, Ullal-4, UN-50); Chintamani (Chintamani-1 and Chintamani-2). Of these, 13 are hybrids and 27 are selections. In addition to these varieties/ selections, 13 hybrids have been developed by utilizing gemrplasm accessions as parents in the hybridisation programme. Till recently the emphasis has been on selecting or producing a hybrid having high yield only and size of the nut was not given much importance till 1980s. Currently efforts are made at all the cashew research stations in the country to identify few accessions with bold nuts for improving the nut size in the prolific bearing varieties. Crop improvement programme through hybridization is receiving greater attention in almost all the cashew research centres of India. Crop improvement programme in Australia also is centered around development of hybrids wherein thousands of hybrids are produced using parents of wide genetic diversity obtained from different countries especially from India and Brazil (Chacko, *et al.,* 1990; Chacko, 1993). A total of 65 accessions in NCFGB have also been utilized as parents (female 55 and male 10) in the hybridisation programme under the ad-hoc research scheme entitled "Network programme on hybridisation in cashew", which was in operation at NRCC/ DCR and AICRP on Cashew Centres (Bhubaneswar, Vengurla, Madakkathara and Vridhachalam) (Swamy, 2011).

Breeding for improved genotypes: Good planting material is a very important input in crop production because it determines the upper limits on yield and the ultimate productivity of other inputs. Objectives of crop improvement in cashew generally include development of new high yielding commercial varieties with such characters as desired tree size (dwarf / semi dwarf canopy), bold nut size (>8 g) with higher shelling percentage (>28%) and higher kernel grade (180 to 210W), bigger and juicy apple, resistance / tolerance to biotic stress (pests and diseases) and abiotic stress (Bhaskara Rao, 1998; Bhaskara Rao **et al.,** 1998). Besides the above (with respect to Nigerian cashew quality) breeding for increased testa peelability is very novel so as to improve Nigerian competitiveness in the cashew global market. Screening of the wide germplasm for these and other traits may lead to the identification of some specific genotypes which may be selected, multiplied and released to farmers. While such procedure may lead to short term variety release, wide crossing of parents in a breeding programme would be necessary for introgression of some economic traits with composite features in hybrid varieties. Currently, Nigeria Cashew germplasm consists mainly of exotic varieties (Adebola and Esan, 2002); there is no record of an improved hybrid cashew as is obtained in some other producing countries.

Cashew quality: Generally, the mode of production, collection and storage practises affect the quality of cashew nuts. Smallholding farmers may harvest apple to meet urgent cash needs, without minding the maturity status of nuts. This practice contributes to about 40% post-harvest losses of cashew nuts. Immature nuts have high moisture content and are unfit for export. Inadequate drying and improper storage, for example, the use of polythene bags instead of jute bags to store harvested cashew nuts enhances the deterioration of stored kernels. Training farmers on good cashew production practises right from the field to storage might help to alleviate defects in nut quality due to these factors. In addition, government support for smallholder farmers to improve their livelihood would reduce the menace of harvesting immature nuts. Due to poor peelability of cashew testa from the kernel, about 64% of the total labour for processing 180 metric tonnes of raw nuts by a small-scale processing plant per month is expended on peeling testa alone (CII, 2002). This has brought significant losses to processors and indirectly Nigerian Cashew farmers. While this problem explain for loses and poor pricing of the Nigerian Cashew, it equally answers for its poor acceptability in the global market. The possible cause either genetic or environmental needs to be investigated. Solution through research would be most welcome as this would enhance the acceptability and worthwhile pricing of Nigerian Cashew. It would also encourage small-scale cashew processors who cannot afford high cost peeling machines. Probable research activities to solving this problem may include: Exploration and collection of cashew genetic resources, evaluation for peelability and trait-specific selection for onward breeding program.

Cashew varieties recommended for different State: So far 61 varieties in India have been released for cultivation as a result of evaluation of germplasm collection and hybridization and selection. These varieties have been released from different research centers of SAUs and DCR (formerly NRCC). Among them 34 are selections and 27 are hybrids. Out of these varieties, salient features of popular varieties are presented below (Eradasappa, 2022):

***Varieties released from AICRP (Cashew) Center, Bapatla, Dr.YSR Horticultural Unioversity, West Godavari,* BPP 8 (H 2/16):** It is a hybrid (H2/16) derived from the cross Tree No.1 x Tree No.39 and released in 1993 for general cultivation in Andhra Pradesh. It has been performing well in Orissa and West Bengal also. This variety is superior to all the other six varieties developed from Bapatla. The variety has mean yield of 14 kg/tree with better nut size (8.2g). Shelling percentage (29%) of this variety is also better than the rest of the varieties released from Bapatla so far. Kernel grade is W210 (export grade).

Varieties released from AICRP (Cashew) Center, Vridachalam, TNAU, Tamil Nadu

VRI-3 (M 26/2): This is a selection from seedling progeny of a high yielding tree collected from a village Edayanchavadi in South Arcot District of TamilNadu and was released in 1991. It has 12.1% perfect flowers. The average yield of this variety is about 10 kg/tree, thus the increase over VRI-2 and VRI-1 being 35 to 39% respectively. The nut size is medium with 7.2gnut weight and shelling percentage of 29.1%. The kernel grade conforms to W 210 export grade. This variety is picking up fast among farmers of not only of Tamil Nadu but also of other states.

VRI (Cw)-5: It is a hybrid developed from the cross M 26/2 (VRI-3) x M 26/1. This was released in the year 2007. The canopy type is compact and branching habit is spreading. The average yield of this variety is about 13.2 kg/tree. The nut size is medium with 7.2g nut weight and shelling percentage of 30.5%. The kernel grade is W 210. The apple colour is pink with yellowtinge and the shape is round and the apple weight is ranging from 50.0 to 53.5 g. This is recommended for all the cashew growing districts of Tamil Nadu.

Varieties released from AICRP (Cashew) Center, OUAT, Bhubaneshwar, Odisha

Bhubaneswar-1: It is a selection from seedling progeny of WBDC V (Vengurla 36/3), a collection from Regional Fruit Research Station, Vengurla and released in 1989. Flowering season is from January to March with medium duration of 70 days. It has cluster bearing habit with about 12 fruits per bunch. This variety has average yield of 10 kg/tree with small nut size (4.6g nut weight). The shelling percentage is high (32%) with kernel grade of W 320. It has been found suitable for cultivation in the sandy and lateritesoils of the East Coast.

Jagannath (BH 6): It is a mid-season flowering Jan-Mar) variety having bold nuts with 8.6 g nut weight. The variety gives an average nut yield of 2.1 t/ha (10.5 kg/tree) and possesses highshelling percentage (32.5 %).

Balabhadra (BH 85): It is an Early flowering (Dec-Feb) variety having bold nuts with 7.4 g nut weight. The variety gives an average nut yield of 2.0 t/ha (10.0 kg/tree) and possesses high shelling percentage (30.0 %).

Varieties released from AICRP (Cashew) Center, Jhargram, BCKV, Kalyani, West Bengal

Jhargram-1: It is a selection from T.No.16 originally collected from Bapatla. It was eleased in the year 1989. It has a medium compact canopy andintensive branching habit. It has on an average,6 fruits per bunch and yield of 8.5 kg/tree with small nut size (5g nut weight). Shelling percentage is 30 and kernel grade is W 320.

Bidhan Jhargram-2: It is selection made from seedling plantation of H-2/15 of Regional Research Station, Bidan Chandra Krishi Viswa Vidyalaya, Jhargram, West Bengal. The variety has mid-season flowering habit with 3-4 fruits per panicle. Appleis golden yellow with a weight of 63g and a meanjuice content of 68.9 per cent. The average nut weight is 9.2g with a kernel weight of 2.85g and high shelling (32%). The kernel grade is W 180.The variety can yield 13.5 kg/tree in 7thharvest

Varieties released from AICRP (Cashew) Center, Vengurla, KKV, Dapoli, Maharashtra: Based on the evaluation of selections from germplasm and hybrid progenies in varietal evaluation trialsconducted at Regional Fruit Research Station, Vengurla, the Konkan Krishi Vidyapeeth (KKV), Dapoli has released the following seven varieties for cultivation in Maharashtra. These varieties have been found to perform well in Goa also. Vengurla-1 and Vengurla-4 are doing well in Uttar Kannada district of Karnataka also. Varieties such as Vengurla-4 and Vengurla-7 are in great demand from farmers.

Vengurla-4: This is a hybrid variety with the parentage of Midnapore Red x Vetore 56 and was also released in 1981. It is a cluster bearing type andwith percentage of perfect flowers of 35 and fruitset of 6%. The yield of nuts is 17.2 kg/tree. The nut weight is 7.7g and shelling percentage is 31. The colour of the apple is red. Kernel gradeis 210 (export grade).

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

Vengurla-9: This is hybrid released in year 2015 in AGM -2015 of AICRP-Cashew. It is a cross between V-4 and VRI-1 (M10/4). It is middle to late season variety with 111 days of flowering duration and is bunch bearing variety with intensive branching. The nuts weight: is 8.9 g with 112 nuts per kg. It gives high yield (7.24 kg/tree) and has shelling percentage of 29.35%. The apple colour is reddish yellow and appleweight: is 69.71 g.

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

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

Goa-2 (Tiswadi-3): Goa-2 was developed and released from ICAR Research Complex, Goa in 2007. It is a selection from Ela village of Tiswadi taluk of North Goa District. The average yield of Goa-2 is 5.5 kg/tree with nut weight of 9.4 g (range : 9.2 – 9.6 g) and the shelling percentage of 29.25. Kernel weight is 2.3 g. The kernel grade is W 210. Apple colour is yellowish orange with cylindrical shape and with average weightof 105 g. Juice content ranges from 68.0 – 72.0 per cent. It is recommended to the state of Goa.

Varieties released by AICRP (Cashew) Center, Madakkathara, KAU, Thrissur

Madakkathara-2: This is a selection from germplasm collection made from Neduvellur in Kerala maintained at CRS, Anakkayam. This variety was also released in 1987. The mean yield is 17 kg/tree. The nuts are bold (7.3 g nut weight) with shelling percentage of 26.2%. Kernel weight is 2g having a count of W 240 export grade. Apple colour is red and with weight of apple 63.3g. Reducing sugar content is 7.8%.

Kanaka (H 1598): It is a hybrid of cross BLA 139-1 X H 3 - 13 released in 1993 from CRS, Madakkathara. It is an early variety. Average yield is 19 kg/tree with a mean nut weight of 6.8g. Shelling percentage is 31%. Kernel weight is 2.1g and quality of kernels conform to W 210 export grade. Colour of apple is yellow.

Dhana (H 1608): It is a hybrid of cross ALGD-1 X K 30-1 released from CRS, Madakkathara in 1993. It has cluster bearing habit. The mean yield is 17.5 kg/tree with a shelling percentage of 28. Kernel weight is 2.2g conforming to export grade of W 210. Yellow is the apple colour.

Priyanka (H 1591): This is a hybrid with parentage of BLA 139-1 X K 30-1 with jumbo nut size developed and released from CRS, Madakkathara in 1995. The yield of nuts is 16.9 kg/tree. The nut weight is 10.8g with kernel weight of 2.87g. Shelling percentage is 26.5. The export grade of kernels conforms to W 180. Colour of apple is yellowish red. Apple weight is 135g. Apple has 57.4% of juice.

Amrutha (H 1597): This is a hybrid with parentage of BLA 139-1 x H 3-13 developed and released from CRS, Madakkathara in 1999. It has yield potential of 18.4 Kg/tree with nut weight of 7.2 g. Shelling percentage is 31.6 and with kernel weight of 2.2 g and kernel grade W 210. Colour of apple is yellow and apple weight is 76.0 g. Apple has 57.4% juice content. It is recommended to the state of Kerala.

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

Varieties released from AHRS, Ullal, UAHS, Shivamogga, Karnataka

Ullal-1: This is a selection from the germplasm collected from Taliparamba in Kerala (8/46 Taliparamba) and released by ARS, UAS in 1984. The variety has 2-3% of bisexual flowers. The average yield is 16 kg/tree. The duration of harvest is long (about 110 days). The nut weight is 6.7g with shelling percentage of 30.7%. The colour of apple is yellow. Kernel grade is W210.

Ullal-3: It is a selection from 5/37 Manjeri and released in 1993. It is early in flowering (November - January) and fruiting period is very short (50-60 days). The fruiting is from January to March and sometimes starts from last week of December. It is a high yielding variety with average yield of 14.7 kg/tree. The nut size is medium with nut weight of 7g. The shelling percentage is 30% and the kernel grade conforming to W 210 grade. The colour of apple is red.

Varieties released from ICAR-DCR, Puttur

Bhaskara: This variety was released during March 2006 for coastal region of Karnataka. This is having midseason flowering habit (Dec-Mar) with a flowering duration of 60 days and has potential to escape from the attack of the tea mosquito bug (TMB) under low to moderate outbreak situation. But the regular insecticidal spray against TMB is essential under severe outbreak situation. The number of fruits per panicle (bunch) ranged from 4 -13. The average yield on 13th year was 10.7 kg/tree with highest yield of 19 kg/tree. The nut and kernel weight are 7.4 g and 2.2 g respectively. The shelling percentage is 30.6 and kernel grade conforms to export grade W240. The apple colour is pinkish orange and juice content is 67.5%. This variety is very popular among the farmers of Dakshina Kannada District of Karnataka and also in neighbouring districts of Karnataka and Kerala.

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

Nethra Vaaman: The country was hitherto lacking dwarf cashew genotypes and for the first time, the Directorate has identified a dwarf cashew variety named Nethra Vaaman. The dwarf genotype was selected from the seedling progenies planted out of imported bulk nuts samples of Brazil. Upon characterisation and evaluation, its slow growth and dwarf character was confirmed. This was evaluated for ten years and recently it is released and recommended for cultivation. The Nethra Vaaman can be maintained with minimum pruning and trimming as an orchard management practice. The genotype is moderately susceptible to major pest of cashew i.e Tea Mosquito Bug (TMB) like any other cashew variety but it is easier to take up plant protection sprays as plants are dwarf. The variety seems to be also amenable for homestead and terrace gardens, and for bonsai cultivation. However, high yield cannot be expected because of its dwarf nature. Tree height (10th year) is 2.5 m (dwarf). Tree Spread (10th year) without pruning is 6.0 m. It has precocious flowering with long duration (>90 days). Nut weight is 5.5 to 6.0 g. It bears glossy, red colour, crispy and less fibrous cashew apples with 50 g weight. It has shelling percentage of 30% and the kernel grade is W 320. It shows special character of stem galling. Its nut yield is 1.2-1.5 kg (4th year of planting).

Nethra Jumbo-1

Nethra Jumbo-1 is a jumbo nut hybrid released in 2021 for west coast region. Nethra Jumbo is an early season bearer with short flowering duration. The flowering starts from December and continues up to March and the peak flowering will be in January and February. The nut weight ranges from 11 to 13 g with an average nut weight of 12 g per nut. The nuts have high shelling percentage (29.1) with 3.66 cm nut length, 2.73 cm nut width and 2.41 cm nut thickness with 18.5 % of CNSL content in the shell. The kernels are bold with 3.4 g average weight and fits in to kernel grade W130. It bears attractive red coloured apples which weigh around 100g per apple with conical to obovate shape. The apples have TSS of 13 ∘ B with 72 per cent of juice content. The season of harvest starts from January and continues till March end. The duration of harvesting period is less which helps to save the labour on picking of nuts. The early availability of raw nuts will help to catch high market price prevailing during early part of cashew season. A ten-year-old tree has a potential to yield around 10 kg per tree. The added advantage of this hybrid is uniformity in nut size, wherein, more than 90 % of nuts are uniform in size. As this hybrid is an early flowering type, the advantage of higher market price in the beginning of cashew season can be exploited. This hybrid can also escape severe pre monsoon moisture stress as compared to late varieties.

***Varieties from HRS, Hogalagere (Earlier at Chintamani), UHS, Bagalko*t**

Chintamani-1: It is a selection from 8/46 Taliparamba, a germplasm collection from Taliparamba in Kerala and released in 1993 from ARS, Chintamani. This variety is recommended for plain region of Karnataka. Its flowering period is from January to April with 2-4 nuts per panicle. The average yield of this variety is 7.2 kg/tree as against the 2 kg/tree of the local varieties. The nut weight is 6.9g with shelling percentage of 31%. The kernel grade is W 210.

Chintamani-2: It is a seedling selection from ME 4/4 of ARS, Ullal and released in 2007 from ARS, Chintamani. This variety is also recommended for plain region of Karnataka. The canopy type is compact and with intensive branching. Its flowering period is from December to January. The average yield of this variety is 12.4 kg/tree. The nut weight is 7.9g with shelling percentage of 30%. The kernel weight is 2.35 g. The kernel grade conforms to W 210. The colour of the apple is red purple with average weight of apple of 70g. Juice content is 60%.

Cashew varieties recommended for different states are given in Table 3.

Table 3. The state-wise recommended varieties

varieties recommended for different States	Recommended varieties
Karnataka	NRCC Sel-2, Bhaskara, Nethra Ganga (H-130), Nethra Vaaman, NethraJumbo-1, Ullal-1, Ullal-3, Ullal-4, UN-50, Vengurla-1 (Uttara Kannada),Vengurla-4 (Uttara Kannada), Vengurla-7 (Uttara Kannada)
Karnataka (Plainsregion)	Chintamani-1, Chintamani-2, Dhana , Vengurla-4, Vengurla-7
Kerala	BLA-39-4 (Madak-1), NDR-2-1 (Madak-2), K-22-1, Kanaka (H 1598), Dhana (H 1608), Priyanka (H 1591), Amrutha (H 1597), VRI-3
Maharashtra	Vengurla-1, Vengurla-4, Vengurla-6, Vengurla-7 , Vengurla-8, Vengurla-9
Goa	Goa-1, Goa-2, Goa-3, Goa-4, Vengurla-1, Vengurla-4, Vengurla-6, Vengurla-7, Vengurla-9
West Bengal	Jhargram-1, Bidan Jhargram-2, BPP-8
Orissa	Bhubaneswar-1, Balabhadra, Jagannath, BPP-8, Dhana
Tamil Nadu	VRI-3, VRI (Cw) 5
Andhra Pradesh	BPP-4, BPP-6, BPP-8 , , BPP-10, , BPP-11
Chattisgarh	Indira Kaju-1

Processed cashew kernel comes in different grades. The classification of cashew kernel is given in Table 4.

Table 4. Classification of Cashew kernel

White Wholes	ScorchedWholes	DessertWholes	WhitePieces	Scorched Pieces	DessertPieces
WW-180 WW-210 WW-240 WW-320 WW-450WW-500	SW-180 SW-210 SW-240 SW-320 SW-450SW-500	SSW (ScorchedWholes Seconds) DW (Dessertwholes)	B (Butts) JH (JumboHalf) S (Splits) LWP (LargeWhite Pieces) SWP (SmallWhite Pieces) BB (BabyBits)	SS (ScorchedSplits) SP (ScorchedPieces)	DP (Dessert Pieces)

Cultivars Developed in Brazil: Brazil clearly needs a more productive germplasm as yields per unit are now very low. "Cashew Comum" and "Cashew Anao Precoce" are the two populations or "types" responsible for these results: the first is characterized by big trees (10-20 m), fruit and cashew apple size variability and production differences from one tree to another. It is the commonest type, in English speaking countries it is called "*Brazilian common*". The second is smaller and its foliage less, it is an early plant with a smaller fruit and cashew apple. In English speaking countries it is called "*Brazilian dwarf*". Both varieties have undergone genetic treatment to fulfil a number of requirements: to increase unit production, with a higher number of fruits per inflorescences, to increase inflorescence per plant and average fruit weights; to obtain resistance to some plant disease such as anthracnose, mainly responsible for production fall in Brazil; to improve fruit quality namely by decreasing tannin contents; to obtain a long flowering and thus prolong the harvesting season, so as to have a well defined harvesting period (NOMISMA, 1994). Recently research by the EMBRAPA-CNPCa carried out in the Ceara State has made it possible to detect, isolate and multiply 4"anao precoce" clones, with excellent production and quality features. The four clones of precocious dwarf cashew tree presently available for planting were developed through individual phenotypic selection from germplasm existing in the Experimental Farm of Pacajus, Ceara, which is native of the municipality of Maranguape, Ceara, by utilization of the polycross method for increasing variability and clonal selection in order to identify the best clones. These clones are characterized by low stature, permitting the mannual harvesting of almost all fruits, and making possible the utilization of the peduncle which is not possible in cashew orchards of the common type; precocious development, hastening the first profitable production from the 4th to the 2nd year; seasonal precociousness, initiating fructification at least 30 days earlier than that of the common type; longer productive cycle, by around 60 days, than the common cashew, thus increasing utilization of the peduncle. Low stature, precociousness and productive potential permit utilization of management techniques impossible in traditional orchards, such as pruning and control of pests and diseases, resulting in greater productivity, reducing the time necessary for recuperation of the capital invested from the 17th year to the 7th. This tree modernizes cashew culture: productivity increases from 250 kg/ha in traditional plantings to 1300 kg/ha and may reach yields above 2000 kg/ha (NOMISMA, 1994) (Fig.14) (Table 5).

Fig. 14. Brazilian Dwarf cashew (Cajueiro Anao Precoce)

Table 5. Salient features of four cashew clones

Clones	Colour of cashew apple	Nut Average weight (g)	Average Prdouction (kg/ha/yr)				
			1st year	2nd year	3rd year	4th year	5th year
CPP06	Yellow	6.5	14	82	755	783	905
CPP09	Yellowish	8.5	51	184	367	367	712
CCP76	Reddish	9.0	31	163	306	307	571
CCP1001	Red	5.5	65	367	557	1187	1493

CCP= Caju Clone de Pacajus
Source: EMBRAPA-CNCPa, technical communication 1991

Method of cashew propagation: Cashew is propagated mainly from the seed in Nigeria. Since seed nut incorporate a wide range of genetic diversity, the genetic integrity of a particular clone or genotype can only be preserved through vegetative propagation. Several methods of vegetative propagation have been attempted in cashew viz., air layering, inarching, budding, marcotting or grafting which may be epicotyls, soft wood, or flush side grafting. The degree of success of each varied in different countries with attending limitations. Of all the methods, grafting was reported to be the best for large-scale clonal production of cashew. Tip or bud grafting is used in East Africa, India, Brazil, and Ghana and up to 100% success rate have been obtained with 10-week old seedlings. Some factors identified to affect the success of grafting includes period of the year or season of grafting. For example, period with high maximum temperature and minimum humidity were marked with higher rate of grafting success. Moreover, the type of propagation structure (mist house, green house, open air and under shade) and the length of the scion have equally been identified as success determining factors (Sagar, 2007). However, soft wood grafting technique has been found to be the best method of propagation and it is recommended for commercial multiplication of cashew varieties. The technic of soft wood grafting is shown in Fig. 15 (Swamy et al., 1998).

Scion shoots

Seedlings showing different steps of soft wood grafting

Soft wood Grafts in the Nursery

Fig. 15. Soft wood grafting technique in Cashew

USES

Orwa *et al*. (2009) reported the varying uses of cashew as follows:

Food: *A. occidentale* is cultivated for its nuts. Botanically, the nut is the fruit; the cashew apple is the swollen, fleshy fruit stalk. The seeds kernels are extracted by shelling the roasted nuts. In production areas, cashew serves as food. Elsewhere it forms a delicacy. The kernels are nutritious, containing fats, proteins, carbohydrates, vitamins and minerals. In Brazil, Mozambique and Indonesia, the cashew apple is also important; it is eaten fresh or mixed in fruit salads, and a drink is prepared from the juice; sweets and jams can also be prepared from it. Young shoots and leaves are eaten fresh or cooked.

Fodder: The cake remaining after oil has been extracted from the kernel serves as animal food. Seed coats are used as poultry feed.

Fuel: The wood is popular for firewood and charcoal. The residue of the shell is often used as fuel in cashew nut shell liquid extraction plants.

Fiber: Pulp from the wood is used to fabricate corrugated and hardboard boxes.

Timber: The wood of *A. occidentale* ('white mahogany' in Latin America) is fairly hard with a density of 500 kg/cm. It finds useful applications in wheel hubs, yoke, fishing boats, furniture, false ceilings and interior decoration. Boxes made from the wood are collapsible but are strong enough to compete with conventional wooden packing cases.

Gum or resin: The bark contains an acrid sap of thick brown resin, which becomes black on exposure to air. This is used as indelible ink in marking and printing linens and cottons. The resin is also used as a varnish, a preservative for fishnets and a flux for solder metals. The stem also yields an amber-coloured gum, which is partly soluble in water, the main portion swelling into a jellylike mass. This gum is used as an adhesive (for woodwork panels, plywood, bookbinding), partly because it has insecticidal properties.

Tannin or dyestuff: The acrid sap of the bark contains 3-5% tannin and is employed in the tanning industry.

Lipids: An oil, cashew nut shell liquid, is produced in the large cells of the pericarp; it has industrial applications and is used as a preservative to treat, for instance, wooden structures and fishing nets. It is also in good demand for paints, synthetic resins, laminated products, brake linings and clutch facings.

Alcohol: In Brazil, Mozambique and Indonesia cashew wine (slightly fermented juice) is enjoyed at harvest time and can be distilled to produce strong alcoholic drinks. In Goa, India, fermenting the juice makes a type of brandy called 'fenni'. In Tanzania, a product called 'konyagi', akin to gin, is made from cashew apple. **Poison:** One of the components of the bark gum acts as a vesicant and has insect repellent properties.

Medicine: Cashew syrup is a good remedy for coughs and colds. Cashew apple juice is said to be effective for the treatment of syphilis. Root infusion is an excellent purgative. Old cashew liquor in small doses cures stomach-ache. The oil obtained from the shell by maceration in spirit is applied to cure cracks on the sole of the feet, common in villagers. Cashew apple is anti-scorbutic, astringent and diuretic, and is used for cholera and kidney troubles. Bark is astringent, counterirritant, rubefacient, vesicant, and used for ulcer. Cashew nut shell oil is anti-hypertensive and purgative; it is used for blood sugar problems, kidney troubles, cholera, cracks on soles of feet, hookworms, corns and warts. The kernel is a demulcent, an emollient and is used for diarrhoea. Buds and young leaves are used for skin diseases. The resinous juice of seeds is used for mental derangement, heart palpitation, rheumatism; it was used to cure the loss of memory that was a sequel to smallpox.

Reclamation: Because of its extreme tolerance of external conditions, it has been planted in poor soils to check erosion.

Intercropping: Has been intercropped with cowpea, groundnuts and horsegram in India. In Andra Pradesh and Orissa in India, casuarina and coconut constitute a popular crop combination.

Research into end use potentials of cashew promoted the development of various innovative products from its apple and nuts. Value addition through processing of agricultural produce has potential to improve it shelve life and increase income of producers (Lawal and Jaiyeola, 2007). Cashew kernels are roasted, fried, spiced, or honey coated and sold in different packages and sizes as snacks. Oil has been mechanically extracted from the cashew kernel which has higher stability at 80 degrees centigrade compared with other commercial oils like palm oil, groundnut oil, corn oil, or cocoa butter. The cashew kernel oil is promising for food and industrial uses. There has been development of improved technique for processing cashew apples into wine, jam, and non-alcoholic beverage of a high nutritional value with vitamin C content of 170-180 mg/100 ml juice. Local juice extractor/processor that produces cashew apple juice adaptable for use on a cottage industry scale has been fabricated and found economically viable. Developed cashew meal from the kernel including bread, candy, cake, biscuits coated with chocolate is found to have good and acceptable organoleptic properties. Cashew nut shells have been incorporated in fertilizer composition, ruminant feeds and hydraulic paints. In view of the food, industrial and medicinal uses to which cashew tree and its products can be put (Table 6), it appears to be one of the most intensively utilised plant in the world. It offers continual opportunity for investment, as well as great potential for economic development (Olife *et al.,* 2013). Cashew kernels are imported in large quantities by the United States and western European countries. The kernels are salted and eaten as a snack and they are used extensively in the manufacture of candies, cakes, cashew flour and cashew butter. Cashew kernels are highly recommended because, in contrast to the peanut, there is no risk of aflatoxin poisoning (Mitchell and Mori, 1987). The kernels are eaten either fresh or roasted and contain a milky juice which is used in puddings. The kernels are roasted and salted and the dried and broken kernels are sometimes imported to mix with old Madeira as they greatly improve its flavour. In roasting great care must be taken not to let the fumes cover the face or hands *etc*., as they cause acute inflammation and external poisoning. Ground and mixed with cocoa the kernels make a good chocolate. Cashew is a versatile nut with its unique combination of unsaturated fatty acids, proteins, carbohydrates, minerals and vitamins. India is the largest producer, processor and exporter of cashew in the world, followed by Brazil and Vietnam. At present cashew is consumed as a snack food in all parts of the world. There is, however, good scope for promoting cashew as a food ingredient as it blends well with every food preparation style. International Nut Council adopted a declaration calling for an international tree nut agreement under the auspices of United Nations Conference on Trade and Development (UNCTAD) with the objective of promoting the consumption of edible tree nuts on a worldwide basis (Nayar, 1998).

The cashew nut shell liquid (CNSL), contained in the oil cavities of the fruit wall, is a toxic yet very important by-product of the cashew industry. CNSL consists primarily of cardol, cardanol and anacardic acid. The CNSL is used in the manufacture of plastics, paints, resins and varnishes . In Tanzania, CNSL has been used for making tribal marks and scars on the face and body and in other countries, it is employed in preserving fish nets, protecting books, and in softening chicken eggs. Anacadic acid, the active ingredients in CNSL, is an effective larvicide used in the control of malaria-carrying mosquitoes. Anacardic acid also kills the snail hosts of schistosomes and inhibits the metabolism of several species of bacteria and molds. CNSL is useful as an anthelmintic against ascaridiasis (Mitchell and Mori, 1987). While the kernel of cashew continues to be the main product of commerce, the CNSL is used as an industrial raw material in the manufacture of paints, varnishes, brake linings for automobiles, friction dust etc (Nayar, 1998). The oil must be used with great caution, but has been successfully applied to corns, warts, ringworms, cancerous ulcers and even elephantiasis, and has been used in beauty culture to remove the skin of the face in order to grow a new one. The hypocarp (apple) is succulent, sweet to very acidic in taste, and very fragrant. It is either eaten raw, compressed and strained to extract juice, fermented into cashew wine, or made into syrup, preserves, chutney, candy, pickles, or used as an ice cream flavour. The hypocarp, often called the cashew apple or pear, is a rich source of vitamin A and vitamin C. In some countries, such as Brazil, the drupe (nut) is less important than the hypocarp (apple). Medical uses of the hypocarp (apple) are varied and include the following: mouth wash and gargle; boiled in sweetened water and used as a treatment for dysentery; treatment for uterine ailments and dropsy; and as a diuretic. Hypocarp tannins are used as an antihypertensive (Mitchell and Mori, 1987). The apple is a red or yellow and has a pleasant subacidic stringent taste, the expressed juice of the fruit makes a good wine, and if distilled, a spirit much better than arrack or rum. The fruit itself is edible, and its juice has been found of service in uterine complaints and dropsy. It is a powerful diuretic.

Table 6. Uses of cashew tree, apple and nut

Cashew parts	Products	Uses	Medicinal importance	Source
cashew tree	Leaves and stem back	For making local concoction	Bactericidal, germicidal, and herbal heath benefit: stops diarrhoea, dry secretion, increase the libido; reduce fever, blood sugar and pressure.	Olife et al. (2013), Dahake (2009), Masaki (1999)
Cashew stem and branches	Wood/timber	Furniture, fishing boats and ship rollers (highly resistant to termite attack)		Chipojola et al. (2009)
cashew stem	Ink and vanishes	Indelible ink for marking and printing linens and cottons		
	Glues	Adhesive for woodwork panels, plywood and bookbinding. Insecticidal properties which prevent insects eating new boxes and books		
Apple	Apple concentrate	For making Juice, juice concentrates, liquor, vinegar, jam, and beverages.	Has higher vitamin C content than guava, mango, and oranges (146.6 - 372.0 mg / 100g fresh apple juice)	Olife et al. (2013)
	Apple flesh	For making pickle, chutney and candied products		
	Pressed cake from apple	Used for cattle feed after drying		
Cashew nut	Cashew kernel	For making snacks, confectioneries, butter, milk	High in protein (21%), carbohydrate (22%), oil, vitamins (thiamine), and 47% fat (heart friendly monounsaturated fatty acid); also rich in manganese, potassium, copper, iron, magnesium, zinc, selenium and zea-xanthin for preventing deficiency diseases and serving as antioxidants	Blomhoff et al. (2006)
	Cashew nut kernel oil (CNKO)	Sweet edible oil		
	Pressed cake from CNK (pomase)	Human and animal feed		
Cashew nut shell	Cashew nut shell liquid (CNSL)	Has high proportion of phenolic compounds. Manufacture of vehicle break lining compounds, water proofing agents, preservative, paints, plastics, type writer rollers, oil and acid-proof cements, industrial floor tiles	Potent antimicrobial agent for treating scurvy, sores, warts, ring worm, psoriasis, leprosy, elephantiasis, and corns.	Mc Conville (1997)

The pseudo fruit of the cashew, the cashew apple, is being utilized to a limited extent in India for conversion into alcoholic drinks and several processed products like cashew apple juice, beverages, jam, jelly, candy and vinegar (Nayar, 1998). The young leaves are edible and older leaves in combination with other plants are used to treat skin diseases and burns. The bark has a variety of medicinal uses such as the treatment of diarrhea and constipation; a gargle; a treatment for ulcers in the mouth; a febrifuge; a medication to lower blood sugar; and a cure for tooth ache and sore gums. The bark and inflorescences are used in traditional Indian remedies for snake bite. The sap, which oxidizes black upon exposure to the air, is employed as an indelible ink marker for cottons and linens. It is also used as varnish and a flux to solder metals. A gum, which exudes from the bark, is used as a substitute for gum Arabic in book binding. The wood is employed locally for construction, storage cases, boats, wheel hubs, and as a fuel (Mitchell and Mori, 1987). The cashew tree is mainly used as fire-wood but also for certain commercial purposes like manufacture of plywood, particle boards (Nayar, 1998). The black juice of the nut (CNSL) and the milky juice from the tree after incision are made into an indelible marking-ink; the stems of the flowers also give a milky juice which when dried is hard and black and is used as a varnish. A gum is also found in the plant having the same qualities as gum arabic; it is imported from South America under the name of *Cadjii gum*, and used by South American bookbinders, who wash their books with it to keep away moths and ants. The caustic oil found in the layers of the fruit (nut) is sometimes rubbed into the floors of houses in India to keep white ants away.

NUTRITIONAL VALUE

The seed (kernel) is highly nutritious (Bakhru, 1988a and 1988b) containing approximately 20 per cent good quality protein, 40 per cent fat (of which about 80% are non-saturated fatty acids) (Agnoloni and Giuliani, 1977) and 26 per cent carbohydrates (IBPGR., 1986). Nagaraja and Nambudari (1986) have chemically characterized the cashew apples and kernels from 16 high yielding varieties and have reported a good amount of variability for kernel protein (32.1 – 43.7%), starch (23.1 – 33.1%), total sugar (9.3 – 19.2%), amino acids (34.3 – 50.5%) and phenols (28.2 – 59.3%) and for apple ascorbic acid (144.4 – 269.1 mg. 100 g^{-1} fresh weight of cashew apple), total

sugar (5.5 – 8.0%), reducing sugar (5.5 – 7.5%), amino acids (7.5 – 15.1%), phenols (8.2 – 23.0%), and tannins (27.4 – 153.4%). Murthy and Yadava (1972) have studied the oil and carbohydrate content of 24 cashew types and reported considerable variability for oil content of shell (16.5 – 32.9%), oil content of kernel (34.4 – 46.7%), kernel reducing sugar (0.9 – 3.1%), kernel non-reducing sugar (1.3 – 5.7%) and kernel total sugar (2.4 – 8.7%). The protein content of the kernel varies from 13.3 to 25.03 per cent. The kernels are very nutritious, containing vitamins A, D and K and between 200-210 mg/100 g of vitamin E. Substantial amounts of calcium, phosphorus and iron are also present (Mitchell and Mori, 1987). Cashew is most versatile of all nuts and is the most popular nut used by the confectionery industry. In USA alone 87 per cent of the cashew nuts are used in nut salting. Whole kernels and pieces are being used in formulating confections, cakes and cookeries. The nuts are exalbuminous and rich in protein, calcium, phosphorus, unsaturated fats. Vitamins (B1, B2, D, E and PP), low in carbohydrates and saturated fats (Table 7). Hence, they are of high nutritive value. As the nut fats are complete, very active and easily digestible, the nuts can be used by both old and infants alike (Nair *et al.,* 1979).

Table 7. Composition of cashew kernels

Constituents	Percentage	Constituents Aminoacids	Percentage
Moisture	5.9	Arginine	10.3
Protein	21.0	Cystine	1.3
Fat	47.0	Histidine	1.8
Carbohydrate	22.0	Lysine	3.3
P	0.45	Methionine	1.3
Ca	0.55	Phenylalanine	4.4
Fe	5.0 mg/100 g	Threonine	2.8
		Tryosine	3.2
		Valine	4.5

The fleshy peduncle of the fruit is called “cashew apple”, although most types are rather pear –shaped than apple-shaped. The apple is juicy and sweet when ripe and it varies in size, shape, colour, juice content and taste. Aiyadurai (1966) reported the existence of yellow, red and pink coloured apples. Albuquerque *et al.* (1960) noticed that the yellow apple tended to be heavier, softer and less astringent than red apples. Usually the apple is 10 times heavier than the nut. The apple is a rich source of vitamin C (250 mg/100 g fresh weight) which is 5 times higher than the vitamin C content of an orange (IBPGR., 1986). Since cashew apples perish within a few days after harvest they are only sold in local markets or processed as juice. In Brazil, Mozambique and Indonesia cashew apple is also important: it is eaten fresh or mixed in fruit salads and a drink is prepared from the juice. Cashew wine (slightly fermented juice) is enjoyed at harvest time and can be distilled to produce strong alcoholic drinks (Van Eijnatten, 1991). The apple is very juicy and the expressed juice has a brix of 12-14° containing 10.15 – 12.5% sugars (mostly reducing) and about 0.35% acid (as malic). It is known for its rich vitamin C content, upto five times that of citrus fruit. The apple is eaten as such by sucking the juice and discarding the residual fibrous mass. Sugar or salt is added sometimes for reducing the astringency (Nair *et al.,* 1979) (Table 8).

Table 8. Chemical composition of cashew apple

Constituents	**Percentage**
Moisture	87.8
Proteins	0.2
Fat	0.1
Carbohydrate	11.6
Calcium	0.01
P	0.01
Fe	0.2 mg/100 g
Vitamin C	261.5 mg/100 g
Minerals	0.2
B carotene	0.09

You might see cashews labeled "raw" in the supermarket, but all cashews undergo some heat in the process to remove the shell and caustic substance. Cashews sold as "roasted" have been cooked twice—once during the shelling process and then roasted to deepen the color and enhance the flavor, sometimes with salt. You will also find dry-roasted, meaning the nuts were cooked without any added oil. Because they are high in heart-healthy monounsaturated fatty acids, cashews make some superfoods lists for their concentration of protein, fiber, minerals, and antioxidants. Though technically a seed, the cashew generally gets the culinary treatment of a nut. You can buy them whole to eat as a snack out of hand or puréed into butter for use as a spread or smoothie ingredient. Owing to their creamy texture when blended, cashews have become a popular ingredient used to make dairy alternatives. This includes cashew milk, nut-based cheese, and nut-based cream sauces and sour cream (Filippone, 2022). Cashew is a highly nutritious and concentrated form of food, providing a substantial amount of energy. The cashew nut kernel has a pleasant taste and flavor and can be eaten raw, fried and sometimes salted or sweetened with sugar. It also contributes as an important source of invisible fat in the diet, being widely used in a variety of ways. There has been a growing demand for cashew in many temperate countries where the demand is increasing. The nut contains an acrid compound which is a powerful vessicant that is abrasive to the skin. The cashew shell contains 25% of this reddish brown oil, industrially known as Cashew Nut Shell Liquid (CNSL) which is a by-product of the roasting process. The kernel is considered to be of high nutritive quality and growing conditions or the variety of cashew may have an influence on kernel composition. The overall composition of the kernel is protein 21%, fat 46% and carbohydrates 25% (Nandi, 2023). One of the most commonly consumed nuts in the world; Cashew kernels contain many beneficial nutrients for health. In which, fat content accounts for 44.9%, starch accounts for 19.82%, sugar is 13.48%; in addition to containing 2.49% of calcium, iron phosphorus and vitamins like B1, B2, D , E, PP. In addition to cashews, cashews apple also have many nutritional components that are beneficial to health. According to studies in the cashew fruit contains vitamin C content 5 times more than oranges; in addition to vitamin B2 along with minerals, protein, sugar and tannin very good for health. In fact, cashew apple can be eaten raw, mixed with vegetables (salad) or processed into fruit juice. This juice can be distilled to produce alcoholic beverages (Asia Commodities, 2023).

HEALTH BENEFITS

Cashew is a versatile tree nut. It is, in fact, a precious gift of nature to mankind. The cashew kernels is a unique combination of fats, proteins, carbohydrates, minerals and vitamins. Cashew contains 47 per cent fat, but 82 per cent of this fat is unsaturated fatty acids. The unsaturated fat content of cashew not only eliminates the possibility of the increase of cholesterol, but also balances or reduces the cholesterol level in the blood. Cashew also contain 21 per cent proteins and 22 per cent carbohydrates and the right combination of amino acids, minerals and vitamins and therefore nutritionally, it stands on a par with milk, eggs and meat. As cashew has a very low content of carbohydrates, almost as low as 1 per cent soluble sugar, the consumer of cashew is privileged to get a sweet taste without having to worry about excess calories. Cashewnuts do not lead to obesity and help to control diabetes. In short, it is a good appetizer, an excellent nerve tonic, a stimulant and a body builder. Cashew is indigenous to Brazil, but India is the country that nourished this crop and made it a commodity of international trade and acclaim. Even today, India is the largest producer, processor, exporter and second largest consumer of cashew kernels in the world (Nayar, 1998).India with its extensive orchards and modern processing machinery, is the chief center of cashew production. Although A. occidentale is cultivated primarily for its kernel and fleshy hypocarp, it is occasionally used for reforestation in tropical America and in Dahomey (Mitchell and Mori, 1987). Research carried out at the University of Bologna has in fact indicated the presence in cashew kernel of numerous vitamins including vitamin E, considered by many to be aphrodisiac (Massari, 1994).

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