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Cashew (*Anacardium occidentale,* L.) Nut and Apple: A Review of Current Production and Handling Recommendations[1]

JULIO C. MONTEALEGRE,[2] NORMAN F. CHILDERS, STEVEN A. SARGENT,[3]
LEVI DE M. BARROS AND RICARDO E. ALVES[4]

Cashew production has been an important economic activity for many tropical countries, providing a variety of food and industrial products (17). The most notable of its products is the cashew nut. Cashew belongs to the family Anacardiaceae that also includes mango and pistachio. The tree gets its scientific name, *Anacardium occidentale,* L., from the heart-shaped nut (27). The cashew apple is actually a swollen receptacle, or false fruit, which supports the true fruit. Although the apple resembles a fleshy fruit, the protruding shell is actually the fruit which contains the prized kernel, or nut, inside.

The cashew tree is a hardy, fast-growing, evergreen perennial with a symmetrical, umbrella-like canopy (24). Although the tree resembles a large bush, it is a true evergreen tree and often attains heights of over 10 m (27). Roots reach vertically to a considerable depth and to a radius twice the canopy spread (1). Flowers are panicle-like, small pinkish, about 40% perfect and 60% male, and insect pollinated. About 70% of the perfect flowers fail to set nuts, resulting in only one or two nuts per inflorescence. Flowering to nut maturity takes from 55 to 70 days.

Of the 30-35 products from the cashew tree, the nut is the most valuable. The nuts are eaten mostly as snacks or used in confectionery and baked products. Among tree nuts, cashew ranks third in world economic importance after almonds and walnuts (26), with approximately 160,000 tons sold annually and a value of more than $2 billion (U.S.). In Brazil alone cashew generates 16,000 jobs in nut processing, 43,000 jobs in farm management and 280,000 temporary jobs during the harvest period (21). Revenues there have been estimated at $200 million a year in kernel exports, besides providing local taxes and a high but unknown value from the sale of the cashew apple and its by-products. The main markets of the cashew nut are the United States, (55%), the Netherlands (10%), Germany (10%), Japan (5%) and the United Kingdom (5%), about 85% of the total consumption. Of the roughly 160,000 tons of nuts that are traded annually, approximately 60% are consumed as salted nuts (24). The remainder is mostly used as an ingredient in confectionery and bakery products.

The fleshy cashew apple can be eaten raw or processed into a variety of products. Cashew fruit contributes to human nutrition by supplying vitamin C, averaging 200mg/100g of juice, four times that of orange juice (17). In several countries, cashew apple products such as juice, wine, vinegar, soft drinks and candies are widely commercialized, further raising the aggregate value of the cashew crop.

The precocious dwarf cashew tree, a selection developed in Brazilian fruit breeding programs (7), has been a very important achievement because it allows hand harvest without ladders and pro-

[1]Florida Agricultural Experiment Station journal series No. R-06540.
[2]Current address: American Agro-Enterprises, Chinandega, Nicaragua.
[3]Professor and corresponding author, and Professor, Horticultural Sciences Department P.O. Box 110690, University of Florida, Gainesville FL 32611-0690.
[4]Researchers. Embrapa/Agroindústria Tropical, C.P. 3761, 60.511-110 - Fortaleza, CE, Brazil.

motes early and expanded flowering and fruit set. With irrigation management, year-round production is possible, expanding the possibilities for both export and processing (12).

Furthermore, clones of the dwarf type have been selected which produce non-astringent, high vitamin C content and high-sugar cashew apples. Information generated by postharvest research on cashew apple has already produced a remarkable improvement in the commercialization of the fresh cashew apple in Brazil. Until recently, cashew apple was sold exclusively in local markets, whereas today it reaches supermarkets in other parts of the country located up to 4000 km from the main production areas in the Northeast of the country (22).

Another product of commercial importance is the cashew nut shell liquid (CNSL), which is extracted during processing of the nut. CNSL is an oily substance used in varnishes, lacquers, paints, and brake linings, for waterproofing, and as a preservative (26). The United States, Japan and Great Britain are the principal markets for CNSL. Although worldwide production of CNSL has increased steadily in recent years, it cannot be considered a valuable economic by-product due to price fluctuations. In 1984 CNSL sold for about $1,500/ ton (24), however, during the past 10 years, prices have been so low (about $300/ton) that CNSL has been utilized as a fuel within the cashew processing.

Medicinal uses include a mixture of the cashew bark and leaves for treating wounds, relieving toothaches and sore gums. It may also be taken internally for dysentery (26). The yellowish sap exuding from the bark repels insects and can be used as a bookbinding gum and as dye for tanning leather.

History of Cultivation

The cashew originated along the northeast coast of Brazil. It is believed that it was domesticated long before the arrival of the Europeans at the end of the fifteenth century (26). From Brazil, Carib natives probably took the cashew to the West Indies. However, it was not until the sixteenth century that Spanish sailors likely introduced the cashew to Central America and Panama (24). When the Portuguese arrived in Brazil, they soon recognized the value of the cashew apple and nut and took the crop to their colonies in the Old World (26). By 1590 the cashew tree had already been introduced to the Portuguese territories in East Africa and Goa (Portuguese India) used also to help control erosion along the coastal regions of these countries (27).

It was not until the beginning of the twentieth century that the nut entered world commerce (26). It is believed that the cashew was adapted so well in India that from there it spread to other parts of tropical Asia and East Africa, where today in Mozambique and Tanzania, cashew grows in the wild (24). Mozambique and Tanzania formally dominated global trade in cashew nuts, but production in those countries declined due to political instability in Mozambique and ineffective agricultural policies in Tanzania (26). In the period from 1975 to 1984, Mozambique's share of world cashew production fell from 27% to 5%; Tanzania's production declined by 7% to 12% of the world share.

As a result of the decline in production of these East African countries, India and Brazil are currently the world's leading producers of cashew nuts. India's share is 35%, Brazil is second with 25% and the combined East African nations' share is 25% (4). Countries throughout the tropics including Indonesia, Vietnam, Guatemala, Costa Rica, Venezuela, Peru, Thailand and Kenya make up the remaining 14%. Brazil's production increased 350% from 1975 to 1989 (26), where most of the 680,000 hectares were planted in the coastal areas of the semi-arid Northeast.

Climatic and Soil Requirements

The cashew is a hardy tree. The tree is somewhat tolerant of drought and can survive prolonged dry seasons of three to five months. Rosengarten (1984) states

that the tree flourishes in the extreme heat of the tropics but can be damaged by frost and it is sensitive to low temperatures when young (27). Dry weather has been recommended during the peak flowering period for best yields (1). The optimal growing conditions include: temperatures from 17°C to 38°C, relative humidity of 65-80%, sunlight from 1500 to 2000 hr/year and wind velocity of 2.25 km/h. Annual precipitation should range from 800 to 1800 mm and be well distributed over five to seven months, although the plant can survive and grow with less than 600 mm or as much as 4200 mm of rainfall.

The cashew tree is well suited to poor lateric or sandy soils (Smith et al., 1992). Good drainage is the main soil requirement (1). As previously mentioned, the tree is widely planted in coastal areas and is used to rehabilitate areas degraded by poorly managed pastures or slash-and-burn farming. Woodroof (1979) comments that the cashew tree is "extremely adaptable as to soil, flourishing even in the sand of open beaches, but it grows poorly in heavy clays or limestone." According to Rosengarten (1984), commercial cashew plantations are recommended in well-drained, friable soils at low elevations in the tropics. Although good soil and adequate moisture are essential for maximum productivity, it thrives to altitudes of about 1000 m (27) and tolerates a soil pH of 4.3 to 8.7.

Varieties

Although widely cultivated in tropical countries, there are still very few selected cultivars and most orchards are planted with seedlings (27, 7). This results in significant heterogeneity of important plant and fruit characteristics such as the canopy shape and tree height, nut and kernel weight, and peduncle characteristics. Traditionally, cultivars were only distinguished by peduncle characteristics such as color (red and yellow), shape (banana, pear, apple, etc.) and firmness (6). However, more recently cashew variability has been organized into two major groups consisting of common and dwarf types, which are mainly differentiated by plant height, canopy diameter, precocity and individual yield capacity (6). There are few recognized cultivars of cashew available.

In India, the National Research Center for Cashew (NRCC) is screening germplasm for resistance to tea mosquito (*Heliopeltis antonii,* Sign.) (26). The NRCC also has identified several dwarf accessions that are early bearing and highly productive. A high proportion of perfect flowers is also another priority characteristic. Several varieties have been selected based on yield and nut size. When selecting germplasm, it is important to keep in mind that tests have indicated that large shells usually have smaller kernels of low density, poor vitality and slow germination (27).

There has been a cashew breeding program in Brazil since the 1960's resulting in the dwarf selections which are cultivated today. This program has focused on individual selection, population selection, hybridization of common and dwarf types into dwarf types, and clonal evaluation. The selection criteria emphasize yield, precocity, plant height, and fruit and peduncle characteristics (6, 7). The dwarf selections developed in Brazil are providing an opportunity to adopt modern production and harvest techniques already utilized in several other tropical fruit crops throughout the world, changing the status of cashew in Brazil from an extractive crop to that of a major cultivated crop (7).

Since 1979, the Vengurla Cashew Research Station in western India has evaluated more than 557 hybrid progenies for high-yielding and superior quality characteristics (25). Apart from a high percentage of perfect flowers, three hybrids in particular have demonstrated other desirable characteristics such as high yields at an early age, medium-to-large nut, high shelling percentage and a large apple with a high juice content. Only through improved breeding and selection will cashew production be significantly increased.

Propagation

Due to the fact that most cashews are produced from seedlings, plantings are quite heterogeneous which causes considerable variation in yield, quality and the form of the fruit produced (24, 26). Research conducted by Rao and Pappiah (1979) showed enormous variations in yields, ranging from 0.5 to 200 kg/tree for mature trees. Other significant variations occurred in growth and other morphological characteristics. Acland (1971) contends that the reason for great variation in the performance of seedling trees is due to the high proportion of cross-pollination.

Because of the wide variations from tree to tree in seedling plantations, much effort has gone into asexual propagation (24). Budding, grafting, layering, cuttings and inarching all have been employed to vegetatively propagate trees with high yields. However, no simple technique has been developed that is "reliable, inexpensive and usable on a large scale" (2). For example, marcotting and inarching were found to be reliable in India but were slow and laborious. Adams cited budding and grafting as the most promising methods for vegetatively propagating cashew. Seedling rootstocks are difficult to grow since the delicate root system is easily damaged when transplanting rootstocks from pots to the field.

In Brazil, side grafting permits up to a 90% success rate when employed immediately prior to sprouting of new buds (9). Bud grafting has been equally effective when done during the reproductive phase, with plants ready prior to the start of the rainy season. The rapid adoption of precocious dwarf clones in the Brazilian northeast has led to the establishment of nurseries as a viable business enterprise.

Seed Germination and Culture

The cashew tree grows with a minimum of attention. It is vigorous, easily cultivated, and somewhat drought resistant. Most of the initial effort goes into the establishment of the plantation. Following removal from the shell, the seeds are typically stored in jute bags in a dry, well-ventilated storage facility (15, 11). There is little information published regarding seed germination, probably since there is almost 100% germination during the first four months of storage and about 95% germination up to six months. After six months storage, percent germination decreases rapidly depending on seed mass, seed quality and storage conditions.

Seeds that pass the density test (do not float when immersed in water) and are stored under dry, ventilated conditions have the longest storage life. Research at EMBRAPA's National Research Center for Tropical Crops (CNPAT) in Fortaleza, Ceara, has shown that after 12 months storage, small, thin seeds (up to 7 g) have the highest germination, up to 60%, while medium-size seeds (8 to 10 g) have about 50% germination. After six months storage large-size (11 to 14 g) and, particularly extra-large seeds (>15 g) have the highest loss in germination rate, with only about 20% after 12 months.

One of the chief causes for loss of germination in cashew seeds is the rapid growth of fungal organisms after 6 months storage. Preliminary tests made by EMBRAPA/CNPAT have shown that colonization of spores most likely occurs during pollination. Therefore, under ambient storage conditions, six months should be the maximum storage time necessary for good germination, since germplasm collections are normally maintained *in situ*. On the other hand, seeds stored under controlled conditions (about 22° C and low relative humidity) will germinate well after five years storage.

With respect to germination time, seeds stored less than four months begin to germinate after 13 or 14 days and continue until about 20 days. Seeds stored for six months or more require about 18 days to germinate. Seeds that require more than 20 days to germinate should be discarded. It should be pointed out that the density test for viability, used particularly in India, is only valid for cashew seeds up to 10 g. Extra-large seeds (>15 g) normally float, however they germinate rapidly and produce vigorous seedlings.

Soil temperature in nurseries is another important factor related to germination of cashew seeds. Gadelha, et al. (1994) showed that covering the soil with burlap resulted in less variation in soil temperature at a depth of 3 cm (28 to 39°C) and a higher percent germination (95.0% to 97.5%) than uncovered soil. A sawdust covering with soil temperatures ranging from 28.3 to 45.5°C had germination rates from 92.5% to 97.5%, while uncovered soil varied from 30.8 to 48.5°C with 75% germination. Also, soil covering affected seedling vigor after germination: burlap, sawdust and uncovered soils had 3.3%, 19.6% and 42.9% defective seedlings, respectively.

Other preliminary studies conducted at the Pacajus Experiment Station of EMBRAPA/CNPAT in Brazil showed the effects of salinity on germination and seedling growth. Seed germination occurred up to electrical conductivity of 1.32 ds/m (deciSiemens/m), while seedlings were more sensitive, withstanding only up to 1.25 ds/m.

Seeds are sown directly into the field, three seeds per stake, to ensure seedling survival during the season. After about one year of germination, only the most vigorous seedling is left per stake. Smith et al. (1992) advised that high-quality clones should be interplanted to reduce the danger of catastrophic outbreaks of diseases and pests.

Spacing recommendations for cashew trees vary. Rosengarten (1984) suggested that trees should be set about 10 m apart in commercial plantations. According to Acland (1971), initial spacing of 9 m is good if the plantation is thinned after seven years. In Kenya, the recommended spacing is 12 m. The recommendation for the Brazilian precocious dwarf types is 7x7 m, 8x6 m or 7x4 m, depending on growing conditions and management practices.

Field maintenance of cashew requires less time and money than for most perennial crops (1). Plantations should be kept relatively weed-free, especially during the early stages of growth. Weed control is important to avoid a fire hazard. Also, weeds conceal the fallen nuts. Minimal pruning is needed to provide space for nut collection and weed control. During the first three years lower branches and suckers are removed. In early years the area between trees can be intercropped with cash crops including cotton, peanut and cassava.

Seedling cashew trees bear fruit about the third year. Grafted dwarf types initiate flowering within six months and, when irrigated, produce up to 30 fruits by the end of the first year. Flowering lasts for two to three months and the fruit matures two months later (24). It is common to have flowers and fruits at different stages of development within the same panicle (10). Under favorable conditions the trees reach maximum production within seven years. Woodroof (1979) stated that a three-year-old tree bears an average of 3 kg of nuts while by the fifteenth year the average is 32 kg of nuts per tree. Trees are productive from 20 to 30 years with some trees bearing fruit for up to 45 years.

Fertilization

Ninety-seven percent of the world cashew production traditionally came from uncultivated seedling trees and small holdings, while at the most 3% is supplied by systematically planted plantations (24). Since the 1980's approximately 50% of Brazilian cashews are produced in medium to large plantations. In India no fertilizers are used by the majority of farmers (18). However, Indian researchers determined that regular applications of 250 g of N, 150 g of P_2O_5, and 150 g of K_2O per tree increased yields from less than 1 kg to over 4 kg of nuts/tree (18). Furthermore, applying fertilizer from planting increased yields more than 4 kg/tree by the fifth year.

Irrigation

Cashew trees produce a significant number of horizontal roots, leading to the erroneous assumption that the tree requires a period of drought to achieve proper flowering and that rainfall alone is

sufficient for maximum fruit yields. It was also thought that cashew could only withstand drought if tree spacing was wide enough to prevent overcrowding (1). This premise was based on the fact that cashew orchards worldwide were planted with common rootstocks with supposed resistance to severe drought. However, recent studies have demonstrated that low productivity of cashew trees under drought stress (220kg nuts/ha) is commercially unprofitable (10). Dwarf precocious cashew trees have attained yields of 5000 kg nuts/ha with the adoption of high density plantings and appropriate cultural practices of fertilization and irrigation (20).

Pests

The cashew tree has several serious pests and diseases which vary by growing region. Insect pests include the white fly (*Aleurodicus cocois,* Curtis), a caterpillar (*Anthistarcha binoculares*) a red beetle (*Crimissa* sp.) and a thrip (*Selenothrips rubrocinctus*). The flies, *Helopeltis anacardii* and *H. schoutedeni,* cause damage by feeding on leaves, young shoots and inflorescences (1). In wet weather, a complex of fungi attacks inflorescences.

In Brazil, the most significant pests are: a caterpillar which attacks new shoots (*Antistacha binocularis*), the nut moth (*Anacampis* sp.), an aphid which feeds on inflorescences (*Aphis gossypii*), thrips (*Selenothrips rubrocinctus*), a trunk borer (*Marshallius* sp.) and a caterpillar (*Thagona* sp) (16).

Freire and Cardoso (1995) cited the following principal diseases encountered in Brazilian plantations: Anthracnose (*Colletotrichum gloeosporioides*), black mold (*Diploidium anacardeacearum*) and gumnosis (*Lasiodipodia theobromae*). They also noted an important fungal disease on the African continent caused by *Oidium* sp. Principal pathogens in cashew nurseries include: *Sclerotium rolfsii, Pythium splendens, Phytophtora* sp. and *Cylindrocladium scoparium.*

Extensive use of insecticides can be expensive and may reduce fruit set. The use of biocontrol and the deployment of genetically resistant cultivars should be a more sustainable and environmentally safer approach to pest management (26).

Harvest and Handling

Cashew apples are very bruise-sensitive, and those destined for the fresh market should be hand-harvested with the nut attached before the occurrence of natural abscission from the tree (24). Harvested cashew apples will keep only for about 24 hours under ambient conditions. For the processing industry, harvest may be by hand or by use of a harvest pole fitted with a collecting bag. The apples should not be harvested by hitting with a stick or by shaking the branches and allowing the fruit to fall to the ground to avoid bruising.

According to Filgueiras et al. (1997), since the cashew apple is not a true fruit, it has a non-climacteric respiratory pattern with no distinct ripening phase. Therefore, it must be harvested with sufficient ripeness for the fresh market. This fact poses some limitations to postharvest life and quality. These authors reported that there are several indices that can be used to determine the optimal harvest stage of cashew apples, notably color, firmness, composition and specific gravity. However, from a practical standpoint, cashew is ready to harvest when the apple is fully developed, firm, without green color and is easily detached from the tree. It is at this stage that flavor, aroma and sugar concentration are maximum, and acidity and astringency are minimum. For the fresh market, the cashew apple must not be misshapen; it must be free from physical injury. For processing it can be misshapen but must be free of disease and insects.

For nut harvest and/or extraction of the shell liquid (CNSL), the apples (along with the nuts) are allowed to drop to the ground to assure full maturity of the kernel (1). The fruits are collected weekly or daily, depending on the weather. Preparation of the cashew kernels is an intricate procedure compared to that for other nut

crops (19). The cashew kernel is surrounded by the toxic resin, CNSL, in the mesocarp. If no precautions are taken, CNSL can contaminate the nuts and cause severe blisters on the skin of any person who comes in contact with it (1). Consequently, the shells are first detached from the apples and sun-dried to reduce the moisture content from 16% to 7% (27). At this moisture content (upon shaking the shells, the nuts rattle) the shells can be safely stored for a year or longer. To extract the nut, the shells are roasted to remove the brown, caustic CNSL, and cracked. Nuts then are further dried to facilitate dehusking and removal of the testa (often manually), graded and packed into appropriate storage containers.

Storage

In Brazil, cashew apples for the fresh market are packed in a single layer on polystyrene trays (21 x 14 cm) so that each tray contains 550 to 600 g (Fig. 2). The trays are shrink-wrapped with plastic film, labeled, placed in corrugated shipping containers (3 trays/container) and palletized. Within the sealed, plastic film, the apples modify the atmosphere, lowering the oxygen level and increasing that of carbon dioxide. This change in atmosphere, together with refrigeration at 5°C, reduces the respiratory rate and extends postharvest life to 15 days (12).

Processed nuts have a relatively long shelf life. After grading, the nuts are packed in cans that have been purged with carbon dioxide and hermetically sealed to prevent deterioration and insect damage (24). Vacuum packing also prolongs shelf life (27). Nevertheless, packed nuts require cold or cool storage below 9°C to ensure that any insects remain dormant. The common unit of sale for the nuts is 22 kg, consisting of two tins.

In summary, cashew is a hardy tree that is well suited to production on marginal lands. Improvements in varietal selections and production techniques could result in significant increases in yields of the nut and the apple. Advances in postharvest handling of the cashew apple could open new markets for this unique product. The bright outlook on the world demand for the nut makes cashew a crop worth considering for a wide range of growers, from subsistence level to large-scale operations.

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