3. Cashew – Dwarf Variety

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3.1. Introduction

The largest number of varieties of the genus *Anacardium* is found in north-eastern Brazil. For this reason Johnson (1973) considered that Ceará state was where the cashew originated. Now about 98% of cultivated cashew is grown in the north-east Brazil (Paula Pessoa *et al.,* 1995).

In Brazil, there are two groups of cashew. The most prevalent is the common type (giant), which grows to heights ranging from 5 to 8 m, but able to reach 15 m. The diameter of the crown generally varies from 12 to 14 m and, in exceptional cases is up to 20 m (Barros, 1995). The other group, the dwarf cashews grow up to 4 m, on average, with a crown diameter of 6 to 8 m. This group of dwarf cashew flowers between 6 and 18 months (Barros *et al.,* 1998).

The flowers are small, polygamous, bunched in large terminal panicles. The fruit is an achene (nut) hanging from a fleshy and juicy peduncle of varying color and size. The cashew nut is rich in vitamins, non-saturated fatty acids and proteins. The peduncle contains large amounts of vitamin C, sugars and minerals (calcium, iron, phosphorus and fibres. Currently less than 20% of the total peduncles produced are used, mainly to consume fresh or made into sweets, jams and diverse drinks. Generally, the ratio of nut to peduncle is 1:10 (w/w).

The root system of the young dwarf cashew is one very well developed main root that branches many times and can grow to 10 m or more in deep sandy soils. Lateral roots develop in the upper soil layers between 15 and 32 cm deep. The length of the superficial roots may reach twice the diameter of the crown in dry-land conditions (Barros, 1995). When irrigated the lateral roots are concentrated around the wet area of soil. The characteristics of the tap and lateral roots are of importance in relation to the fertilization of cashew. Falade

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(1984) when studying the effects of topography, soil texture, stoniness and the presence of a hardened soil layer on the development of the cashew root system, reported great variation in the depth of the main root and distribution in depth and length of the lateral roots.

3.2. World production and trends

In 2004, the total world area occupied by cashew was 3.09 million ha and production was 2.27 million mt, providing a yield of 0.73/ha (Table 3.1). The principle producing countries responsible for 83.9% of world production are Vietnam, India, Nigeria, Brazil, Indonesia and Tanzania. In 2002, the largest yields were produced in Vietnam and Tanzania, with 2,920 and 1,250 kg/ha. The smallest yields were generated in Brazil and Benin, with 1,350 and 220 kg/ha respectively.

Table 3.1. Production, harvested area and yields of cashew nut, 2004.

Countries	Production	Harvested Area	Yield
	mt	ha	kg/ha
Vietnam	825,696	282,300	2,920
India	460,000	730,000	630
Nigeria	213,000	324,000	660
Brazil	182,632	691,059	260
Indonesia	120,000	260,000	460
Tanzania	100,000	80,000	1,250
Côte d’Ivoire	90,000	125,000	720
Guinea-Bissau	81,000	212,000	380
Mozambique	58,000	50,000	1,160
Benin	40,000	185,000	220
Worldwide	2,265,473	3,089,078	730

Source: FAO, 2006.

The small yields in Brazil are in part, related to the area under old cashew trees relative to that of clones of the more productive premature dwarf cashew.

From 1995 to 2004, world production of cashew nut doubled as a result of government incentives in the producing countries and expansion of consumer markets. This trend, though still growing, has been increasing more slowly in the last seven years (Fig. 3.1). The greatest increase in production and the area planted to cashew occurred in Vietnam, where cashew nuts production grew four-fold during 1995–2004.

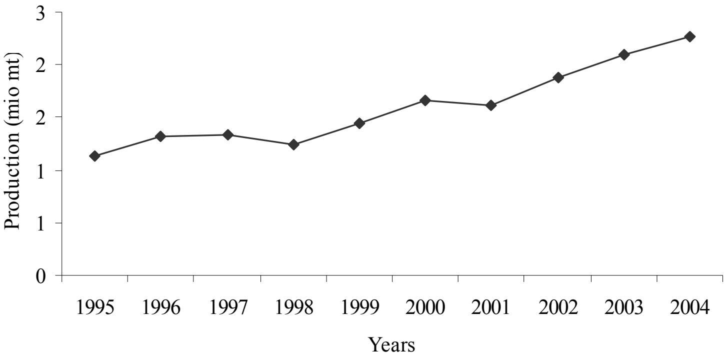

Fig. 3.1. World production of cashew nut, 1995-2004 (FAO, 2006).

During this period, world exports of cashew nut grew 2.5 times fold. Although exports remained reasonably constant between 1995 and 1999, they started increasing in 2000 (FAO, 2006). In 2002, the principle exporters were India, Vietnam and Brazil (with 46.35%, 24.36% and 13.18% respectively) of nuts exported in 2002. In Europe, most of the cashew nuts imports are redistributed through the port of Rotterdam, which makes the Netherlands the fourth major exporter for this commodity.

In 2002, the total value of the crop was US$ 240.9 million, with a variation in price ranging from US$ 3.12/kg for Vietnamese cashew nuts to US$ 4.10/kg for nuts re-exported by the United States. At that time, the Brazilian cashew nut traded on average at US$ 3.38/kg.

In 2002, the principal importers of cashew nuts were the United States (approximately half of the total worldwide volume of exports), the Netherlands, England and Germany. The considerable participation of the North American market in cashew nut trade has meant that this market has become a regulator of world market prices. It is likely that worldwide consumption of cashew nuts will continue to increase.

3.3. Climate and soil

3.3.1. Climate

The cashew tree is an evergreen plant, although a partial replacement of the leaves can occur. Owing to its sensitivity to low temperatures, it geographic distribution is confined to regions between 27ºN and 28ºS (Frota and Parente, 1995). In spite of being a tropical fruit in origin, the cashew develops well in temperatures varying from 22 to 40ºC, although Parente *et al.* (1972) cite 27ºC as the ideal average temperature for normal development and fruit bearing. Owing to the influence of altitude on temperature, cashew plantations may be found at altitudes up to 1,000 m close to the equator. In higher latitudes and altitudes above 170 m, the yield is negatively affected (Aguiar and Costa, 2002).

The cashew develops well between 70% and 85%, relative humidity. Trees will grow in regions where the relative humidity is 50% for a long period of time if the soil contains a good reserve of moisture or irrigation is used. In regions where the air relative humidity is above 85%, fungal diseases of the leaves, flowers and fruits increase.

Wind has little influence on a cashew plantation. However, at velocities of 7 m/s or higher, Aguiar and Costa (2002) reported an increase in loss of flowers and fruits and trees being blown over.

According to Aguiar and Costa (2002), trees are established successfully when the annual precipitation is within the range 800 to 1,500 mm, distributed over 5 to 7 months along with a 5 to 6 month drought that coincides with the flowering and fruiting phases. Frota *et al.* (1985, cited by Aguiar and Costa, 2002) reported successful cultivation in regions with annual precipitation of up to 4,000 mm; however, if there is a drought of 4 to 7 months, then this rainfall is not always well distributed.

3.3.2. Soil

In Brazil, especially in the north-east, the majority of cashew plantations grow on Quartzarenic Neosols (Quartz Sands), Latosols and Argisols (Podzolics). These are deep soils with good drainage, and with no stones or impervious layers, but with poor chemical fertility (Crisóstomo, 1991). In India, the cashew is cultivated on soil that is infertile, leached, acidic and sometimes containing excess changeable aluminium (Al) (Hanamashetti *et al.,* 1985, Gunn and Coks, 1971; Falade, 1984; Badrinath *et al.,* 1997). On the other hand, Menon and Sulladmath (1982) reported that satisfactorily prosperous plantations existed on soils that are volcanic, iron-rich, lateritic rusty, alluvial, clayey, and those with a high water table, at times subject to flooding. According to Latis and Chibiliti (1988), the cashew requires fewer nutrients than other fruit trees, and for this reason many plantations are found on soils of marginal fertility. However, research has shown positive responses to mineral fertilizers. (Falade, 1978; Maamashetti *et al.,* 1985; Sawke *et al.,* 1985 and Grundon 1999). Falade (1984) concluded that the physical and chemical characteristics of the soil influence the height of the plant as well as the diameter of the crown, and the morphology of the root system. He concluded that light textured soils, free from stones and without an impervious layer or horizon within the top 100 cm are the best for growing cashews.

Before establishing a plantation, the soil should be sampled and analysed to determine the need for soil amendments and fertilizers. In already established orchards, soil and leaf analysis provide supplementary information as to the recommendations for fertilizers and soil amendments. Table 3.2 gives data used to evaluate the fertility of the soil.

3.4. Soil and plantation management

3.4.1. Soil preparation and seedling planting

For new plantations, existing surface vegetation and roots, especially around the area where the pit will be prepared, should be removed to minimise competition from other plants. For soil preparation, the use of heavy machinery should be avoided, to diminish the risk of soil compaction.

Liming, when necessary, should be performed in two steps, the first before aeration and the second at ploughing. The quantities should be sufficient to increase base saturation to 60% and the levels of exchangeable calcium (Ca) and magnesium (Mg) to a minimum of 3 and 4 mmolc/dm^3, respectively (Crisóstomo *et al.,* 2003).

The seedlings should be planted into pits, 40 x 40 x 40 cm for sandy soils and of 50 x 50 x 50 cm for medium texture soils with the pits spaced at 7 x 7 m or 8 x 6 m. At the bottom of the pit apply calcareous dolomite at the required amount. The pit should then be filled with a mixture of surface soil, 10 L of cured corral manure, phosphate according to soil analysis, and 100g of Frits[1], 30 days before the seedlings are transplanted. Bovine manure, in general, substantially increases the electrical conductivity of the soil, sometimes causing irreversible damages to the transplants. Kernot (1998) considers that it is undesirable for the electrical conductivity of the saturated water extract to exceed 0.30 dS/m.

[1] F.T.E. Br-12 9% Zn, 1.8% B, 0.8% Cu, 3.0% Fe, 2.0% Mn, 0.1% Mo

3.4.2. Plant management

The transplants should remain upright and lateral shoots should be removed up to 1 m in height, with the object of leaving three or four of the most robust branches, aiming to obtain plants with good crown architecture. It is recommended to remove the flowers in the first year so that the plants will grow more vigorously. Pruning, generally, is limited to removing sick, dry and poorly growing branches. Removing the lower branches should be minimized because the fruit is borne at the edges of the branches occupying the lower two thirds of the plant (Oliveira and Bandeira, 2002).

Soil disturbance to control weeds when necessary, should be not deeper than 15 cm (20 cm maximum) to avoid cutting or damaging the roots. To preserve the soil from erosion (wind or water), mechanical or manual mowing is recommended in between the rows of the plants, and using chemical or manual weeding to keep the soil under the crown clear of weeds. This procedure reduces the competition of weeds for water and nutrients and even facilitates harvesting of the nuts.

To reduce the cost of planting and maintaining an orchard, it is desirable to inter-crop with plants of a short growth cycle (maize, beans, cassava, sorghum) until the third/fourth year. If this practice is adopted, a space of at least one meter should be kept between the tree and the inter-crop. Fertilization of the latter may be necessary to reduce the competition between it and the cashew for nutrients.

3.5. Mineral nutrition

3.5.1. Uptake and export of nutrients

Erroneously, the cashew is considered to require low levels of plant available nutrients because many plantations are found in soils of low natural fertility to which no fertilizers are applied. However, yields do increase with the addition of fertilizers (Ghosh and Bose, 1986; Ghosh, 1989; Grundon, 1999). After germination the cotyledons meet the demand for nutrients but at approximately 45 days this supply is exhausted and development of the root system is induced (Ximenes, 1995).

In each growth cycle, the nutrients are removed from the soil to supply the vegetative parts of the plant (leaves, branches, trunk and roots) and for export in the harvested fruits and pseudo fruits. Thus plant growth and satisfactory harvests are only possible by replacing the nutrients exported by the harvested parts. Some values for exported nutrients are shown in Table 3.3.

Table 3.2. Recommended physical and chemical soil attributes for the interpretation of soil analysis in Brazil and Australia.

Brazil (Crisóstomo, 2003; Raij *et al.*, 1997)			Australia (Kernot, 1998)		
Attribute	Class	Level	Attribute	Class	Level
pH (1:2.5) $CaCl_2$ 0.1 M	Satisfactory	5.5–6.0	pH (1:5) Water (1:2.5)	Satisfactory	6.0–6.5
Electrical Conductivity (dS/m)			Electrical Conductivity (dS/m)	Good Elevated	<0.15 >0.30
P-resin (mg/dm^3)	Low Adequate Elevated	<12 13–30 >30	Phosphorus (mg/dm^3) sodium bicarbonate	Low Adequate Elevated	<30 30–50 >50
Potassium ($mmol_c$/ dm^3)	Low Adequate Elevated	<1.5 1.6–3.0 >3.0	Potassium ($mmol_c$/kg)	Low Adequate Elevated	<0.1 0.2–0.4
Calcium ($mmol_c/dm^3$)	Low Adequate Elevated	<3 4–7 >8	Calcium ($mmol_c$/kg)	Low Adequate Elevated	<1.5 1.6–1.8 >1.9
Magnesium ($mmol_c/dm^3$)	Low Adequate Elevated	<4 4-7 >8	Magnesium ($mmol_c$/kg)	Low Adequate Elevated	<0.2 0.2–0.3 >0.4
Copper (DTPA) (mg/dm^3)	Low Adequate Elevated	<0.2 0.3–0.8 >0.8	Copper (mg/kg)	Low	<0.3
Zinc (DTPA) (mg/dm^3)	Low Adequate Elevated	<0.5 0.6–1.2 >1.2	Zinc (mg/kg)	Low Marginal Elevated	<0.5 0.5–1.0 >1.0

Sources: Raij *et al.*, 1997; Kernot, 1998; Crisóstomo *et al.*, 2003.

Table 3.3. Export of nutrients by cashew nuts and the pseudo fruit.

Source	Nut					
	N	P	K	Ca	Mg	S
	g/kg					
Mohapatra *et al*. (1973)	31.36	4.15	6.30	-	-	-
Haag *et al*. (1985)	6.76	0.70	3.28	0.24	0.67	0.27
Fragoso (1996) CCP 76 [(1)]	11.79	1.28	6.16	0.38	2.23	0.60
Fragoso (1996) CCP 09 [(1)]	11.35	1.47	7.25	0.27	2.19	0.66
Kernot (1998)	13.80	2.00	6.50	1.00	1.60	0.70
	Peduncle					
	N	P	K	Ca	Mg	S
	g/kg					
Mohapatra *et al*. (1973)[b]	6.16	0.85	3.90	-	-	-
Haag *et al*. (1985)[a]	7.14	0.66	2.93	0.14	0.64	0.26
Fragoso (1996) CCP 76[a (1)]	0.90	0.10	1.16	0.01	0.13	0.04
Fragoso (1996) CCP 09[a (1)]	0.81	0.11	1.32	0.01	0.12	0.06
Kernot (1998)[b]	8.50	1.30	8.50	0.90	0.90	0.80

[a]fresh weight; [b]dry weight.

[(1)]CCP: Cashew Clone “Pacajus” 09 or 76.

3.5.2. Functions and importance of nutrients

Nitrogen (N): Reddy *et al*. (1981) and Ghosh (1986) report impressive increases in production by increasing the amount of nitrogen applied. Ghosh (1989) showed that increasing the amount of N applied significantly increased the duration of flowering and the number and weight of nuts. The symptoms of N deficiency are seen initially in the older leaves, characterized by chlorosis in the apex region of the lamina, but because N can be mobilized and redistributed within the plant, the young leaves remain green (Plate 3.1). Generally, plants deficient in N have: (a) low stature, fewer branches and fewer leaves; (b) pale leaves due to less chlorophyll (Plate 3.1); (c) when deficiency is severe leaves fall and branches die.

Chemical analysis of the leaves together with soil analysis is used to evaluate the nutritional state of the orchard and formulate fertilizer recommendations. Haag *et al*. (1975) (Table 3.4) consider 13.8 g N/kg of dry matter as insufficient, in agreement with a suggestion of Kernot (1998). These authors considered that adequate levels of N were between 24.0 to 25.8 and 14 to 180 g/kg of dry matter, respectively. Such a large difference may be attributed to the genetic material used by the two authors.

Phosphorus (P): Phosphorus is required in a smaller amount than either N or K. Table 3.3 shows the quantity of P exported by the fruit ranging from 0.7 to 4.15 g/kg and the pseudo fruit from 0.11 to 1.30 g/kg. Such differences are due to the form of expression of the results, fresh weight and dry weight. The visual symptoms of P deficiency are characterized, initially, by dark green coloration of the leaf, which in the more advanced stages, turns an opaque green before the leaves fall prematurely. In general, plants deficient in P have smaller leaves than well-nourished plants. Due to nutrient redistribution, the visual symptoms are observed in the leaves on the lower third of the crown.

Chemical analysis of the leaves together with soil analysis indicates the nutritional state of the plant on which P fertilizer recommendations can be based. Table 3.4 shows foliar P composition reported in Australia, Brazil and Zambia, which are very similar.

Table 3.4. Comparative compositions of nutrients found in mature cashew leaves in Australia, Brazil and Zambia.

Nutrient (in DM)	Richards (1993)	Haag *et al.* (1975)	Latis & Chibiliti (1988)
	Australia	Brazil	Zambia
Macro-nutrient	----------------------------	g/kg	----------------------------
N	15.0	22.9	17.2
P	1.08	1.4	0.2
K	0.62	8.9	0.9
Ca	3.8	2.1	1.2
Mg	2.6	3.4	0.7
S	-	1.8	-
Micro-nutrient	--------------------------	mg/kg	----------------------------
B	-	51.7	12.6
Cu	-	12.7	-
Fe	-	83.1	78.8
Mn	-	139.0	73.2
Zn		25.0	8.7

Potassium (K): At harvest, 1,000 kg cashew nut and 10,000 kg of fresh peduncle contains about 115 kg K (Fragoso, 1996). The symptom of K deficiency is similar to that of N and P, starting in the oldest leaves, which show light chlorosis on the edges. In the advanced stages, the chlorosis reaches the centre of the leaf lamina, remaining green only at the base, in appearance like an inverted “V”. Remembering that visual symptoms only become evident when the deficiency is in an advanced stage, chemical analysis permits a more accurate diagnosis. Kernot (1998) considers an adequate leaf K is between 7.2

and 11.0 g/kg (Table 3.4). On the other hand, the values found by Haag *et al*. (1975) are much larger and vary between 11 and 20 g/kg. This difference, possibly, may be attributed to the genetic material used because the latter author worked with the Giant Cashew.

Calcium (Ca): The initial symptoms of Ca deficiency, according to Avilán (1971), are seen as ripples in new leaves (Plate 3.2). Because Ca has little mobility in the plant, it has to be applied frequently.

Magnesium (Mg): The quantity of Mg absorbed by the cashew plant is generally less than that of Ca and K. In general, Mg deficiency is due to competition with other ions like Ca^{2+}, K^+ and NH_4^+ for uptake by roots (Mengel and Kirkby, 1978). Most of the Mg in the plant is in chlorophyll but it is also an enzyme activator, especially those involved in the transfer of phosphate radicals rich in energy and the synthesis of nucleic acids. The characteristic symptom of Mg deficiency is interveinal yellowing which starts from the main vein and develops to the edges (Plate 3.3). It is usually seen in the lower leaves, due to the ease of translocation to regions of active growth.

Sulphur (S): The symptoms of S deficiency are seen at the beginning of plant growth. The older leaves become chlorotic and, at the same time, become rigid (Plate 3.4). Necrosis appears at the apex accompanied by curling of the affected tips and torn edges. Sulphate is readily translocated within the plant.

Boron (B): The points of active development above ground and in the roots cease to elongate when boron is deficient, and, if the deficiency persists, become disorganized, lose their normal color and die. With death of the buds and the youngest leaves, the adjacent ones become leathery. In general, plants deficient in boron over-produce shoots, with a duplication of the symptoms on the new shoots.

Copper (Cu): Copper deficiency results in a darkening of the green areas of the leaves. The young leaves are longer and curled down, as though they lack water. Growth seems to be unaffected, at least in the first months of the plant’s life.

Iron (Fe): Cashew tree growth is seriously compromised in the absence of iron. In just one month, the visual symptoms of it deficiency appear, characterized by severe chlorosis in young leaves. With increasing deficiency, the leaves become translucent, remaining light green only in the oldest leaves.

Manganese (Mn): In the cashew, Mn deficiency symptoms appear initially in the youngest leaves, characterized by pale green coloring, developing later into greenish-yellow and, in some leaves, the edges become brown. Plants deficient in manganese have a small number of leaves and growth slows down although there is a great development of lateral branches. The occurrence of large clusters of small leaves in the shape of a rosette is common followed by the leaves drying, and falling prematurely.

Zinc (Zn): In the absence of zinc, the plants have short internodes and few lateral branches. In deficient plants, the youngest leaves appear small, elongated, and with a color varying from green to pale green, but the veins remain green. The lower mature leaves develop normally.

3.6. Fertilization

Ghosh and Bose (1986) evaluated the effect of fertilization with N, P and K singly and in combination with other minor and micro-nutrients. They showed that larger yields of cashew nuts were obtained with a combination of N, P_2O_5 and K_2O equivalent to 200, 75 and 100 g/plant/yr, respectively. Later, Ghosh (1989), working with seven-year-old plants for three consecutive years, concluded that the best yield was obtained with N, P_2O_5 and K_2O equivalent to 500, 200 and 200 g/plant/yr. Mahanthesh and Melanta (1994) found that only 100 g P_2O_5 was necessary when they tested 0, 200, 400 and 600 g N/plant/yr. With P_2O_5 and K_2O at 200 and 400 g/plant/yr, respectively, Ghosh (1990) concluded that the weight of the nut, number of nuts, height and vigour of the plants were increased and reached a maximum with 600 g N/plant/yr. Grundon (1999), during three consecutive years found, for four year-old plants, substantial increases in nut production with the application of up to 288 g P and up to 176 g S/plant/yr, but there was no increase in yield from applying up to 3,000 g K_20/plant/yr. Best yields from fifteen year-old plants was with 250, 125 and 125 g/plant/yr of N, P_2O_5 and K_2O, respectively, when the fertilizer was applied in a circular band 1.5 m wide and 1.5 and 3.0 m from the trunk (Subramanian *et al*., 1995). Crisóstomo *et al.* (2004) reported that the maximum yield of cashew nut (1,536 kg/ha), in the sixth year of cultivation on dryland, was obtained with 700 and 45 g/plant/yr of N and K_2O, respectively. Overall, from the economic point of view, doses of N and K_2O recommended were 107 and 41 g/plant/yr with an economic return of US$ 355.36 ha/yr. When evaluating dry matter production, Vishnuvardhana *et al.* (2002) observed that the largest yields were obtained with 1000, 250 and 250 g/plant/yr of N, P_2O_5 and K_2O, respectively, but economically, 500, 250, 250 g/plant/yr N, P_2O_5 and K_2O produced the best results.

Generally, little or no emphasis has been given to the economic evaluation of fertilizer use for cashew. In field experiments during six years in India, Vidyachandra and Hanamashetti (1984), tested 127, 181 and 108 g N, P_2O_5 and

K_2O/plant/yr, alone or in combination with minor and micro-nutrients. The profit was Rs 19.10 (US$ 0.42)/plant when micro-nutrients were added. In Australia, according to Grundon (1999), fertilizing normally with N and K generated costs varying from US$ 0.16 to US$ 0.32 plant/yr. This author also reported that using larger amounts of fertilizer generated costs varying from US$ 169 to 468 ha/yr, when compared to the amounts used traditionally.

3.6.1. Fertilizer recommendations in dryland cultivation

Post-planting fertilization (first year): Fertilizers containing N and K should be applied during the rainy season in three or more equal parts, in a circular groove 10 to 15 cm deep and 10 to 15 cm wide, at a distance of approximately 20 to 30 cm from the stem of the plant and covered with soil, to reduce the loss of ammonium by volatilization.

Fertilization for growth and production: Nitrogen and K rich fertilizers are recommended starting from the second year (Table 3.5) and should be applied in three or more equal applications. On the other hand, P fertilizers should be applied all in one application. The depth and width of the fertilization groove are the same as for post-planting, except the distance from the stem should be increased such that it is situated under the external third of the crown canopy (Crisóstomo *et al.,* 2003).

3.6.2. Fertilizer recommendations in irrigated cultivation

Post-plantation and fertilization for growth and production: In irrigated cultivation, soluble N and K-rich fertilizers, solid or liquid, are applied in the irrigation water, improving their distribution and penetration to the root system. Fertilizers supplying P also may be applied via irrigation water provided the necessary precautions are taken to avoid clogging the emitters (spray and drip). The recommended amounts for the different plant growth phases are outlined in Table 3.5.

3.7. Soil analysis and fertilizer recommendations

3.7.1. Brazil

The criteria for interpreting soil analysis results for fertilization recommendations for cashew (Table 3.5) permit separation of areas with high probability of reaction to a certain nutrient, those of medium and those of low reaction. Other than this, expected productivity, the age of the plant and the plantation system (irrigated or rain-fed) are also considered.

Table 3.5. Fertilization recommendations for pre-mature dwarf cashew in planting, growth and production phases in both irrigated and dryland conditions.

Fertilization	N	P-resin (mg/dm^3)			K-soil (mmol$_c$/dm^3)		
		0-12	12-30	>30	0-1.5	1.6-3.0	>3.0
Year	g/plant	--------------- P_2O_5 (g/plant) --------------			-------------- K_2O (g/plant) --------------		
Planting	0	200 (180) [(1)]	150 (140)	100 (90)	0	0	0
Growth							
0-1	60 (45)	0	0	0	60 (50)	40 (30)	20 (20)
1-2	80 (70)	200 (160)	150 (140)	100 (90)	100 (90)	60 (50)	40 (30)
2-3	150 (120)	250 (220)	200 (180)	120 (110)	140 (120)	100 (90)	60 (50)
3-4	200 (150)	300 (290)	250 (230)	150 (140)	180 (170)	140 (130)	80 (70)
4-5	300 (220)	300 (290)	250 (230)	150 (140)	180 (170)	140 (130)	80 (70)
Production							
Expected yield (kg/ha)							
<1,200	400 (300)	200 (160)	100 (80)	100 (80)	150 (120)	100 (80)	80 (80)
1,200-3,000	700 (520)	300 (240)	200 (160)	150 (120)	300 (240)	200 (160)	150 (120)
>3,000	1,000	400	300	200	450	300	200

[(1)]Values in parenthesis refer to cultivar in dry land.

Apply 50 g de F.T.E. BR-12 plant/yr for years 2 to 4 and 100 g starting from year 5.

Source: Crisóstomo *et al.*, 2002; Crisóstomo *et al.*2003.

3.7.2. Australia

Table 3.6 presents suggestions for cashew fertilization from the second year, without taking into consideration soil analysis.

Table 3.6. Fertilization suggestion for cashew.

	Year 1	Year 2	Year 3	Year 4	Year 5	Year >5
Macro-nutrient			g/plant/yr			
N	-	200	400	600	800	1,200
P	-	30	80	100	140	170
K	-	150	400	600	800	1,200
Ca	-	100	100	200	300	400
Mg	-	100	100	200	250	300
S	-	5	10	20	30	45
Micro-nutrient						
B	-	0.1	0.2	0.3	0.4	0.5
Cu	-	0.1	0.2	0.2	0.3	0.4
Fe	-	1	2	4	6	8
Mn	-	0.2	0.4	0.5	0.7	1.0
Mo	-	0.001	0.001	0.001	0.001	0.001
Zn	-	0.2	0.4	0.6	0.8	1.2

Source: Kernot, 1998.

3.8. Irrigation

Although the cashew may grow and produce in regions with an annual precipitation above 600 mm and with a drought of 4 to 5 months, irrigation allows maximum productivity, increasing the harvest period and improving the quality of the peduncle and the nut. Studies in Brazil and other countries have shown that irrigation could increase productivity by up to 300%, depending on the region.

3.8.1. Irrigation methods

It is recommended to use micro-irrigation (spray or drip), because it has the following advantages over other methods of irrigation: decreased incidence of leaf sickness and weeds, water saving by decreasing losses by evaporation and greater efficiency of water use. Micro-irrigation can also be adapted to different soil and topographies; there is a saving in labour costs and efficient application of fertilizers via irrigation water (fertigation). The initial cost of a system of micro-irrigation for cashew varies from R$ 3,000 to R$ 4,500 (US$ 1,000 to US$ 1,500) per hectare.

Where spraying is used it is recommended to have one jet per plant, with a nominal flow of 30 to 70 L/h and wetting diameter of 3.5 to 5.0 m. In dripping, a minimum of four drippers per plant ought to be used per adult plant in clayey soils, and up to eight drippers per plant in sandy soils.

To choose between spray and dripping as a system of irrigation, the water availability (quantity and quality) should be considered. In dripping there is a greater savings in water and energy, because the loss of water by evaporation from the soil surface is less and the system operates at a lower pressure. On the other hand, the risk of emitter blocking is greater than with spray irrigation, thus better filtering, especially when surface water with a lot of organic matter is used. Dripping also offers the advantage of not wetting the fruits that fall onto the ground, allowing less frequent collecting where the primary product required is the nut.

3.8.2. Water requirements

In Australia, Schaper *et al.* (1996), reported that the plant could be irrigated only between flowering and harvest without decreasing yield compared to irrigating during the entire drought period. This saves much water.

The water needs of the plant vary with climate, the plant's foliar area, the growth phase of the plantation and with the irrigation method used. During periods of high evapo-transpiration, 5 L of water/day are recommended for each square meter of soil surface shaded by the plant crown or area wet by the emitters (Table 3.7). The frequency of irrigation depends on the water retention capacity of the soil and should vary between two and four days, for sandy and clayey soils, respectively.

With drip irrigation, the volumes of water recommended in Table 3.7 may be reduced by about 15%. The number of drippers per plant should increase gradually, according to the age and stature of the plant, from one drip dripper during the first year to up to four, six or eight per adult plant in clayey, medium textured and sandy soils, respectively.

Soil humidity or water tension monitoring is recommended, in order to ensure that the volumes of water applied and the frequency of irrigation best serve the needs of the plant. Tensiometers can be used to monitor soil water content. For each homogenous area, in terms of soil and cultural phase, tensiometers should be put in at three different locations where there is the greatest concentration of roots. This allows identification of sensors with readings well above or below the average and when this occurs it is necessary to determine if the problem is in the sensor or in the irrigation system (blocked emitters, leaks in the supply lines etc.).

Table 3.7. Average values of crown projection areas, percentage of soil covered by the plant and volume of water to be applied in irrigation as a function of plant age.

Year of crop	Crown projection area	Soil covering	Volume of water
	m^2	%(1)	L/plant/d(2)
1st	1	2	5
2nd	5	10	25
3rd	15	30	70
4th	25	50	120
5th +	30	60	145

(1)Assuming the spacing between plants to 7 x 7 m.
(2)If the area wetted by the nozzle is greater than the crown projection, the volume of water to be applied should be chosen as a function of the wetted area.

Source: Miranda, F.R. de., 2005; unpublished data.

For the cashew, tensiometers should be installed at two depths in each location of monitoring: the first at 20 cm and the second at 50 cm deep. The distance of the sensors in relation to the tree trunk varies from 30 cm in the first year of crop up to 1.6 m for adult plants. When drip irrigation is used, the tensiometers should be installed a lateral distance of 20 cm from the dripper. The readings from the tensiometers should be performed in the morning, preferentially. For cashews planted in sandy soil, the soil water tension between irrigations should vary between 8 and 25 centibars. For clayey soils, the ideal range is between 30 and 50 centibars. Lower readings in which the minimum values cited indicate that irrigation is excessive. Reading higher than the ideal range indicates that the soil is drier than desirable and the quantity of water ought to be increased and/or the irrigation interval reduced.

3.8.3. Fertigation

The application of fertilizers through the irrigation water (fertigation) has the advantages of increasing the efficiency of the fertilizers and reducing the costs of labour and machinery for its application. Fertigation allows the application of nutrients with greater frequency, without increasing the cost of the application, minimizing losses by volatilization and leaching and optimizing nutrient absorption by the roots. The nutrients most frequently applied in fertigation are those with greater mobility in the soil, like N and K (Oliveira *et al.,* 2002).

To apply nutrients by fertigation, tanks of the solution, where the fertilizers are pre-diluted in water, and an injecting device are necessary. The types of injectors most utilized in fertigation are: injector pumps, venturi and differential pressure tanks.

There are many advantages to fertigation: a) uniform application of nutrients; b) application of nutrients according to the needs of the plant and the rate of uptake; c) greater efficiency of nutrient use due to its mobility in the wetted zone of the soil where the root system is concentrated; d) savings on labour and agricultural equipment; e) reduction in soil compaction from the use of heavy equipment; f) ability to apply nutrients more frequently thus reducing nutrient losses (Santos *et al.,* 1997). Fertigation needs to be carefully managed to avoid soil acidification and salination in the root zone. To avoid blocking the emitters the fertilizers used should be fully soluble in water and should not form precipitates, especially calcium and iron phosphates.

3.9. References

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