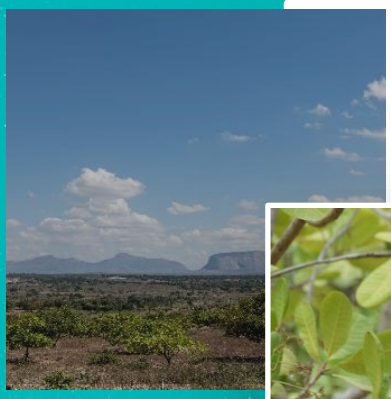

oCashew Cultivation in Africa

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INTRODUCTION

Africa plays a critical role in the twelve-billion-dollar global cashew industry: approximately 60% of the world's cashews are produced in Africa, largely grown by three million small-scale family farms.

Yet, African cashew production faces critical risks and untapped potential. Cashew productivity on the continent is below global averages. Farm and tree yields remain un-optimized, due to aging stock and low awareness and adoption of good agricultural practices. Pests and diseases further threaten the health of cashew farms.

To bring African cashew production to its full potential, stakeholders in the industry must have up-to-date, easy-to-access information on the key challenges and best practices of cashew cultivation on the continent.

Existing literature on cashew cultivation is dated, and has critical knowledge gaps on best practices. This manual seeks to fill these gaps. Developed in collaboration with leading researchers and agronomists in the African cashew sector, this manual summarizes the best practices for cashew cultivation on the continent across key topics such as suitable land for cashew plantations, optimal techniques for grafting new seedlings, major insect pests and diseases of cashew and their control methods.

By equipping key stakeholders in the industry with this critical knowledge – cashew tree growers to implement best practices and improve yields, governments to create targeted, cost-effective interventions, and researchers and teachers to focus on the most impactful needs and practices – together, we hope to grow Africa's cashew sector and generate meaningful social and economic value for the continent.

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ABBREVIATIONS

%	Percent
cm	Centimeter
CNSL	Cashew Nut Shell Liquid
EOLSS	Encyclopedia of Life Support Systems
FAO	Food and Agriculture Organization
g	Gram
ha	Hectare
hr(s)	Hour(s)
kg	Kilogram
KOR	Kernel Out-turn Ratio
lb(s)	Pound(s)
m	Meter
ml	Milliliter
mm	Millimeter
NPK	Nitrogen Phosphorus Potassium (fertilizer)
◦C	Degree Centigrade
PMD	Powdery Mildew Disease
SC	Soluble Concentrate
SG	Standard Grade
SHOT	Shell Out-turn
sp.	Species
UG	Under Grade
WRS	Warehouse Receipt System

1. CASHEW CROP BACKGROUND

Cashew (*Anacardium occidentale Linn*) is an evergreen tree crop which belongs to the family *Anacardiaceae*, which also includes mango and pistachio nuts. The cashew tree is native to central America, the Caribbean Islands and northern South America, with its center of diversity in north-eastern Brazil, where the three states of Ceará, Piauí and Rio Grande do Norte account for more than 90% of Brazil's annual cashew production.

According to the Encyclopedia of Life Support Systems (EOLSS), naturally occurring cashew trees have been reported from as far north as Mexico and as far south as Peru, as well as in the West Indies. Cashew was one of the first fruit trees from the New World to be widely distributed throughout the tropics by early Portuguese and Spanish explorers.

Cashew was first discovered by Portuguese traders and explorers in Brazil in 1578 and was subsequently introduced to Portuguese colonies across Africa and India over the following few decades. During this time period, cashew was considered an ideal crop for soil conservation, forestation, and also wasteland development. As such, the principal aim of these cashew planting efforts was to help control soil erosion on the coast, as opposed to the production of cashew nuts and apples (Bradtke, 2007).

In Africa, cashew has consistently been used by international agroforestry projects to reforest areas, combat desertification and control flooding, as it is fast-growing and drought-resistant. Currently, cashew is recognized as a vital crop in combating global warming by multiple African countries, who are significantly expanding cashew tree plantings.

2. SUITABLE CONDITIONS FOR THE GROWTH AND DEVELOPMENT OF CASHEW

2.1 Soils

Cashew is widely regarded as a robust tree crop that can grow in any soil types, with little or no effect on productivity. While it is true that cashew has few soil requirements and can adapt itself to a wide range of soil conditions, its performance in terms of growth and yields is significantly improved by fertile soils of a suitable type.

The best soils for cashew are deep and well-drained sandy loams without a hard pan, which facilitate the quick development of the tap root and the lateral roots system. Deep sands, sandy loams, gravelly soils and red laterite soils have been shown to be ideal for cashew in a number of African countries. Cashew also grows well on pure sandy soils, such as the Kalahari sands in Mongu, Zambia and Angola, but this may lead to mineral deficiencies that require special nutritional attention. Waterlogging and flooding often have a negative impact on cashew production. For this reason, heavy clay soils with poor drainage are not suitable for cashew cultivation.

According to the FAO (1994), the optimum pH of soil for cashew growth is between 4.5 and 6.5. A soil pH below 3.8 or above 8.0 will negatively affect cashew production, as shown by the findings of the Ikisan Agri-Informatics and Services Division in Tamil Nadu, India (Widiatmaka *et al*., 2001). The cashew tree does not tolerate saline soils well and tends to grow poorly in valleys, floodplains and swampy areas that have poor drainage.

In summary, red sandy loam, lateritic soils and coastal sands with a slightly acidic pH and good drainage are optimal for cashew production (Ngatunga *et al.*, 2001).

2.2 Climate

Cashew is a tropical tree crop that grows in a wide range of climates. According to several sources, cashew grows in about thirty countries across the globe within a band of approximately 25 degrees north and south of the equator. The most suitable growing temperatures range between 7°C and 40°C (Danida 2003, Ohler 1979). According to Ohler (1979), temperatures outside this range tend to cause damage to young trees and flowers, though there is evidence of cashew trees thriving in temperatures as high as 49°C in India (Agronet.com, IKISAN).

Cashew flowering is not affected by day length. Trees normally flower towards the end of the rainy season, when new shoots emerge, and a dry spell during flowering and fruit setting ensures a better harvest and high quality cashew nuts. Heavy rainfall, evenly distributed throughout the year, is not favorable for cashew trees, though they will still grow and sometimes set fruits. An ideal climate for cashew has a well-defined dry season of at least four months to produce the best yields. By contrast, the combination of excessive rainfall and high relative humidity during flowering may result in flower and fruit drop as well as an increased incidence of fungal diseases.

Generally speaking, cashew trees can withstand rainfall levels anywhere between 300 and 4,000 mm per annum. However, for optimal vegetative growth, good flowering and fruit setting, average annual rainfall should be between 800 mm and 1,600 mm, with a pronounced dry season of 5 to 7 months (EOLSS). Higher rainfall can cause excessive vegetative growth, to the detriment of flowering and fruit setting. Although cashew trees are fairly drought-resistant, lower rainfall leads to irregular flowering and fruiting, which reduces production, and can also reduce the size of the fruits and nuts. The distribution of rainfall across the year has a direct impact on the incidence of flowering: for example, year-round rainfall tends to lead to constant flowering, while each well-defined dry season in a year induces a single flush of flowering.

Under optimal conditions, there is no rainfall from the onset of flowering until a higher proportion of harvesting has been completed as this can lead to the development of fungal diseases like anthracnose as well as leaf and nut blight, that causes flower and fruit drop. As the nuts and apples are developing, rain leads to rotting and severe crop losses due to diseases, while rain during the harvesting period causes the nuts on the ground to deteriorate rapidly as they start to germinate after four days of damp conditions.

3. PREPARATION OF NEW LAND FOR PLANTING CASHEW

3.1 Bush clearing

The bush clearing process is typically the most expensive, labor-intensive and time-consuming activity for cashew farmers, whether it involves 1 ha or over 500 ha. The main objective is to ensure that the ploughing, harrowing, laying out the field, and digging the planting holes takes place during the dry season and to facilitate the movement of tractors and other machines.

Large-scale cashew planting in Africa often requires greenfield development, namely the use of land that has not previously been used for any human activity. Depending on the planting area, land clearing must be done at least one month before the start of the first rains and as much as three months before for large areas of land (Masawe *et al.*, 2019). If the bush is cleared manually, the clearing will take more time and involve significant supervision to prevent laborer absenteeism. Using machinery to clear the land reduces the time and supervision requirements – the authors note that, in Tanzania, Zambia and Togo, a bulldozer like D7 cleared between 1 and 5 hectares of land per day depending on the type of trees, vegetation and landscape (Masawe *et al.*, 2019) – but the overall cost is similar.

When clearing the land with machines, it is important to hire an operator who has experience in clearing agricultural lands. This is because only trees and shrubs should be removed and the top soil must be properly preserved. The removed vegetation is typically gathered on the outskirts of the farm, where it is chopped, heaped and burned. If the quality of the tree wood is good, the material can be used to make charcoal and generate additional revenues for the farmer.

Figure 1: A caterpillar clearing land

Source: Authors

3.2 Land preparation

The land preparation for planting cashew trees is done in the same way as other annual crops, with ploughing and harrowing. A second harrowing may be necessary in areas with fertile soils and high rainfalls due to the growth of weeds. Alternatively, herbicides can be used to suppress weed growth before transplanting the cashew seedlings, which also facilitates the practice of intercropping.

Figure 2: Ploughing and Harrowing

Source: Authors

3.3 Tree spacing

It is important to choose the spacing of the cashew trees before laying out the field and digging the planting holes as both depend on the planned spacing. Recommended spacing within and between rows of cashew trees ranges from 6 x 6 meters to 12 x 12 meters. The majority of agricultural extension staff, particularly in West Africa, believe that a spacing of 10 x 10 meters within and between rows is ideal, but this is yet to be confirmed by reliable field data. Due to the lack of industry consensus, optimal cashew spacing remains a controversial topic and depends on a large number of variables, including the tree variety, soil type, soil fertility and, particularly, the frequency and intensity of rainfall.

There are four types of commercialized cashew varieties: Common, Dwarf, Giant and Intermediate. Common, Giant and Intermediate varieties are spreading and therefore require wide spacing for optimum growth. A commonly recommended spacing for Common cashew varieties is 12 x 12 meters, which entails 69 trees per hectare, assuming a rectangular planting pattern. Dwarf cashew varieties can be planted at a spacing of between 5 x 5 meters and 6 x 6 meters, which entails between 278 and 400 trees per hectare, assuming a rectangular planting pattern. Giant cashew varieties are not commercialized in Africa, but their optimal spacing can be between 15 x 15 meters and 20 x 20 meters between and within rows. On cashew farms with a high density of trees, the practice of thinning can help maximize yields.

Unfortunately, there are no registered varieties in most cashew-growing countries in Africa, except Tanzania and Mozambique. The most common spacing used in major African cashew-growing countries in Africa are 10 x 10 meters and 12 x 12 meters, in a rectangular planting pattern. Extension staff in Zambia, Malawi and most of West Africa recommend a spacing of 10 x 10 meters for optimal growth and production, despite the lack of scientific data to support this, while 12 x 12 meters is generally favored in East Africa and Mozambique.

However, even 12 x 12 meters has been found to be insufficient for local cashew trees with large canopies. For example, in Mtwara, Tanzania, the country's main cashew-growing region, trees were planted at a spacing of 12 x 12 meters but, once they reached fifteen years old, they began to overlap with each other. Where cashew tree canopies overlap, flowers will not set nuts and produce and so cashew farmers in Mtwara had to engage in canopy manipulation.

For large-scale cashew plantations, the authors recommend an initial spacing of 7 x 7 meters, later thinned to a spacing of 7 x 14 meters and finally thinned a second time to a maximum spacing of 14 x 14 meters. This practice of high density planting followed by thinning is widely

recommended, but it should be noted that the thinning process – which involves cutting, chopping, removing, and disposing of a large quantity of wood, logs and debris from the farm – is highly resource-intensive. For this reason, high density cashew tree planting may not always be the best option, especially for small-scale farmers.

In areas with fertile and sandy to sandy-loamy soils with medium rainfall, a closer spacing of 6 x 6 meters can be utilized. However, thinning of trees between alternating plants will be necessary at later stages to expand the spacing to 6 x 12 meters and finally to a spacing of 12 x 12 meters. This will maximize production for the first few years due to the relatively higher number of plants per unit area. However, while increasing cashew productivity, this approach will reduce the area available for intercropping.

A spacing of 10 x 10 meters could be adopted in areas that have sandy-clay soils, low soil fertility and low rainfall. The wider the spacing, the fewer trees per unit area, which leads to increased open spaces and a greater potential for intercropping. However, wider spacing facilitates the growth of weeds, if there are no intercrops. For this reason, intercropping is strongly recommended when establishing a new cashew farm or plantation with wider spacing.

3.4 Field layout

The field or farm is laid out after the land is fully prepared through ploughing and harrowing. The objective of this process is to achieve optimal spacing, to ensure that the available land is fully utilized and to facilitate the movement of machines through the farm. During this phase, farmers often set plantings on the corners of right-angle triangles, using Pythagoras' Theorem or the "3-4-5 method", as it is sometimes known, scaled to the selected spacing. For example, if the farmer is using a spacing of 10 x 10 meters, the trees should be planted on the corners of right-angle triangles with sides of 6 meters, 8 meters and 10 meters.

3.5 Digging planting holes

Planting holes can be dug only a few days before transplanting provided decomposed manure or well-fermented compost is used and the area to be transplanted is less than 2 hectares. However, according to the Naliendele Agricultural Research Institute in Tanzania, it is advised to start preparing planting holes between 1 and 3 months before the onset of the first rains for larger farms as the digging and refilling of the holes will take considerable time. The recommended dimensions of the planting holes are approximately 50 x 50 x 50 cm, which is approximately the height of one's knee.

When digging the planting hole, the top soils (0-20 cm deep) should be separated from bottom soils. Depending on the fertility of the soil, the top soil should be combined with 20 grams of NPK fertilizer and 5 to 15 kilograms of manure and then used to refill the planting hole, with the bottom soils added last to make a small mound. A 1 meter tall peg should be fixed at the center of the hole until the transplanting stage (Masawe *et al*., 2019). Note that any rainfall may cause a small depression as it settles the loose soil in the dug hole. If the manure used was not well-decomposed, one should allow the mixed components to decompose further for three weeks to one month before transplanting. If manure was well-decomposed, then transplanting can take place immediately.

Figure 3: Preparation of planting holes

a. Dig hole 50 cm (wide, long & deep)

b. Separate top and bottom soils

c. Prepare well-decomposed manure

d. Add manure on top soil

e. Mix top soil and manure thoroughly

f. Start re-filling the hole with the mixture

g. Complete re-filling the hole with bottom soil and insert a peg to mark the center of the dug hole

h. Make a mound

Source: Authors

3.6 Pre-germination and seed sowing

Based on observations from Tanzania, Mozambique, Ghana and Zambia, freshly harvested cashew seeds should germinate within 7 days. However, year-old cashew seeds may take an additional 15 to 45 days to germinate, depending on the moisture content of the nuts and storage conditions. For those intending to directly plant cashew during the rainy season, which is not recommended, it is strongly advised to soak the cashew seeds for 24 hours before sowing the seed in the planting holes (Figure 4a). In order to achieve a higher success rate and uniform germination, pre-germination is preferable, especially when the cashew seeds have been stored for more than six months (Figures 4b-4e).

Pre-germination is performed on sand beds covered with dry grass or special seed bed stands in commercial multiplication centers and public institutions. After pre-germination, cashew seeds can be either directly sown in the planting holes during rainy seasons or first placed in polythene pots. In order to germinate properly, pre-germinated cashew seeds must be sown with the scar facing upwards, in the same way the nut hangs on the tree, and at a depth of 1 to 2 cm. Sowing deeper than 2 cm may prevent the radical from lifting the cotyledon out of the ground while depths of less than 1 cm risk the loss of valuable soil moisture: where possible, mulching, sowing substrates (natural and artificial) and polythene pots, can help preserve moisture in the soil.

Figure 4: Procedures of sowing cashew seeds

a. Soak seeds overnight (24 hrs)

b. Sow seeds in sand bed and cover with dry grasses

c. Remove grasses to check if seeds start germination

d. Prick germinating seeds

e. Seeds with radicals

f. Pre-germinated seed sown in a pot

g. Sow seeds with scar facing upwards (in the fields or in pots)

Source: Authors

4. CASHEW PLANTING MATERIALS

There are two types of cashew planting materials: seeds, which can be further divided into normal seeds, clonal seeds and polyclonal seeds, and seedlings, which are either grafted or un-grafted.

4.1 Normal Seeds

Normal seeds are obtained from unselected cashew trees and the quality of the tree and the seeds is usually unknown.

4.2 Clonal Seeds

Clonal seeds are harvested from selected mother cashew trees that have been established by vegetative propagation (i.e. grafting, budding, air layering, cutting or tissue culture).

4.3 Polyclonal Seeds

Polyclonal seeds are harvested from a special orchard designed to produce cashew seeds, which either has a systemic or next neighbor design. The polyclonal seed orchard is established using either vegetatively propagated commercial cashew varieties or selected elite cashew mother trees.

4.4 Grafted Cashew Seedlings

Grafted (or budded) seedlings may flower in the year they are planted and retain the characteristics of the parent trees in terms of vegetative growth, color of the vegetative/reproductive parts, yield and nut quality. Grafted seedlings grow reproductively, due to their flowering hormones, and tend to grow laterally as they develop branches.

4.5 Un-grafted Cashew Seedlings

Un-grafted seedlings will start flowering in the second or third year, but will not necessarily retain the characteristics of the parent trees, with the exception of those raised from polyclonal seeds with elite parent trees, in terms of yield and nut quality. In fact, cashew research trials in Tanzania showed that certain trees raised from polyclonal seeds can perform better than the parent trees with regards to yield and nut quality.

Un-grafted seedlings are transplanted to the field in the same way as grafted seedlings, but the level of care after transplanting is significantly lower, as un-grafted seedlings normally grow vegetatively and upright rather than laterally.

Figure 5: Type of planting materials

a. Clonal or Polyclonal Seeds

b. Seedlings

c. Grafted seedlings

d. Budded Seedling

Source: Authors

4.6 Timing of cashew seedling transplanting

The timing of transplanting depends on the size of the farm. For large farms, the process can start early under irrigation to ensure that all seedlings are transplanted before the first rains. This helps ensure that the root system of the young trees is well-established during the rainy season so that they are equipped to survive the dry season. For small farms, cashew seedlings can be transplanted at the beginning of the first rains, when there is adequate moisture in the soil.

The majority of the small-scale farmers transplant as soon as the first rains arrive as their farms are small and so the exercise can take hours, if not days. However, on large-scale plantations, transplanting can take anywhere from several weeks to months. In this case, transplanting can be undertaken under irrigation up to two months before the first rains, particularly in areas where annual rainfalls are lower than 800 mm. This helps avoid a long period of supplementary irrigation by ensuring the root systems of the young trees are well-established by the end of the rainy season. In areas where rainfall is higher than 800 mm, transplanting can take place under irrigation about a month before the first rains.

4.7 Procedure for transplanting grafted and un-grafted seedlings

Both types of seedlings are transplanted in the same way (Figures 6a-6m). If the planting holes were prepared in advance, one should remove the peg marking the planting hole and dig a round hole in the same spot to a depth of about 20-25 cm or the length of the polythene pot holding the seedling. If the bottom of the polythene pot is closed, one can use a sharp knife to

cut it open before placing the pot in the planting hole. One should then place the seedling pot in the hole and remove the soil on one side of the hole to facilitate the cutting of the polythene pot. To do this, one can use a grafting knife to cut the polythene pot from the bottom upwards and loosely open the cut sides. One can then slowly refill the opened hole with soil, taking care not to press the soil, and, holding the two sides of the cut polythene pot, one should lift it out while shaking it gently. Once the pot has been removed, one can complete the refilling of the hole and ensure that the soil ball holding the seedling is covered with un-pressed soil.

It is strictly prohibited to compress the soil around the seedling as it will break or damage the soil ball holding the root system of the seedling, which may cause the death of the seedling due to shock or a fungal infestation of the broken roots. When transplanting the grafted seedling, the root collar and point of the union should remain uncovered by soil. The planting exercise is completed by inserting a peg to tie the seedlings to protect them from logging due to strong winds. One can then place the removed polythene pot on top of the peg to show that it was not left in the soil.

Some farmers fail to remove the polythene pots, especially when the polythene pots are opened on both ends, due to a lack of knowledge. This is not best practice as the plastic will cause the root and stem to form a collar, which will break in strong winds regardless of the age of the tree.

If there is no rain and the soil is not wet, to maximize the chances of the seedlings' survival, one should irrigate the seedlings immediately to remove all air bubbles in the loose soils and bring the root system into contact with wet soils. This will also naturally compress the soil without destroying the roots system. Finally, one should create a basin around the seedling to attract rain water harvesting.

Figure 6: Transplanting seedlings

a. *Shake the peg clockwise and remove it*

b. *Open the hole about 20 cm deep in order to sit the seedling*

c. *Prepare a seedling to be transplanted*

d. *Insert the seedling in the hole*

e. *Refill soil on one side to hold the soil ball of the seedling*

f. *Cut polythene pot from bottom upwards*

g. *Add mixed soil while shaking and lifting the two sides of the cut polythene pot*

h. *Continue shaking and pulling until the polythene pot is out of the ground and do not compress the soils around the seedling to avoid breaking the soil ball*

i. *Make a basin for holding water without compressing soil*

j. *Re-insert a peg to tie seedling*

k. *Punch the polythene pot on the peg*

l. Tie the seedling on the peg using sisal twine

m. Irrigate the seedling to naturally compress soils

Source: Authors

4.8 Care after transplanting

Transplanted seedlings, whether grafted or un-grafted, need to be given good care to ensure that they do not suffer from moisture stress, weed competition, shade from sunlight, disease or insect-pest damages.

As outlined above, un-grafted seedlings require less care compared to grafted ones as they normally grow vegetatively and upright, assuming the growing tip is not attacked by pests and there are no suckers emerging from the stem that need to be removed. The seedlings need sufficient mulching in the dry season to preserve soil moisture, and regular monitoring for any insect-pest or disease infestations to implement control measures as soon as possible.

In the case of grafted seedlings, the scion grows reproductively because it has flowering hormones. Suckers also often emerge below and at the graft union (Figures 7a and 7b), which must be checked for and removed on a regular basis as they grow aggressively and compete with the scion for nutrients. If they are not removed, the scion will be suppressed and likely die within months.

Removing the suckers (or de-suckering) that grow below and at the graft union should be done continuously in the first and second years until the tree stem reaches a height of 50 to 100 cm and the tree canopy has an umbrella shape. It is fairly easy to differentiate the leaves of the vegetative suckers from those of the grafted scion (reproductive leaves) in the early stages of the young cashew tree's development: the vegetative suckers have leaves with sharp tips at the end (Figure 7c) while the grafted scions have leaves with oval or round tips at the ends (Figure 7d).

Figure 7: Sucker growing below and at graft union

a. *Grafted before reaching 45 days*

b. *Grafted seedlings over 45 days*

c. *Leaves of un-grafted seedlings (have sharp tips)*

d. *Leaves of grafted seedlings (have round/oval tips) like mature leaves*

Source: Authors

REPLACEMENT OF DEAD SEEDLINGS

When transporting seedlings from the nursery to the field for transplanting, generally a few seedlings will die due to various reasons, including transportation or transplanting shock, root damage during loading or unloading and damage incurred during the removal of the polythene pot. A routine visit to the farm after transplanting is advised to check the development of the newly-established plants and mark empty planting stations using a long-flagged pole. Any gaps should be filled as soon as the dead trees have been identified.

SUPPLEMENTARY IRRIGATION

Young transplanted cashew seedlings do not have a well-established root system to get enough moisture from the soil. Therefore, supplementary irrigation is necessary if it does not rain after

transplanting and the soil is dry. In years of severe drought, the mortality rate for young cashew trees is usually very high. This can be reduced by mulching the young trees and performing a supplementary irrigation twice a week. It is recommended that the irrigation takes place early in the mornings or in the evenings.

WEEDING AND INTERCROPPING

Young cashew trees compete poorly with weeds for nutrients and moisture in the soil. If the farm is not intercropped with annual crops, a strip weeding of 100 cm is recommended (i.e. 50 cm on each side of the transplanted seedling or young tree: see Figures 8a and 8b). At a spacing of 12 x 12 meters, the remaining distance between the rows will be 11 meters. One should allow grass to grow in these areas and then plough or harrow this succulent grass before it begins flowering, depending on the vegetation and soil type. This will increase the humus content of the soil, which will in turn increase the water retention capacity, eliminate the risk of fire hazards during dry season and prevent the development of breeding grounds for cashew insect-pests.

Intercropping cashew with annual crops in the first few years is highly recommended in order to cover the operational costs associated with managing the farm (Figures 8b and 8c). As cashew trees will not provide any significant revenue in the first two years and the maintenance of the field is very expensive, intercrops can help generate vital cash returns until the cashew trees start producing, which is typically in the third to fourth year after planting.

The distance from the main stem of the cashew tree to the intercrops should be 50 cm in the first year (Figures 8a and 8b), one meter in the second year and one additional meter for each consecutive year until there is no more space. Intercrops should not be planted close to the tree stem as they will physically obstruct the control of diseases and insect-pests (Figure 8c).

Figure 8: Intercropping or strip weeding

a. Strip weeding

b. Well spaced intercrop

c. Badly spaced intercrop

d. Ploughing, harrowing or manual preparation of trench

Source: Authors

There are several advantages to intercropping on cashew farms, some of which are specific to particular types of annual crops:

- Increased household food security through annual crops;
- Increased soil fertility as crop residues decompose;
- Availability of crop residue with which to feed livestock;
- Improved soil structure as crop residues decompose and increase the soil's water-holding capacity;
- Improved aeration, water infiltration and nutrient availability for feeder roots thanks to weeding;
- Conserved moisture, reduced soil temperatures (cover crops), controlled nutrients loss through leaching thanks to the presence of cover crops;
- Reduced farm operational costs thanks to cover crops limiting soil erosion; and
- Improved soil fertility thanks to leguminous crops by releasing and fixing nitrogen in the soil.

CASHEW PRUNING

There are three types of pruning in cashew, namely formative pruning, light pruning and heavy pruning. All three types of pruning are important annual agronomic practices and recommended for cashew farmers. However, it should be noted that pruning of any kind in cashew leads to a

reduction in yield. Therefore, considerable care must be taken when undertaking pruning, especially in the first three years.

Formative pruning

The branches of cashew trees raised from grafted seedlings have a tendency to grow laterally or sidewise. After one year of growth, a formative pruning should be done to ensure that the tree develops an umbrella-shaped canopy. Trees raised from un-grafted seedlings normally grow upright and naturally form an umbrella shape canopy, if the growing tips were not destroyed or damaged by insect-pests, so formative pruning is rarely necessary.

Formative pruning is done by gradually removing the branches of the grafted plants until the stems reach a height of 50 to 100 cm. A very common error in the first and second year of pruning is to remove all cashew branches to about 1 to 2 meters above the ground (Figures 9a), which delays the vigorous growth of the trees and therefore fruiting, which in turn reduces cashew production and associated income. Overly pruned trees will take longer to form a good canopy, which is essential to production as cashew trees bear nuts on the periphery of the canopy.

Another aspect of formative pruning involves gradually removing branches that are touching the ground in the first two years (Figures 9b). In the second year, the pruning height should be approximately 50 cm above the ground. From the third year onwards, the pruning is carried out in order to allow nuts that have fallen underneath the trees' canopy to be easily collected (Figures 9c).

It is evident that branches control the root development and therefore care must be taken to ensure that branches that are not touching the ground are left un-pruned until the tree is well-established. Otherwise, formative pruning should be performed for the first two to three years after the establishment of the cashew tree as it is vital for the optimal development of the tree.

Light pruning

This is an annual agronomic practice for mature cashew trees that involves removing branches that are touching the ground or obstructing machine operations. It also involves removing dead and diseased branches, shoots or suckers growing underneath the tree canopy that hosts diseases, and sucking insect-pests. This process can be done using machetes, heavy pruning shears and bow saws.

Heavy pruning

Heavy pruning is performed on mature cashew trees every 3 to 5 years, depending on the tree's growth rate. This involves removing large branches obstructing the collection of nuts underneath the cashew tree's canopy or obstructing machine operations, such as ploughing and harrowing. Heavy pruning is usually carried out using motorized chain saws to smoothly cut off the branches. Axes are not recommended as they can cause the branches to crack and the rough cuts can lead to an attack of stem borers.

Figure 9: Formative pruning

a. Incorrect pruning (delays production for 2-3 years)

b. Correct pruning (umbrella shaped canopies start producing in the 2nd year)

c. Well-pruned trees producing heavily in the 3rd year

Source: Authors

FIRE BELT OR FIRE BREAK

Bush fires seriously damage cashew farms and cashew plantations in many African countries. To reduce the risk of bushfires on large farms, it is recommended to put fire belts (20 to 30 meter) around the cashew field, particularly during the dry season which is also the time for flowering/fruiting.

If the farm is intercropped, one should plough and harrow the residues of the intercrops to incorporate them in the soil during the dry season. If the farm was not intercropped, strip weeding along the cashew tree rows is strongly recommended, as well as ploughing fire belts to create a barrier between a potential bushfire and the farm. On small farms, farmers are encouraged to weed and bury the grass, leaving the land bare.

Figure 10: Fire belt

Planting annual crops around the farm or ploughing the area

Source: Authors

WINDBREAK BARRIERS

When clearing land for large-scale cashew planting, it is important to clear it in blocks separated by natural vegetation, in accordance with the environmental protection regulatory authority of each country. This natural vegetation will function as a wind break for the new cashew trees. Alternatively, one can plant fast-growing trees around the farm to do the same. However, one should avoid planting fast-growing trees that take up a lot of moisture in the soil, like *acacia amarela*, as these will suppress the growth of cashew trees planted nearby.

ROUTINE CONTROL OF INSECT-PESTS

Young cashew trees are highly susceptible to damage caused by insect-pests. Therefore, it is important that young cashew trees are routinely inspected for symptoms of insect-pest attack, in order to effectively control infestations.

5. CASHEW DISEASES AND INSECT-PESTS AND THEIR CONTROL MEASURES

5.1 Cashew diseases

There are several diseases that cause considerable damage to cashew trees:

- Powdery mildew (*Oidium anacardii*);
- Cashew leaf and nut blight (*Cryptosperiosis sp*.);
- Anthracnose (*Colletrotricum gloeosporioides*);
- Dieback (*Phomopsis anacardii*);
- Fusarium wilt (*Fusarium oxysporum*);
- Leaf spot (*Pestalotia heterocornis*); and
- Damping off.

The economic impact of cashew diseases is limited in West Africa, whereas the damage of diseases like powdery mildew, anthracnose and dieback are much greater in Eastern and Southern Africa.

POWDERY MILDEW

Description

Powdery mildew is the leading cashew disease in Eastern and South-Eastern Africa and is caused by a fungus called *Oidium anacardii* Noack, which attacks all the tender parts of immature cashew trees, including young shoots, flushes, inflorescence, young tender nuts and fruits. However, once a cashew tree has reached maturity, it is no longer vulnerable to powdery mildew.

The infested parts of the tree will turn whitish and later brownish, before dropping off (Figures 11a and 11b). Infested apples tend to crack (Figure 11c) while infested young nuts develop grey lesions and wrinkle, which significantly reduces their quality when they have matured. If they are processed immediately, the quality of the kernels will remain good but, if stored for more than six months, the quality will deteriorate and the Shell Out-Turn (SHOT) – popularly known also as Kernel Output Ratio (KOR) – may drop from 48-52 lbs (best quality) to below 45 lbs (very bad quality), which renders processing uneconomical.

Control

Powdery mildew can easily be controlled through cashew tree sanitation (cultural method) followed by chemical control.

Sanitation of the cashew trees – or cultural control of powdery mildew – involves physically removing off-season shoots, which are sources of inoculum for powdery mildew, and cutting out water shoots and any other susceptible tissues infected with mildew that may act as a source of infection. In Tanzania, removing water shoots under the tree canopy has been shown to delay the onset of the powdery mildew disease for 2 to 3 weeks which, in turn,

reduces the number of rounds of fungicidal application from the recommended 3 to 4 rounds to 2 to 3 rounds. However, it is worth noting that, for sanitation to be effective, it must be performed on all farms in the area.

Chemical control involves the use of fungicides to combat the powdery mildew disease. These cashew fungicides can be categorized into two groups, namely sulphur and water-based. Sulphur fungicides can come in the form of dusts or wettable powders, both of which are acceptable in organic food chains. However, sulphur fungicides cannot be used in soils with a pH lower than 4 as they tend to increase the soil's acidity, which can affect the growth and yield of annual crops.

Sulphur fungicide is applied using a motorized blower that can project the dust up to 18 meters. It is applied to cashew trees when 20% of the flowering panicles have emerged and 5% of the panicles are infected with the disease. The recommended rate is 0.25 kg per tree for dust or 87.5 g per tree per season for wettable sulphur, applied every two weeks (14 days). Four to five rounds of application are generally sufficient to bring the disease under control.

There are several brands of water-based fungicides available that have been officially registered in Tanzania, Mozambique and Kenya for the control of powdery mildew disease. The active ingredients therein include penconazole, triadimenol, hexaconazole and many others. Water-based organic fungicides have the advantage of both protecting the trees from and curing powdery mildew, whereas sulphur fungicides only do the former.

Water-based fungicides can be applied when more than 10% of the flowering panicles are infected by the disease. The application rate depends of the size of the cashew trees: for trees with a canopy diameter of more than 10 m, the rate of application is 15 mls per 1 liter of water per tree, whereas for trees with a canopy diameter of less than 10 m, the application rate is 10 mls per 1 liter of water. The fungicide should be applied every three weeks (21 days) and three to four rounds of application are generally sufficient to bring the disease under control.

Figure 11: PMD on cashew tree

a. PMD on young leaves

b. PMD on Inflorescence

c. PMD on mature Apples

d. Flushing leaves free from PMD

e. Inflorescence free from PMD

f. Apple free from PMD

Source: Authors

CASHEW LEAF AND NUT BLIGHT

Description

Leaf and nut blight was not known to attack cashew trees until it was first reported in Tanzania and Mozambique in 2002. The disease is caused by the fungus *Cryptosporiopsis* sp. and attacks all young tender shoots, leaves, young cashew apples and nuts. In the initial stages, the disease usually presents as small, scattered brown spots on the leaf lamina, which later increase in size and start to cover more of the leaf's area, with dark brown edges. Another early sign of the disease is chlorotic brown spots on both sides of the tender leaves.

The diseased leaves eventually curl and defoliate (Figure 12b). The infested young tender nuts develop a dark color like coal tar spots (Figures 12c and 12d) and, in severe cases, turn black and fall down (Figure 12e). The disease is spread by rain showers and wind and so, if there are no rain showers during the flushing and fruiting period, there is no risk of blight.

Figure 12: Leaf and nut blight on leaves and nuts

a. Tender flush

b. Inflorescence

c. Tolerant variety

d. Susceptible variety

e. Highly susceptible variety

Source: Authors

Control

The disease can be controlled through cultural methods followed by chemical control. The cultural method involves gathering and burning or burying all diseased fruits, branches and twigs left in the cashew field to reduce the source of inoculum. For chemical control, fungicides with the following active ingredients have been found to be effective in Tanzania: difenaconazole WG, trifloxystrobin 10% SC, picoxystrobin and trifloxystrobin + tebuconazole. Disease control is advised if it rains during the flowering-fruiting setting period. Otherwise, a blight outbreak is unlikely.

ANTHRACNOSE

Description

Anthracnose is a fungal disease caused by *Colletotrichum gloeosporioides* and, in East Africa, the disease attacks mature nuts and apples. In Brazil, the disease has similar symptoms to cashew leaf and nut blight, which makes it difficult to visually differentiate them. Anthracnose is the most devastating disease affecting cashew trees, especially in South America, where it occurs in both dwarf and common cashew tree types and is one of the biggest constraints to cashew production.

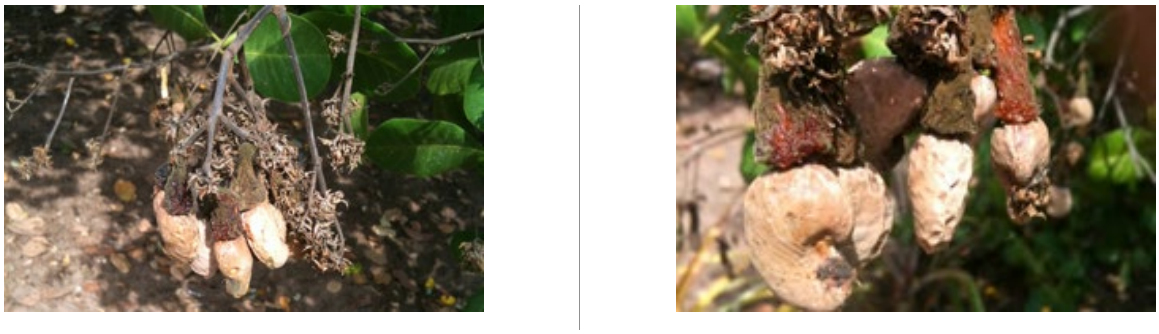
In Africa, the majority of the local and improved planting materials are resistant to anthracnose, but the disease remains prevalent in all major cashew-growing countries, including those in West Africa. Anthracnose is generally only an issue if it rains during the fruiting and harvesting period.

The infected nuts and apples decay, dry out, and shrivel, remaining on the infected shoots as “hanging nuts”. Hanging nuts often remain on the cashew panicle and act as a source of inoculum in the following season.

Control

Farmers usually do not control this disease as it affects only a few trees. However, the optimal response uses an integrated approach of cultural methods and chemical control. Fungicides such as Difenaconazole (applied every two weeks at a rate of 7.1 mls/liter of water) are recommended, as are copper-based fungicides, such as Kocide (applied every two weeks at a rate of 3 to 5 g/liter of water).

Figure 13: Anthracnose on apples and nuts



Source: Authors

FUSARIUM WILT

Description

The cashew fusarium wilt disease is caused by the fungus *Fusarium oxysporum* and was first reported to have attacked cashew trees by Tibuhwa and Shomari (2012) in Magawa, Mkuranga in the Coast region of Tanzania. This disease can kill the whole cashew tree within three to four weeks of the first symptoms appearing, which generally involve the leaves of the infested tree turning from green to yellowish before defoliating and causing the entire tree to wilt.

Control

To date, there is no known control measure available, but it is recommended that farmers burn trees displaying symptoms and then sterilize the tools used to cut them down. The fusarium wilt disease often spreads from one tree to adjacent ones and so can present a threat to the entire farm’s cashew trees if not promptly addressed.

Figure 14: Fusarium wilt

a. Initial stage

b. Middle stage

c. Final Stage

Source: Authors

DIEBACK

Description

Dieback is another cashew disease caused by a fungus called *Phomopsis anacardii*, which often uses wounds or scars from sucking insect-pests on the plant's soft tissues as an entry point. Infection starts from the tips of tender leaves and flowers before proceeding towards the base.

Control

There are no specific fungicides reported to effectively control the disease. However, the control of sucking insect-pests help to reduce the incidence of dieback in cashew trees.

PESTALOTIA LEAF SPOT

Description

Pestalotia leaf spot is caused by a fungus called *Pestalotia heterocornis* and usually attacks mature leaves, causing angular and irregular leaf spots (or lesions), which are reddish brown on the top of the leaf and pale grey-whitish on the bottom. As the disease progresses, these lesions become thinner, papery and necrotic and ultimately lead to the defoliation of the leaves. The disease can also attack young seedlings raised in nurseries with mineral-deficient soils. In East Africa and West Africa, the disease is not severe and its economic impact very limited.

Control

In case of severe infestations, the disease can be controlled using copper-based fungicides, such as Kocide (applied at a rate of 3 to 5 g/liter of water every two weeks).

Figure 15: Leaf spot

a. On young seedlings and mature leaf

b. Algal leaf spot affected leaf

Source: Authors

DAMPING OFF

Description

Damping off is the most serious disease in cashew nurseries globally and is caused by various fungi, including *Fusarium* sp., *Pythium* sp., *Phytophthora palmivora* Butler, *Cylindrocladium scoparium* Morgan, *Selerotium rolfsii* Sacc and *Pythium ultimum* Trow.

When young seedlings are infested, they stop growing, withering gradually and displaying circular water-soaked stripes on the root collar. The roots may rot, which leads to lodging of the seedlings. This disease mainly affects young cashew seedlings in nurseries with poor drainage or container-raised young plants.

Control

In order to control this disease, one should avoid fields and soils that are known to have been previously infected and consider fumigating soils before placing them in the polythene pots. One should also avoid excessive watering of nursery seedlings and ensure that plant containers are well-perforated for water drainage.

Figure 16: Damping off disease on seedlings

Source: Authors

5.2 Cashew insect-pests

There are a number of insect-pests globally reported to attack cashew, but the most common ones in Africa are as follows:

- Helopeltis bug (*Helopeltis sp*.);
- Coconut bug (*Pseudotheraptus wayi*) and aeroplane bug (*Anoplocnemis curvipes*);
- Mealybug (*Pseudococcus longispinus*);
- Stem borer (*Mecocorynus loripes*);
- Stem girdlers (*Analeptes trifasciata* and *Paranaleptes reticulata*);
- Thrip (*Selenothrips rubrocinctus*); and
- Apple and nut borer (*Thylacoptila paurosema*).

CASHEW HELOPELTIS BUG

Description

There are three types of helopeltis bugs that attack cashew, namely *Helopeltis anacardii* Miller, *Helopeltis schoutedeni* Reuter and *Helopeltis antonii* Signoret, of which the first is most common in Africa. All three are sucking pests and attack young leaves, young shoots, inflorescence and young nuts, which are then marked by brown or black lesions, the exact color depending on the age of the tree. Heavily infected trees can be easily recognized by their scorched appearance (as if they have been incinerated during a bushfire) and will not flower or set nuts as the growing tips have been completely destroyed and all new shoots will be immediately attacked (Figures 17b and 17c). As outlined above, attacks on shoots and inflorescence by helopeltis bugs and other sucking pests often lead to dieback by providing an entry point for the fungus.

Control

The insect-pest can be controlled using biological and chemical methods. Biological control using weaver ants (*Oecophylla longinoda*) has proven to be fairly effective. For effective control in cashew fields, the weaver ants must be enhanced and can be introduced from other trees, such as citrus, but care must be taken to ensure that ant nests from different trees are put on the cashew tree in question for optimal pest control results.

There are several insecticides that can control the insect-pest but they should only be applied when there are visible attack symptoms and care must be taken to ensure that the insecticides are appropriately targeted. For example, broad-spectrum insecticides, while likely to be effective, will also kill beneficial insects, such as natural enemies and pollinators. The recommended insecticide is synthetic pyrethroids, namely *Lambda cyhalothrin* at a rate of 5 mls mixed with 1 liter of water, which can optionally be mixed with water-based fungicides (for the control of powdery mildew disease) and sprayed together.

Figure 17: Coreid bug (helopeltis sp.)

a. Adult

b. Effect on growing shoot

c. Attack on inflorescence

Source: Vengolis; Authors

COCONUT AND AEROPLANE BUGS

Description

The coconut bug (*Pseudotheraptus wayi*) and aeroplane bug (*Anoplocnemis curvipes*) pose a significant threat to cashew trees, as well as coconut trees, and suck the developing nuts and young shoots of cashew.

Once attacked, very young nuts shrivel and fall down prematurely. Other nuts continue to mature but, once they are processed, the kernels inside display black spots. These spotted kernels are sold at lower prices in local, regional and international markets as they require more labor and time to be removed manually.

Figure 18: Coconut and aeroplane bugs

a. Pseudotheraptus wayi

b. Anoplocnemis curvipes

c. Attack on young nuts

d. Effect of attack on cashew kernels

e. Weaver ants new and old nest

Source: Authors

Control

The control methods for coconut and aeroplane bugs are the same as those used to control helopeltis bugs.

CASHEW MEALYBUG

Description

The cashew mealybug (*Pseudococcus longispinus*) is not a common cashew pest, but random outbreaks on a single farm or plantation do occur. Mealybug infestations appear on the cashew tree as tiny, soft-bodied insects surrounded by a fuzzy, white soot around the stems, leaf nodes, inflorescence and nuts (Figures 19a-19d). Mealybugs attack developing shoots and nuts (young and mature), covering them with white soot. Affected shoots and nuts are often completely covered with a whitish waterproof substrate and subsequently shrivel or fall down prematurely. Developed nuts are also covered in white soot, which diminishes the quality of the kernel and leads to them being sold as under grade nuts.

Control

Many natural enemies feed on and kill mealybugs on fruit trees and these beneficial insects keep mealybug numbers at manageable levels. Naturally occurring predators of mealybugs include ladybird beetles, green and brown lacewing flies, spiders, minute pirate bugs, and larvae of predaceous midges. Of these, the mealybug destroyer lady beetle, *Cryptolaemus montrouzieri*, is generally the most effective in controlling mealybug populations.

As the mealybug secretes a waxy substance to protect itself, its eggs, and the young nymphs from a wide range of chemicals, there are few effective chemical controls that will penetrate the substance and kill the insect-pest. However, chemicals with soap characteristics have the potential to wet the white substance, which then fatally exposes the pest to the sun. For example, insecticidal soaps, horticultural oil, or neem oil insecticides applied directly have been successfully in suppressing mealybug populations. Mealybugs can also be effectively controlled using insecticides like Profenofos (applied at a rate of 7.1 mls per liter of water per tree/round).

Figure 19: Mealybug

a. On the leaf

b. On Inflorescence

c. On young nuts

d. On mature nuts

Source: Authors

STEM BORER

Description

Stem borers (*Mecocorynus loripes*), also known as cashew weevils, are among the most destructive cashew pests. The adult is a dark grey-brown weevil measuring around 2 to 3 cm long and of a knobbled appearance (Figure 20a). Its wings are fully developed, but it is not known to fly.

The female weevils lay eggs in a small hole in the bark of the trunk or branch. The resulting larvae are legless grubs, whitish in color with brown heads (Figure 20c), which bore through the bark and move downwards, feeding on the sapwood of the tree and generating a brown-black gummy frass on the trunk and main branches. Severe attacks can lead to the death of the tree (Figure 20b).

Control

Severely infested trees must be destroyed, using the following steps. First, all adult weevils must be collected and destroyed by separating the head from the body manually. Second, the tree must be cut and de-barked to expose all the larva galleries – all larvae and pupae should be dropped on the ground, where they will be killed by natural predators. Finally, the tree must be cut down and fully burned.

If the infestation is relatively light, one does not have to destroy the tree, but instead should kill all adult weevils and destroy all larvae and pupae in the manner described above.

Figure 20: Stem borer

a. Adult weevils

b. Effect on the trunk

c. Larva

Source: Authors

STEM GIRDLERS

Description

Paranaleptes reticulata and *Analeptes trifasciata* are known commonly as the cashew stem girdlers and are both species of beetle in the family *Cerambycidae*. The former is mainly found in East Africa while the latter is more prevalent in West Africa.

The adult beetles girdle branches of 3 to 8 mm in diameter, leaving a V-section cut and only a narrow, central pillar round the pith zone, which eventually breaks off. These pests are most common on abandoned or poorly attended cashew farms.

Control

To control stem girdlers, one should ensure that the cashew farm is properly attended with regards to weeding, pruning and intercropping where possible.

Figure 21: Stem girdlers

a. *Paranaleptes reticulata*

b. *Analeptes trifasciata*

Source: Authors

THRIP

Description

Thrips (*Selenothrips rubrocinctus*) are minute, slender insects with fringed wings and unique asymmetrical mouthparts. Several thrip species feed on plants by puncturing and sucking the contents, but they are not common cashew pests and most farmers know very little about them. Random outbreaks can occur in certain years, but are generally limited to a fraction of a farm's trees. Both nymphs and adults suck and scrape the leaves' undersides, mainly along the main veins, causing yellowing that progressively turns gray, giving the leaves a silver appearance and potentially causing leaf drop precociously (Figure 22). Heavily infested flowers may not open for fertilization, which significantly lowers crop yields.

Figure 22: Thrip

a. *Red-banded Thrip nymph*

b. *Red-banded Thrip Adult*

c. *Thrips' effect on leaf*

Source: Authors

Control

Chemical control has proven to be effective, in particular synthetic pyrethroids, such as *Lambda cyhalothrin* (applied at a rate of 3 to 5 mls mixed with 1 liter of water).

APPLE AND NUT BORER

Description

Cashew apple and nut borers (*Thylocoptila paurosema*) are one of the most destructive pests in cashew and can cause huge economic losses in the post-harvest phase. It is generally more widely known among cashew processors and warehouse operators than farmers and agricultural extension staff as it tends to present itself in poorly fumigated warehouses holding cashew nuts.

There are two species of apple and nut borers recorded in India: *Thylacoptila paurosema* and *Nephopteryx* sp. *Thylacoptila paurosema* species can cause up to 10% crop losses in serious cases whereas *Nephopteryx* sp. can cause up to 60% crop losses. These caterpillars bore into tender apples and nuts, causing shriveling and sometimes precocious falling down. If the nuts do not fall off, the larvae often eat the kernel from the inside while the nuts are being stored in the warehouse, leaving ash-like substrates (Figure 23b).

Once hatched from eggs, the caterpillars bore into either the nut or apple. In the early stages, the young larvae focus on the joints of nuts and apples, scraping the epidermis, and later bore into them, plugging the entry holes with excreta and feeding on them. Once infested, the nuts and apples do not develop further. Only a single caterpillar is generally seen either in the apple or nut, but there are reports of up to five larvae being found in apples and up to three in nuts.

Control

The total removal and destruction of dead and dried inflorescence during the pre-flowering season is an effective cultural method for controlling the pest population. One can also spray dichlorvos at a rate of 1 ml/liter of water during the off-season. If an infestation is observed in the field or warehouse, one should spray *Lambda cyhalothrin* every two weeks until there are no more adult moths sighted. It is also important to ensure that the previous year's crop is not mixed with the current year's crop.

Figure 23: Apple and nut borer

a. Healthy nut (open cut)

b. Kernel completely destroyed by the larvae

c. Kernel being destroyed by the larvae

d. Adult apple and nut borers

Source: Authors

6. MANAGEMENT OF CASHEW ORCHARDS, HARVESTING AND BY-PRODUCTS

6.1 Rehabilitating cashew orchards

Rehabilitating cashew orchards is the process of reviving an abandoned or neglected cashew orchard and re-initiating production. This involves bush clearing, stump removal, thinning dead or diseased cashew trees and pruning old cashew trees. It also involves controlling diseases and insect-pests, filling gaps in open spaces and intercropping, which helps reduce the labor costs in weeding the cashew farm or plantation.

6.2 Upgrading cashew orchards

Upgrading cashew orchards is the process of increasing the productivity of an existing cashew orchard. This involves selective thinning, top-working, gap filling using grafted seedlings, clonal and polyclonal seedlings, intercropping, and controlling diseases and insect-pests.

Selective thinning is done after one year of observing the performance of existing cashew trees, after the application of the pesticides to control any diseases or insect-pests. In East Africa, poor performing trees should be identified between October and November and subsequently thinned in December or January. In West Africa, poor performing trees should be identified between February and April and thinned in May or June.

6.3 Harvesting cashew nuts

In West African countries, cashew harvesting primarily takes place between February to May and, in a few isolated cases or years, harvesting can continue into June for late-flowering trees. When cashew apples are mature, they naturally fall to the ground (Figure 24a). The fruits are then collected and heaped in a pile under a cashew tree canopy, where nuts are then manually separated from apples (Figure 24b). The nuts are sun-dried for about 2 to 3 days – if the sun is not scorching – to reduce the moisture content to 10% or below. If the sun is scorching, drying is best done under the shade of trees or man-made structures. Sufficiently dry cashew nuts will make a rattling sound when spread by hand.

Figure 24: Cashew harvesting

a. *Fruits usually fall on the ground at maturity*

b. *The fruits are heaped for removing nuts*

c. *Apple are left to rot in the field*

Source: Authors

6.4 Cashew by-products

While the cashew kernel is the most commercially valuable component, cashew by-products have a number of uses that can generate additional income for producers. Very often, cashew apples are discarded by the farmer and left in the field to rot (Figure 24c) and remain highly underutilized in African countries. However, cashew apples have a wide range of potential applications:

- Agricultural uses (e.g. as compost);
- Energy and industrial uses;
- Fresh fruit and food products;
- Fresh and fermented/distilled beverages;
- Canned and pulped products (e.g. jam);
- Confectionary; and
- Livestock and poultry feed.

While an average tree produces 8 to 10 times more cashew apple than nut in terms of weight, apples are only available on a seasonal basis for at most 120 days a year, which is a limiting factor for apple processors. Cashew farms are also often dispersed over a large area, which makes the collection of quality cashew apples for processing challenging. This problem is compounded by the fact that cashew apples are also highly perishable and susceptible to physical injury, as more than 60% of cashew apples are moderately to severely damaged when they fall naturally from the tree. This leaves them especially vulnerable to microbial attacks by yeast and fungus during harvest, transportation and storage. Despite these constraints, most African countries have a range of cashew apple products, including clarified and cloudy juice, juice concentrate, syrup, squash, jam, wine, gin and brandy. Examples of these products from different countries are shown in Figure 25 below. These include fenny, a popular cashew apple gin, produced in Goa, India (Figure 25e).

Figure 25: Cashew apple products

a. *Cashew apple juice brands from Ghana (left), Tanzania (center) and Benin (right)*

b. *Cashew apple jam from Ghana (left) and Tanzania (right)*

c. *Cashew apple wine from Ghana (left) and Tanzania (right)*

d. *Cashew apple brandy from Ghana*

e. *Fenny from India*

Source: Authors

When cashew nuts are processed, the kernels, which constitute 20-25% of the total weight of the nut, are separated from the shells, which account for the remaining 75-80%. These shells can be used to produce cashew nut shell liquid (CNSL) and cashew shell cakes or briquettes. CNSL has a number of industrial applications, including brake linings, wood preservatives,

fumigation, car paints and lubricants. Shell cakes can be used as an inexpensive bio-fuel in bakeries, factories and other industrial settings.

Figure 26: Cashew shell products

a. CNSL

b. Shell cakes

Source: Authors; IndiaMART

Cashew kernels that are broken or split during processing fetch lower prices on the global market compared to whole kernels. As a result, these split kernels or baby bits are often processed into a range of high-value products, which are more profitable. These products include cashew butter, powder, paste and, as of recently, cashew milkshake (Figure 27).

Figure 27: Cashew kernel products and by-products

a. Cashew kernel split pieces

b. Cashew baby bits

c. Cashew butter

d. Cashew milk shake

Source: Author

7. CASHEW QUALITY AND STORAGE

7.1 Quality

In the export market, raw cashew nuts are traded according to grades and pre-defined quality parameters. Most African cashew-producing nations, however, do not require grading raw cashew nuts and do not trade according to grades – with the exception of Tanzania.

Nevertheless, conducting grading and quality control tests are critical to meeting buyers' requirements and negotiating higher prices. Cashew nuts that are deemed to be higher quality can sell at a higher price than lower quality nuts.

The following parameters are collected for quality control:

- Number of bags;
- Lot weight (kg);
- Nut count (number of nuts per 1 kg of raw cashew nuts);
- Grade;
- Defective nut rate (share of non-usable kernels in a sample of raw cashew nuts);
- Foreign materials (share of foreign materials in a sample of raw cashew nuts);
- Moisture content (%); and
- KOR or shell out-turn (SHOT) (pounds of usable kernel per 80-kilogram bag of raw cashew nut).

Figure 28 below provides a visual introduction to the different types of cashew kernel and a reference point when conducting tests of quality.

Figure 28: Types of cashew kernel

a. ***Good kernels***
White, creamy color and well-shaped
100% are accepted

b. ***Spotted kernels***
Have one or more spots or marks (insect bites). Parts that don't have a spot or mark can be consumed
50% are accepted

c. ***Immature kernels***
Shriveled and not well developed due to harvesting too early
50% are accepted

d. ***Oily kernels***
Have an oily, yellow appearance because they have stayed too long on the ground
0% are accepted

e. ***Spoiled/bad kernels***
Either completely rotten or contain traces of yellow powder because they have been eaten by insects
0% are accepted

f. ***Void kernels***
Either small/underdeveloped kernels or empty shells
0% are accepted

Source: Authors

TESTING FOR KERNEL QUALITY

Sampling

Before performing tests on quality parameters, one must take a representative sample. The number of bags sampled and the number of samples to take depends on the size of the lot, as shown in the following guidelines:

Table 1: Sampling guidelines based on lot size

LOT SIZE (# OF SACKS)	# OF SACKS TO SAMPLE	# OF SAMPLES
1-10	All sacks	1
11-100	10	1
101-500	50	2
501-1000	10% (50-100)	3
1000+	8% (80+)	5

One must have access to the equipment in Figure 29 below in order to sample and conduct tests on quality parameters.

Figure 29: Materials needed to sample and conduct quality tests

a. Electronic balance with precision of 0.5 grams

b. Specialized scissors for shelling raw cashew nuts

c. Scoopers to separate kernel from shell

d. Plastic bowls (ideally in three colors to ease sorting kernels)

e. Latex gloves to protect hands

f. Plastic buckets (one bucket per sample)

Source: Authors

Before conducting tests of quality parameters, one must follow the following initial sampling process:

- All samples are arranged onto a flat surface – this is called the “mother sample”;
- The mother sample is mixed well to form a homogenous sample;
- The mother sample is then divided into four equal parts or “quarters”;
- To form new samples, two opposite quarters should be mixed and combined in a bucket;

- The two remaining quarters should be mixed and combined in a second bucket.

Quality tests can now be performed on each of the two buckets, the two most common of which are outlined below.

Defective nut rate

The defective nut rate indicates the share of non-usable kernels in a sample. This is calculated using the following formula with data from weighing various types of kernels:

$$\frac{\text{Weight of spotted \& immature kernels (with shell)} + \text{weight of rejected kernels}}{\text{Total weight of sample}} \times 100\%$$

A defective nut rate below 15% is considered standard grade while a rate between 16% and 24% is considered below grade. A rate above 24% is not acceptable and the sample will be rejected. A lower defective nut rate is more favorable for buyers, as this indicates that there are a greater number of usable kernels.

Kernel output ratio

Kernel output ratio (KOR) is the most important quality parameter for raw cashew nuts because it determines the quality of the kernel inside the shell. In general, buyers of raw cashew nut, especially cashew nut processors, value larger, high quality kernels.

Many buyers perform cutting tests to determine KOR before buying large quantities of cashew nuts to estimate how much revenue they will generate. If producers are able to form cooperatives and negotiate group sales, they may choose to perform tests to estimate the KOR and negotiate a higher price for their raw cashew nuts.

A KOR test must follow the following instructions:

- Measure a 1,000-g sample of raw cashew nuts. A weight between 998 g and 1,002 g is acceptable. Record this result;
- After weighing the sample, count how many nuts are in the sample and record this result;
- Weigh all foreign materials (e.g., stones, sand, miscellaneous items) and record this result.
- Use specialized scissors to cut open each nut, cutting it into halves. Ensure the two halves are kept together and the kernel remains in the shells;
- Classify all nuts according to Figure 25:
    - **Good kernels:** Remove from shells, but do not remove the peel, and place in a green bowl. Weigh and record the result;
    - **Spotted kernels and immature kernels:** Place in a blue bowl, with shell on. Weigh and record the result. Remove all shells and place nuts back in the bowl. Weigh and record the result; and

- **Oily, spoiled and void kernels:** Place in a red bowl, with shell on. Weigh and record the result.

KOR is expressed as the weight of usable kernels (in lbs) per 80-kilogram sack of raw cashew nuts. KOR is calculated using the following formula with data from weighing various types of kernels:

$$\left(\text{Weight of good kernel } \textit{(in g)} + 50\% \times \text{weight of spotted kernel } \textit{(in g)} + 50\% \times \text{weight of immature kernel } \textit{(in g)}\right) \times \frac{80}{454}$$

KOR varies based on country and region. In general, a KOR of 46 to 48 is considered good, while a KOR of 48 to 55 is considered excellent. The KOR can go as low as 40 or below, at which point it is no longer economical to process the nuts as the overall cost of production will exceed the price offered for the final product.

TechnoServe is launching an Android application to easily calculate and save data on KOR and other key quality metrics for raw cashew nuts, as well as capture pictures as well as geo-tagged and time-stamped information. The application will be available for free on the Google Play Store by the end of 2020 and be available in English, French and Portuguese.

QUALITY STANDARDS BY COUNTRY

The following sub-section outlines quality standards from Vietnam (a major buyer of raw cashew nut) and Tanzania (the only African cashew-growing nation with its own quality standards system).

Vietnam

Vietnam classifies raw cashew nuts into the following four grades based on the number of nuts per kilogram of raw cashew nuts. Lower nut counts are more favorable (and achieve higher grades) because they indicate larger-sized cashew nuts.

Table 2: Vietnamese Cashew Grading System

GRADE	NUMBER OF NUTS PER KG OF RAW CASHEW NUTS
A	<= 150
B	151-180
C	181-200
D	201-250

Additionally, Vietnam requires the following sensory requirements and physical properties.

Table 3: Sensory Requirements

ITEM	REQUIREMENTS
Shape	Nuts must have characteristic shape
Color	Have uniform colors –may be grey-white to pink-white, light grey to grey, light brown to specific brown
Odor	Have no foreign odor
Insects	Do not contain live insects

Table 4: Physical Property Requirements

PROPERTY	REQUIREMENTS
Moisture, % mass, not more than	10.0
Out-turn, % mass, not less than	25.0
Defective cashew nut, % mass, not more than	10.0
Foreign matter, % mass, not more than	1.0

Tanzania

Actors in Tanzania grade cashew nuts into Standard Grade (SG) and Under Grade (UG), before sending them to the warehouse for auctioning through the Warehouse Receipts System (WRS). The SG cashew nuts with moisture content of less than 10% can be stored for over a year without a loss of kernel quality (i.e. Shell out-turn (SHOT) or KOR). For UG cashew nuts, the kernel quality starts to deteriorate within the first six months of storage.

According to the official definition, the SG cashew nuts in Tanzania must have the following quality characteristics:

- A grey or light brownish shell without wrinkles;
- Mature with an audible cracking sound when dropped on a hard surface;
- A moisture content of 10% or below;
- A nut count per kilogram of 200 or below; and
- A KOR of 48 lbs per 80-kilogram bag or above.

In Tanzania, the UG cashew nuts must have the following quality characteristics:

- Mature;
- A moisture content of 10% or below; and
- A KOR of between 44 and 47 lbs per 80-kilogram bag.

Figure 30: Cashew nut grading based on Tanzania system

a. Un-graded RCN

b. Standard Grade

c. Under Grade

Source: Authors

7.2 Storage

The packing materials for storage of cashew nuts is essential to maintaining the quality of raw nuts throughout the year. Cashew nut is a living seed that must be properly aerated. However, most African cashew farmers use any available type of bags to store cashew nuts, including polypropylene woven sacks, which are made specifically for seeds, fertilizer, flour, sugar among other commodities (Figure 31). However, polypropylene woven sacks are not ideal for cashew nut storage as they do not allow for proper air circulation in the bag: as a result, the humidity causes the nuts to begin to germinate and turn in color from grey to brownish.

The optimal and recommended storage bags are jute and sisal gunny bags (Figure 32). Dry cashew nuts are placed in jute or sisal bags, which weigh a total of 81 kg including the 1 kg jute bag (Figure 32d), and then stored on pallets in a ventilated room, store or a warehouse (Figures 32f and 32g), and never on the floor (Figure 32e).

Figure 31: Polypropylene woven bags that are not suitable for cashew nut storage

Source: Authors

Figure 32: Cashew gunny bags

a. *Sisal gunny bags of different types*

b. *Single jute gunny bags*

c. *Dried RCN ready for filing into jute bags*

d. *Filling and sewing RCN in jute bags*

e. *RCN in bags stored on the floor in a warehouse (not recommended)*

f. *RCN in bags being stored on wooden pallet in a warehouse (recommended)*

g. *RCN in bags stored on wooden pallet domestic (recommended)*

Source: Authors

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9. AUTHOR BIOGRAPHIES

Prof. Peter A. L. Masawe

Professor Peter A. L. Masawe is a retired Principal Agricultural Research Officer, a cashew Breeder and Cashew Value Chain Specialist with over 33 years' experience in the cashew industry and over 31 years of project management and supervision in Sub Saharan Africa.

He is one of the most prominent cashew breeders in the World after releasing 54 new cashew varieties. He has undertaken consultancy services with United Nations Universities in Finland, The World Bank, Centre de coopération internationale en recherche agronomique pour le développement (CIRAD), The Adventist Development and Relief Agency (ADRA-Mozambique), Australian Government Overseas Aid Program (AUSAID) supporting ADRA Mozambique, Development Aid from People to People (ADPP) Mozambique, Common Fund for Commodities (CFC), TechnoServe (Ghana), European Commission in Mozambique, Hivos Foundation in Harare Zimbabwe), African Cashew Initiative (Ghana), African Cashew Alliance in Ghana, governments, public and private institutions, private companies, several local and international NGOs and individuals cashew farmers.

He was employed by the World Bank in Mozambique as International Cashew Expert (2000-2003), and was a Technical Advisor to the Cashew Development Project in Ghana (2006-2007). He was a Regional Coordinator for Cashew Improvement Network for Eastern and Southern Africa for 7 years and a Lead Scientist for National Cashew Research Programme for 28 years. He is an author/co-author of twelve cashew books and has 66 publications in local and international journals. He was given a national award as one of the best agricultural research scientists in Tanzania in 2017. From January 2018, he was employed as a Technical Advisor to the Cashew Infrastructure Development Project in Zambia funded by African Development for two years. He is also an Adjunct Professor for Nelson Mandela African Institute of Science and Technology in Arusha, Tanzania.

Mr Rui B. Matos

He is an agronomist with vast experience in agribusinesses, plant production and sector transformation. Over 23 years of experience working in cashew sector 17 of which at service of public sector (Cashew Rehabilitation Project under umbrella of former Cashew Secretariat State and later INCAJU) – 1997 till December 2013, he assumed several technical leading positions at provincial and national level.

In 2013, he left the state and joined TechnoServe Mozambique as Project Manager in the MozaCaju Project for 4.5 years. He played a role in influencing Mozambique and Zambia Cashew sectors transformation. In Zambia, he supported the government's

decision to revamp cashew sector through trainings in nursery management, seedling grafting and planting as well as high level persuasion meetings with Deputy Minister of Agriculture (April 2013) and high officials of the Zambian Agriculture Ministry and Western Province local government officials and producers. This support contributed to Zambia attracting an investment from the African Development Bank of US$ 45 million for a 10-year project to support production and processing. In Mozambique, he played a huge role in influencing cashew stakeholders and developing partners to share the same vision for the future of the sector.

In 2018, he founded the 23 Matos Consultoria e Serviços Lda and since then has been delivering various national and international consultancies as independent consultant to clients such as Norgesvel, SIDI, Nitidae, The Gorongosa National Park, TechnoServe (Mozambique) and (Benin) and Commercial Farmers.

Mr Kouami N’djolosse

Mr. Kouami N'DJOLOSSE was born in 1975 at Savalou in Benin. He did his primary and secondary school studies in the same city. After obtaining the Baccalaureate in 1995, Mr Kouami N’djolosse did his graduate studies at the University Polytechnic College of the National University of Benin, current University of Abomey-Calavi, in the "Environment management and Protection" specialty. He obtained an Engineering Degree in 2000.

Mr. Kouami N’djolosse was recruited on April 15th, 2002 by the Central Region’s Agricultural Research Center (CRA-Centre) of the National Agricultural Research Institute of Benin (INRAB) to work in a cashew research and development program. Since that time and until now, he continues working on cashew research. During his career, Mr Kouami N N’djolosse 's interventions focused mainly on three research areas, namely: (i) cashew planting material development, (ii) cashew production technical routes improvement, and (iii) knowledge transfer in these cashew production areas. He has tens of scientific publications.

Mr Kouami N’djolosse has also participated in research on other species such as African locust bean, shea tree and teak.

In addition to his professional career, Mr Kouami N’djolosse continued his graduate studies and obtained a Master of Science degree in agricultural entomology in 2011. He is currently a PhD student in genetics and plant improvement since 2017 at the Doctoral School of Life and Earth Sciences of the Faculty of Sciences and Technologies at the University of Abomey-Calavi in Benin.

Mr Soulé Abdoulaye Manigui

Mr Soulé Abdoulaye Manigui is an Agronomist, with more than 20 years' experience in the Agriculture Development Sector. After obtaining a degree in Engineering in Animal Husbandry at the University of Ibadan in Nigeria, he graduated with a Master Degree in Rural Economics at the Université Catholique de Louvain-La-Neuve in Belgium.

Mr Soulé Abdoulaye Manigui has expertise in several areas such as Policy analysis and development, coordination and supervision of the entire process of developing and finalizing basic documents for the chain value and for the various sub-sectors, value chain analysis, project/programme management, cross-cutting integration of gender and environmental dimensions into the agriculture sector strategies, development of public-private partnerships, International development cooperation.

From 1998-2002, he was the Director of Programming and Long-Term Planning(DPP) of the Ministry of Agriculture, Livestock and Fisheries of Benin where he coordinated and supervised the whole process of elaboration of the national policy, projects and programs to support the implementation of the national policy and monitoring and evaluation of the main orientations of the national policy implementation, facilitated the process of institutional reforms in the agricultural sector

From 2002-2004, as a National Director of Agriculture (DAGRI) at the Ministry of Agriculture, Livestock and Fisheries of Benin, he facilitated the process of the definition, implementation and follow up the national policy for agriculture sector development, mainly on innovation aspect and technology improvement for crop production including the plant protection law regarding new chemicals for plant protection.

In addition to this position, he was in charge of Monitoring Performance Cooperation and Rural Finance working as Technical Advisor to the Minister of Agriculture at the Ministry of Agriculture, Livestock and Fisheries of Benin, where he has put in place planning instruments and mechanisms.

From 2006 to 2013, during 8 years, he served as a Programme Officer at Belgian Development Agency, currently Enabel, formerly BTC, and has also acted as interim resident representative of Belgian Development Agency.

From 2013-2015, he was in Accra and as Head of Information Unit throughout a sub-regional programme on cashew value chain covering several countries in west Africa including Benin and Côte d'Ivoire where he participated in the reform process in cashew value chain management and policy.

In 2016, he elaborated the national strategy for the development of the cashew nut sector in Benin.

From 2016-2017, as a consultant he worked for NGO TechnoServe Benin for their cashew value chain project. He then was recruited as full-time employee as a Deputy Coordinator of BeninCajù project, one of the most important projects implemented by NGO TechnoServe in Benin. In July 2017, he was promoted as the Deputy Country Director of TechnoServe and also in charge of sector policy and support to institutions.

Mr Siaka Kodjo

Mr Siaka KODJO is the Director of Programme of Agricultural Territorial Development Agency of Borgou-Donga and Collines (ATDA4) in Benin. In this position, he is the Vice Director of the Agency which is in charge Cashew, Cassava and soya beans improvement in Benin. During 2018, he was the Technical Research Agricultural and Food Advisor (CTRAA) of the Minister of Agriculture, Livestock and Fisheries of Benin. In 2019, he had two trainings in Cashew planting materials production in Brazil (AMBRAPA) and Tanzania (TARI Naliendele). Previously, he was a Researcher at ''Centre des Recherches Agricoles du Centre (CRA-C)'' of the National Agricultural Research Institute of Benin (INRAB) and Deputy Director of ''Centre de Recherches Agricoles du Centre'' (CRA-C) of Savè. He was previously in charge of the Scientific Committee of the Permanent Secretary (SP/CT) of the Centre of Agricultural Research of the Central part of Benin (CRA-Centre). He is also Vice Head for the Regional Central Research Program (PRC) of the Centre based at Savè, Collines' Department. Engineer Agronomist-Economist at the Faculty of Agronomy Sciences of University of Abomey-Calavi (Bénin) in 1985, he is a post graduate in many fields such as Data Bank management, field experimentation management, Rapid Rural approaches, local community auto development etc.

He got a degree of Master of Sciences (MSc) in Natural Resources Management in the same University in 2006 at Doctoral School of Agronomic Sciences Faculty (FSA) of Abomey-Calavi University. He performed on the fields of cropping system improvement, Natural resources Management, Non Timber Products processing (Borassus aethiopum.Mart), Integrated Soil Fertility Management (ISFM), Rapid Rural Appraisal (RRA), Community based development implementation and monitoring, Rural Development Project management, etc. In the few past years, he collaborated with IFDC (International Fertilizer Development Center) for the PAGEFCOM Project management in Zou and Collines departments and with ACi /GIZ program where he worked on Farmers and technicians training on cashew production experiments/implementation; harvest and post-harvest technologies, Value link improvement and cashew economics. He also got experience on beekeeping integrating in cashew orchards. The most of the professional activities dealt with rural extension programs, research on main crops as cassava, yam, maize and farmers training, advocating and trials on natural resources management such as crops and non-timber products value link improvement. Master trainer in the Cashew Value chain improvement, he has a high capacity of farmers training in cashew nursery establishment, cashew orchards improvement by thinning and pruning, cashew nut harvest and post-harvest, integration of beekeeping to cashew orchards.

He has a high capacity computer use notably on software such as Microsoft Word, Excel, PowerPoint. He performed in database management with software such as Minitab, Stat box, SAS, SPSS, GenStat etc.