A GUIDE ON DEVELOPING CASHEW VARIETIES AND IMPROVED PLANTING MATERIALS

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Published by:

Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ)

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F + 49 61 96 79-11 15

I www.giz.de

Registered Offices

Bonn and Eschborn Germany

Place and date of publication:

Ghana, December 2018

Responsible editor:

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Printed in Accra, Ghana.

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ACKNOWLEDGEMENT

This technical manual has been published by the Competitive Cashew initiative (ComCashew), a private public partnership project under the lead implementation of the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. The project is mainly funded by the German Federal Ministry for Economic Cooperation and Development (BMZ) and also by various private and public institutions.

The Competitive Cashew initiative (ComCashew) acknowledges all contributors for their inputs and Prof. J.A. Kwarteng of the University of Cape Coast for final editing and completion of the manual.

FOREWORD

Cashew is increasingly becoming the nut of choice given its health benefits and the hype it currently enjoys on the global market. This translates as an increase in demand and ultimately high prospects for producing countries. Despite these opportunities, there still exist a number of challenges especially in the area of production. Producing countries, most of them in Africa, still struggle to increase productivity and to ensure that their produce are of high quality and meets international standards. Training has been recognized as one of the most effective tools in addressing this challenge. In this regard, the GIZ/Competitive Cashew initiative (ComCashew) has since 2009 trained over 500, 000 farmers from Benin, Burkina Faso, Ghana, Ivory Coast, Mozambique and Sierra Leone. Capacity development of about 300 experts through ComCashew's Master Training Program also ensures that knowledge and experiences are multiplied throughout the African sub region. Regardless of these efforts, there still remains a gap in the availability and accessibility of high quality training and information materials to promote Good Agriculture Practices as well as good harvest and post-harvest practices.

In response to this, ComCashew publishes a number of production manuals to provide useful and practical information for trainers, cashew producers and anyone looking to go into cashew production. The Guide on Developing Cashew Varieties and Improved Planting Materials, one of these manuals, highlights the importance of improved varieties for higher productivity as well as the approach used in developing these varieties.

Given the increasing change in trends and improvements in research and technical know-how, revised editions of production manuals are foreseen so as to provide in-depth and up -to - date technical information to promote continuous improvements in cashew productivity.

I am grateful to all financial and technical contributors for their support in publishing this manual and look forward to similar collaborations for a sustainable cashew industry.

Hon. George Oduro,

Deputy Minister

Ministry of Food and Agriculture, Ghana (MoFA).

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1 Introduction

Cashew (Anacardium occidentale L.) was previously considered a forest tree and therefore received little attention as a cultivated crop in most countries. However, cashew is currently recognized as a very important tree crop in terms of its economic, social and environmental significance. It is an important export crop in a number of countries in Africa where 1,823,000 tons of raw nuts, accounting for 59% of the total world production in 2017, was produced (ComCashew, 2018). Currently, West Africa leads the rest of Africa as the largest producer of cashew nuts and contributes 47% of the world's production. This volume accounts for 80% of the continent of Africa's production in 2017. The position of West Africa in the production of cashew in Africa and in the world has been made possible by a number of factors including favorable weather conditions, increased area brought under cashew cultivation, and farmers' growing interest in the crop since the 1990s as a result of increased prices of cashewnuts. Unfortunately, the majority of the 2.5 million producers in Africa struggle to improve their incomes from cashew orchards because, in general, the average yields of cashew trees in the region remain rather low (3-6 kg / tree) compared to what is obtained in the major producing countries of the world such as India, Vietnam, Brazil and Tanzania where yields of 10 to 15 kg / tree are obtained (Masawe, 2010; Tandjiekpon, 2010).

The lack of improved planting materials appears to be a serious problem across the continent and, therefore, requires due attention (Masawe, 1994; Mneney and Mantel 2002). It is evident that apart from Brazil, a majority of other cashew growing countries in the world do not appear to have rich cashew gene banks (Masawe, 2010). However, the existing cashew germplasm in different countries could be utilized to generate new cashew varieties with desirable traits through hybridization (Masawe et al., 1998). New varieties need to be suitable to the cashew processing technology.

1.1 Importance Of improved planting material (IPM) on yield

Yields from cashew trees and consequently yields per unit area can be greatly improved by using high-performance planting material. The use of high performance planting material means farmers will no longer have to try to increase yields only through increasing the area cultivated (a process known as extensification), but can achieve the same goal through intensification. The process of intensification allows farmers to get more yield from the same piece of land by growing improved cashew planting material. This is important because intensification will reduce the competition between cashew trees and food crops for agricultural land and also help reduce deforestation.

Improved planting materials are known to have contributed to tripling or quadrupling the productivity of cashew in West Africa. Although the existing cashew trees in West African are resistant to drought and other typical regional environmental factors, its productivity is low and need to be improved to achieve better returns on investment as well as the desirable quality (Weidinger et al., 2012).

The absence or lack of improved (high-performance) planting material and the unavailability of selected seeds of good quality compel growers to use nuts from "all kinds of sources" for the establishment of plantations. Cashew trees in such plantations are very heterogeneous in terms of yield and quality of nuts produced. In such plantations, only 10 to 20% of the trees tend to have good yields. The rest of the trees tend to have very low productivity and in some cases do not produce anything at all. This state of affairs is undesirable because the low productivity of the cashew trees does not allow growers to receive enough returns for expanding and maintaining their plantations.

1.2 Purpose of the guide

This guide has been produced as a manual to contribute to the development of the cashew value chain sector in Africa. First, it places specific emphasis on the importance of using improved planting material to improve yield and quality of nuts produced as well as the competitiveness of the cashew sector in Africa. Furthermore, this guide describes the role of some stakeholders and the approach being used to develop improved cashew planting material.

Indigenous cashew plants in African countries are already adapted to local environmental conditions through the process of natural selection (Masawe, 2010). As the evaluation of planting material of the cashew plantation is very time consuming and costly in terms of time as well human and financial resources, it is better to pay special attention to material already adapted to local conditions before considering or relying on the importation of planting material from outside Africa.

The Agricultural Research Institute of Naliendele has developed a new cashew varietal improvement approach which reduces the required number of years from 15-20 years to 9-14 years. Such important advances in research on such an important export crop deserve to be widely disseminated.

1.3 Target Groups

This guide addresses three main target groups, namely:

Researchers working in the field of cashew production. This includes all categories of researchers involved in research directed at developing improved cashew planting material from cashew trees of high- performance.

Extension officers who are knowledgeable and are responsible for disseminating high-performance cashew planting materials to producers who are the end users. These extension workers must be convinced of the importance of using improved high-performance planting material and the need to make it accessible to the farmers they supervise. Nursery operators and their respective farmers' associations who should understand and be convinced of the importance of using improved high-performance planting material. These groups should appreciate the process of developing high performance planting materials and how the use of such materials impact the yield of the orchards they plant.

2 Cashew Trees

Cashew is a native to north-eastern Brazil, but is now cultivated in a number of tropical countries. Brazil is the only place where both cultivated and wild cashew trees are found. However, in all countries, cashew trees are variable in types, branching patterns and flowering habits. Each of these characteristics influences varietal development in terms of production and productivity.

2.1 Types of cashew trees

Mitchell and Mori (1987) reported that the following four types of cashew trees were found in nature: dwarf, common, giant and wild cashew types. However, in the process of crop improvement, medium types of cashew trees (semi-dwarf) have been developed through natural crossings or hybridization by controlled hand pollination (Masawe, 2009 and 2010). It is evident that now there are five types of cashew trees in existence when cashew hybrids are included. Hybrids are variable in size, potential yields, and tolerant to insect pests and diseases depending on the reason for developing the hybrids and the type of parents used in the hybridization process.

2.2 Cashew branching pattern

With the exception of wild cashew trees, each of the cashew tree groups described above in section 2.1 can also be categorized into three sub- groups: trees with extensive branching patterns, trees with intermediate branching patterns, and trees with intensive branching patterns. Trees with extensive branching patterns are likely to be lower yielding (although some may have excellent nut quality) while those with intensive branching to a large extent appear to be high yielding even though some can also have small nuts. It is important to note that yield character is genetically controlled although the environment has some influence on it. Cashew trees are highly cross-pollinated, although self-pollination also takes place. There are no records of self-incompatibility in cashew (Ohler, 1979; Masawe, 1994). Cashew is mainly pollinated by wind or insects like bees, butterflies, flies, crawling insects, etc. (Northwood, 1966; Nawale et al. 1984; Heard et al. 1990).


Extensive branching




Intermediate branching

Intensive branching

Figure 1-6: Branching pattern of cashew trees

2.3 Cashew flushes

Flushes may grow vegetatively or reproductively depending on the phenological phase of the respective growing tip. A majority of the flushes produced between April and June (south of equator) and between September and November (north of equator) develop to flowering panicles. Cashew flushes may vary in shape, size and in color depending on the genotype (Masawe, 2006). Some cashew varieties are easily identified by the type of leaves or flushes (see Plates 2A, 2B, 2C and 2D). Greenish, brownish, pinkish, reddish or intermediate color flushes are most common (Masawe, 2006). Maturity of the flushes varies considerably and this has been observed to be associated with tolerance to some cashew diseases like blight and powdery mildew (Anonymous, 2008). Flushes which mature rapidly are tolerant to pests and disease as opposed to those that have prolonged period of remaining tender before hardening.

A

B

C

D

Figure 7- 10: Different types of cashew flushes

2.4 Cashew flowering types

Cashew trees differ in time of flowering, which partly explains why cashew harvesting takes four months and even longer in some seasons (Subbaiah, 1983). However, there are three types of cashew trees as far as flowering is concerned: early flowering, medium flowering and late flowering. Under normal circumstances, cashew trees that are not irrigated have two peaks of flowering (Northwood, 1966; Ohler, 1979). The first peak south of the equator occurs in August while the second occurs in October. The first peak north of the equator is in December while the second one is in February. Flowers produced in the first peak normally give over 75% of the annual production of the cashew tree (Masawe, 2009). There are some exceptions where cashew trees remain with one peak of flowering (due to stress like drought) or flower continuously when under irrigation (Bezzera et al. 1972; Barros et al. 1984).

However, there are varieties that have only one peak of flowering and a short duration for nut harvesting.

2.4.1 Cashew flowers

There are three types of cashew flowers. These are male, hermaphrodite and abnormal or sterile flowers (Damodaran, 1966; Mota, 1973; Joseph, 1979; Thimmaraju, 1980; and Masawe et al., 1996). Examples of these types of flowers are presented in Plate 3. Some authors have reported cashew flowering panicles to possess only staminate (male) and perfect (male and female) flowers (Rao and Hassan, 1957; Davis, 1999; Ascenso and Mota, 1972; Kumaran et al., 1976). Male flowers have one large stamen (anther and a filament) and several small stamens. Abnormal flowers are like male flowers but they do not have the large stamen.

Hermaphrodite flowers have both large and small stamens and have the female part (stigma and style).

The first flowers to open are the male and abnormal flowers followed by hermaphrodite flowers. Similar observations have been reported by Moranda (1941), Rao and Hassan (1957), Northwood (1966) as well as Masawe et al., (1996). Although cashew flowers are reported to be self- fertile and not self-pollinated, bagged flowers did not set nuts (Northwood, 1966; Free and Williams 1976; Masawe, 1994). In studies, the removal of male flowers is important in case an insect finds its way inside the pollination bag.


Male Abnormal Hermaphrodite

Figure 11- 16: Different types of cashew flowers

In the area south of the equator, cashew flowers usually start opening around 8.00 am and mostly are male and abnormal ones (Anonymous, 1992). Hermaphrodite flowers open around 9.00 am. In West Africa, flower opening starts around 6.00 am. Flower opening mainly depends on relative humidity and temperature. However, observations have shown that some genotypes delay flower opening until mid-day (Kapinga, 2009- Personal communication). Low temperatures have been shown to delay flower opening (Anonymous, 2008).

3 Approach in developing cashew varieties (Identification of mother trees, Identification of Standard Clones, Genetic trials, and Hybridisation)

In any crop breeding program, the development of new varieties starts with germplasm collection, evaluation, mass selection (or introduction clones/varieties), establishment of genetic trials and release of the varieties. In annual crops this may take about three years. However, in cashew, it takes many more years to develop a variety due to the prolonged period of time it takes cashew trees to reach optimum yields. The following section will focus more on selection and evaluation of elite mother trees, genetic trials, scion orchards and polyclonal seed orchards.

3.1 Procedures to identify elite mother trees

Identification of elite mother trees (Germplasm expedition) is a very important step in initiating a cashew-breeding programme. Local germplasm collection is very important because materials found within a country are already adapted to the local environment through natural selection. Introduction of foreign materials with desirable characteristics is an added advantage to expand the cashew gene bank for future selection.

Mother trees may be identified in research farms, farmers' fields and existing cashew plantations. The best time for identification of mother trees is when about 10% of the trees have some mature cashew fruit as this is the period when all important characters like yield can be predicted and nut quality can be assessed at farm level. Identification of mother trees usually involves a team comprising research technicians, extension staff and farmers with coordination by breeders. Training should be held for team members prior to the expedition to identify mother trees.

3.2 Capacity building of expeditors

Training of expeditors who will be involved in identifying elite mother trees should be conducted at the onset of fruit maturity in cashew farms. The training, which should take place in the farmers' fields, usually involves agricultural extension officers in the districts, research technicians, project staff and farmers. During the training the following should be explained in detail to the expeditors:

- the historical background of the cashew industry in the country
- the status of research and development on cashew in the country compared to other cashew growing countries in Africa, Asia, and Brazil
- weakness in Research and Development and possible solutions. The weaknesses and

possible solutions should come out of participatory discussion involving all expeditors

- strategies for crop improvement and expected benefits
- procedure for developing cashew varieties and the role of expeditors in the successful development of National Cashew Varieties, and
- the selection criteria to be used in selecting mother trees and their importance.

Note: During training of expeditors it is important to exchange experience among participants on how and when to implement the activities including deadlines for filling in the forms which will be used to collect data on the trees. Record contact details (e-mail, mobile numbers) of each expeditor for easy communication.

During training the following should be emphasized for thorough understanding:

- High yielding
- Cashew Panicle Bearing Types
- Easy Separation of the Nuts from the Apples
- Identification of Nut Quality in the Field
- Cutting Test and Easy Peeling of the Testa
- Acceptable Nut Quality, and
- Trees Resistance to Major Cashew Disease and Insect Pests

3.2.1 High Yielding

The term "high yielding" is relative in cashew production. This is because the yield of a cashew tree depends on the cashew tree variety although the age of the tree also plays a substantial role. However, under good soil and weather conditions, elite cashew mother trees can produce yield twice its age beginning from year three. In Tanzania, the standard cashew variety used in evaluating new varieties produces over 80 kg/tree per year at the age of 20 years. Some individual cashew varieties produce as high as 100 kg/tree per year at the same age. However, minimum yield requirements for the selection of elite mother trees should be guided by the information.

Table 1: Yields of elite mother tree by age

Age (Years)	Yield per Tree(Kg)				
	<10	10-15	20-30	>30	>40
<10	Good	Best	Elite	Elite*	Elite***
10-15	Bad	Good	Best	Elite	Elite*
>15	Bad	Bad	Good	Best	Elite

3.2.2 Cashew Panicle Bearing Types

Cashew bearing types can be categorized into three groups: cluster nut bearing type, gradual nut bearing type and extended nut bearing type (Plate 4).

Cluster nut bearing

Cluster bearing is characterized by a lot of nuts maturing together on the flowering panicles. Usually cashew trees exhibiting cluster nut bearing have short duration of nut picking. It should be noted that some heavy cluster nut bearing trees may have nuts that are smaller (high nut count >200/kg). However, it is normal to have higher yielding cashew varieties with big nuts even in cluster bearing types and these are the most preferred.

Gradual nut bearing

Majority of cashew trees falls in this category and are considered to be good depending on the length of nut picking. The shorter the period of nut picking the better the variety. This is due to the fact that it reduces production costs in terms of labor and security guard costs.

Extended nut bearing

Cashew trees exhibiting extended bearing characteristics are not good as they have prolonged nut picking periods which lead to increased production costs. In most cases they have jumbo nuts or very big apples.

Cluster bearing Gradual bearing Extended bearing

Figure 17- 22: Cashew bearing types

3.2.3 Easy Separation of the Nuts from the Apples

This characteristic is important for long term storage of cashewnuts. Cashew varieties that exhibit difficult separation of the nut from the apple have a shorter shelf life. The flesh which remains on the nut could absorb moisture while in storage and cause the nuts to initiate the germination process. Plate 5 shows the two types of nuts with and without dry apples flesh.

Figure 23: Nuts with and without apple flesh

3.2.4 Identification of Nut Quality in the Field

The nut shape, nut weight and nut sizes are very important qualities particularly in processing factories. Small cashew nuts are expensive to shell and yet they fetch lower prices in international markets. Bold and bad nuts can easily be recognized in the farm (Plate 6). Bold nuts are likely to produce whole kernels during mechanized processing.

  

Rear view | Front view | Side view

  

Good nut shape | Bad nut shapes | Bad nut shapes

Figure 24-29: Bold and bad nuts on cashew tree

3.2.5 Cutting Test and Easy Peeling of the Testa

External appearance of the nut does not guarantee that the quality of the kernel inside is good. Some cashew varieties may have good external appearance but inside they may contain bad or immature kernels—a characteristic which is genetically controlled. A cutting test must therefore be done (Plate 7) to know if cashewnuts from the respective tree can give wholes, splits or butts recovery during processing. Another important factor is to confirm if the peeling of the testa from the kernel is easy or not. Easy peeling of testa assures wholes recovery and kernels of acceptable quality as they will not have any scratches resulting from peeling knives.

  

kernel filling | Good kernel wholes recover | Easy peeling of the testa

Figure 30-32: Cutting test

3.2.6 Acceptable Nut Quality

Several components or important factors are taking into consideration when determining the quality of cashew nuts. These include the following:

- Nut weight >7g
- Shelling percentage >25%
- Shell out-turn ≥ 48 (freshly harvested nuts)
- Wholes recovery at shelling (Bold shaped nuts)
- Easy peeling of testa
- Easy detachment/separation of the nuts from the apples

Note: > means greater than; ≥ means equal to or greater than

3.2.7 Trees Resistance to Major Cashew Disease and Insect Pests

The expeditors should be informed that currently there are no diseases of economic importance in cashew in West Africa. However, it is important for them to know the characteristics of common cashew diseases such as powdery mildew, anthracnose, cashew leaf and nut blight etc. The main cashew diseases are shown in Plate 8, Plate 9 and Plate 10 respectively.

Figure 33: Powdery mildew disease

Figure 34: Anthracnose disease

Figure 35-38: Cashew leaf and nut blight disease

It is important to explain that insect pests like Helopeltis bugs, Coconut or Aeroplane bugs, Thrips and Mealybugs are abundant in all cashew growing areas in Africa and should be controlled if their attacks reach economic threshold levels. Biological control of the sucking pest using weaver ants (Oecophylla longinoda) has been shown to reduce pest infestation in other countries. Plate 11 shows insect-pest and their attack on shoots, leaves, stem, nuts and kernels.

Adult Helopeltis bug

Effect on growing tips

Effects on inflorescence

Cashew stem girdlers

Effect on branches

Stem borer

Effect on tree trunk

Figure 39-47: Cashew insect-pests and their damages

4 Practical Session on Nut Quality

An important component of the training is the practical session. This practical component is very important because the expeditors need to know exactly what an elite mother tree is. Emphasize aspects of Best out of the Best approach. Let expeditors understand and appreciate the financial and human resource implications on selecting inferior trees. Use samples from factory to demonstrate nut quality (Cutting test) by comparing the following:

Shape versus Whole recovery Shape versus kernel filling Shape versus Voids Peeling of the testa.

Note: As part of the practical training, arrange to undertake a field visit to a cashew processing unit to practically see the quality aspects being discussed here.

4.1 Farmers' sensitization and field data collection

To undertake farmers' sensitization and field data collection, each expeditor is expected to organize farmers' group sensitization meetings in their respective operational areas and explain exactly what is supposed to be done. During the sensitization meetings, farmers should be educated to ensure that they understand the importance of the germplasm expedition. It is usual to observe reluctance among some farmers to cooperate for fear of losing their trees therefore expeditors should not be discouraged by such farmer reactions. The following actions should be undertaken during sensitization and field data collection:

- Ask farmers who believe they have an elite cashew tree to identify themselves.
- Shortlist them and make visits to their cashew farms to observe trees. This may take more than one day as trees may be in different locations.
- Make on the spot decisions about whether or not the trees they present qualify as elite trees.
- Label any tree that qualifies by painting a ring of blue color around the tree.
- Measure the canopy diameter and the height of all trees that qualify as elite trees.
- Determine location of each tree that qualifies as elite if GPS is available.
- Give any farmer with an elite tree a small gunny bag for nut collection for the selected trees.

The following activities should be undertaken after the field sensitization and identification of elite trees:

i. **Submission of list of trees identified**

Expeditors must send to breeders a copy of the list of trees identified by name of the farmer and location.

ii. Verification of field data

The scientist and the technician should visit selected villages/sites to inspect and collect more data on earmarked trees and also to verify earlier data (Note: at this stage some trees may be rejected).

iii. Labeling of selected trees

Researchers or technicians should conduct a second visit to the selected trees. During this visit yield data should be collected and samples labeled. If an outstanding tree is identified it must be painted with a second ring of red color which means that the tree will have two rings (blue and red). Where possible, rapid cutting test can be undertaken for the most promising trees. Otherwise, samples will be analyzed in the laboratory at the research station

(**Note**: at this stage some trees may be rejected or flagged as potential).

A third, fourth and fifth visits are made until there are no more nuts on the selected trees. During visits ensure that a sample of 1.2kg from each selected tree is collected for nut quality analysis. It should be noted that yield record in farmers' fields is in most cases not accurate as losses may not be reported. Other challenges with the record may arise from such issues as vandalism, intentional uncooperative attitude, farmers forgetting to collect nuts, and mixing of nuts. In view of this, the scientists/technicians need to agree on how to make yield estimates while the nuts are still on the tree. This will avoid elimination of potential promising trees due to absence of yield records

4.2 Activities in year two

The following activities should be undertaken during year two:

Step 1

Call a one-day meeting of expeditors who were involved in the identification of elite mother trees. Share with them the outcome from the identification of the pre-selected mother trees.

Step 2

Start doing DUS Test (i.e. recording DISTINCT characters of each tree from flowering to fruiting using Data Quality Control Standard of Descriptors for Cashew (Lihong et al., 2014 and IBPGR, 1986; or Cashew Descriptors by the International Board for Plant Genetic resources).

Step 3

Continue monitoring yield and undertake nut quality analysis. Undertake final selection of elite mother trees.

Step 4

Establish cashew genetic trial comprising of 20 to 30 trees in two different sites. Ensure good agricultural practices (GAPs) while doing this. Good agricultural practices should cover the preparation of planting holes, application of fertilizers, pest control, and formation pruning and this should be undertaken in the first three years. Data should be collected for 5- 6 years and analyzed from years 3 to 6 and make a selection of the first cashew clone/varieties. Data collection can take more years depending on availability of funds to maintain the trial and consistency in data collection.

5 Establishing Cashew Genetic Trials

Cashew, like other crops, is environmentally sensitive. Recent data have shown that some cashew trees perform well in certain environments while others perform well across environments (Masawe et al., 1999). In view of this, it is highly recommended to test selected mother trees or selected clones in different agro-ecological sites to identify those which are stable across environments. Materials to be tested have to be multiplied vegetatively to produce plants which are genetically similar. Due to land limitations and inadequate financial resources to support a long term crop like cashew, the genetic trials need to have a minimum number of replications that will give acceptable results in terms of coefficient of variations (CVs).

5.1 Trial design

The design of genetic trials depends on the character to be studied. The most common designs used in cashew include lattice, randomized and complete randomized block designs.

5.2 Plot sizes and replications

Cashew trials tend to occupy quite large land areas due to the spacing requirements within and between trees. The spaces can vary between 10m to 12m depending on soil types, soil fertility and rainfall regime. This means that the higher the number of trees per plot the larger the area required to be put under a cashew trial. This has an additional implication for the number of days that will be required to complete one round of data collection. Basically, data on the disease score and flowering must be completed in one day. Field trials have shown that a plot size of 3-4 trees provides accurate data with acceptable coefficient of variations. Also, many years of observation in cashew trials have shown two replicates to be adequate. It must be mentioned however that having three replications will lower the CVs and hence increase precision of the trial.

5.3 The number of entries

Cashew is a long term crop requiring intensive labor as well as substantial human and financial resources and research trial efforts take many years before results are concluded. It is thus important to evaluate as many varieties as possible in a single trial. However, attention must be paid to the number of entries because it can lead to an increase in operational costs (field maintenance, data collection and quality of data collected). Experience in Tanzania has shown that the number of entries should range between 15 and 30. A lower number of entries will not be economical for such a long term trial while a higher number of entries will reduce the quality of the data collected.

5.4 Planting a cashew genetic trial

A cashew genetic trial is established with grafted seedlings obtained using scions from elite mother trees or selected clones that have been identified based on the field data as well as breeders' judgment. The transplanting needs to take place at the on-set of the first rains for the trees to be properly established. Doing this will avoid supplementary irrigation during dry season as the root system of the trees will have been well established by then. It should be noted that the lateral root systems of the cashew trees grow to be about twice the canopy size. With this in mind, the spacing of entry clones needs to be either 10m x 10m or 12m x 12m depending on location, availability of moisture and soil fertility. The plot size will be four trees in three replicates.

5.5 Data collection

A well-managed grafted cashew trees field will start producing cashewnuts two years after planting, but will give economic yields in year three. Yield records must be compiled on a tree basis throughout the fruiting season. An example each of the field data entry form and spreadsheet used for summarizing data before analysis is presented in Table 2 and Table 3 respectively.

Table 2: Field data entry form

Rep	Entry No.	Tree No.	Height (m)	Canopy Diameter (m)		Amount of nuts harvested by dates (kg)						
1	A	1		D1	D2	1	2	3	4	5	……	Total
1	A	2										
1	A	3										
1	A	4										
1	B	1										
1	B	2										
1	B	3										

1	B	4											
1	C	1											
1	C	2											
1	C	3											
1	C	4											
1	D	1											
1	D	2											
1	D	3											
1	D	4											
1	E	1											
1	E	2											
1	E	3											
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1	T	1										
1	T	2										
1	T	3										
1	T	4										
2	A	1										
2	A	2										
2	A	3										
2	A	4										
2	B	1										
2	B	2										
2	B	3										
2	B	4										

D1 = Diameter 1 D2 = Diameter 2

Table 3: Spreadsheet for summarizing data before analysis

Rep	Entry clone	Tree No.	Yield (Kg)	Nut weight (g)	Kernel weight (g)	%OT	Height (m)	Diameter (m)	Canopy area (m^2)
1	A	1							
1	A	2							
1	A	3							
1	A	4							
1	B	1							
1	B	2							
1	B	3							
1	B	4							
1	C	1							
1	C	2							
1	C	3							
1	C	4							
1	D	1							
1	D	2							
1	D	3							

1	D	4							
1	E	1							
1	E	2							
1	E	3							
1	E	4							
1	F	1							
1	F	2							
1	F	3							
1	F	4							
1	.	1							
1	.	2							
1	.	3							
1	.	4							
1	T	1							
1	T	2							
1	T	3							
1	T	4							
2	A	1							

2	A	2							
2	A	3							
2	A	4							
2	B	1							
2	B	2							
2	B	3							
2	B	4							

Key: OT=Outturn g=gram kg = kilogram m = meter

Selection can take place in year five depending on soils types, rainfall pattern, field management, consistency in data collection and record keeping which could be used in the analysis to enable the selection to take place.

Genetic trials are very important in helping to find out if performance of selected individual cashew mother trees is genetically or environmentally controlled. In recent years, cashew breeding in Tanzania has come up with a new approach for the selection of improved cashew genotypes which reduces the number of years for obtaining cashew varieties from 15-20 years to 9-12 years (see Figure 1).

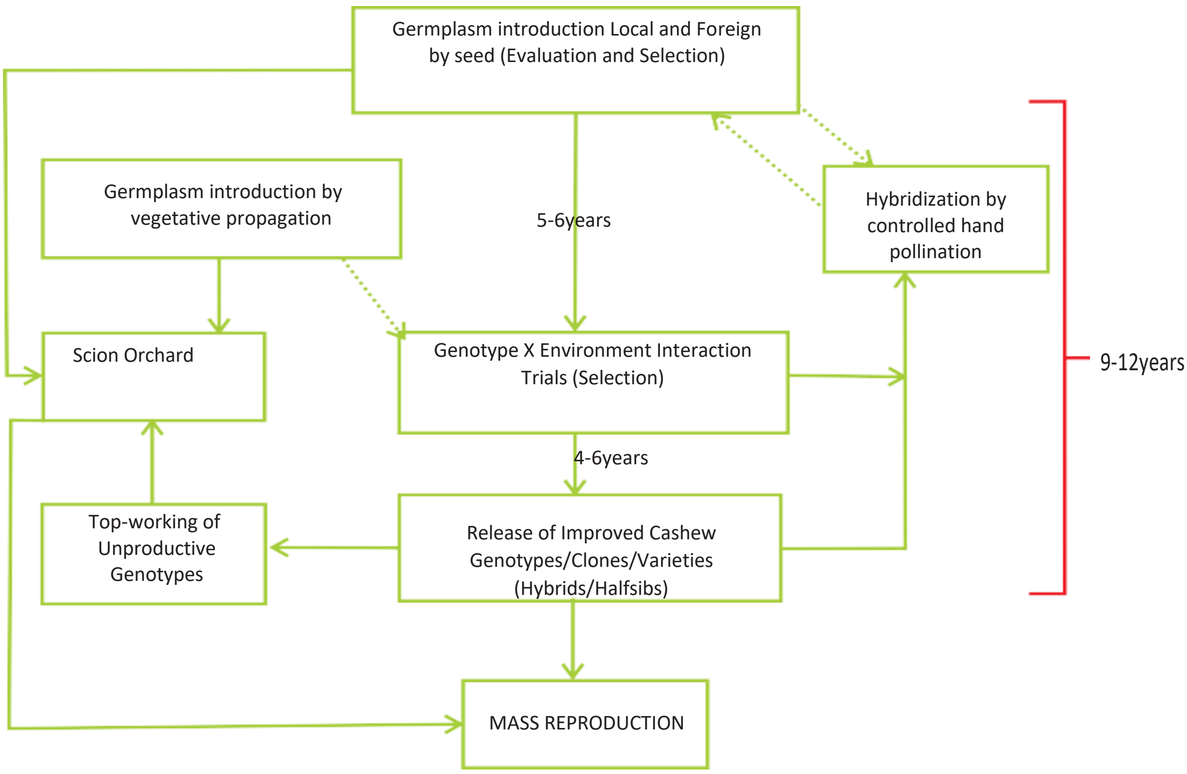


Figure 50: Accelerated cashew breeding programme

Source: Masawe, 2009

5.6 Distinctness Uniformity and Stability (DUS) Test

Two years before a variety is released, an official Seed Certification Institute or Agency is invited to conduct a Distinctness Uniformity and Stability (DUS) Test. The DUS Test should be conducted by breeders in collaboration with seed certifiers. However, guidelines can be prepared using Data Quality Control Standard of Descriptors for Cashew (Lihong et al., 2014) and IBPGR (1986).

5.7 Registration of cashew varieties

Based on yield data, high yielding clones/hybrids are identified after analysis has been undertaken. They are then subjected to DUS testing before they are accepted for registration as new cashew varieties.

6 Establishment of Scion Orchard

Scion orchards are established by grafted seedlings in areas close to cashew nurseries. A cashew nursery is a relatively small plot of land used for propagating seedlings by seeds or vegetative means before they are transplanted to their permanent stands. In practice, the seedlings which would be planted at wide spaces in the field, are closely aligned in the nursery in a relatively small area. This closeness offers the following advantages:

- It is easy to effectively regulate plant nutrients, moisture in the plants' root zone as well as the intensity of solar radiation.
- Seedlings can be sorted and graded into lots on the basis of differential vigor e.g. vigorous, strongest seedlings and stunted weak growing seedlings respectively.
- Raising planting materials in the nursery is time and labor-saving because nursery operator deals with just a small plot.
- It is easier to observe the first signs of pest and disease attack and protect the seedlings.
- When a cashew nursery is to be established, the following rules for selecting a suitable nursery site should be observed:
- Select a relatively level or gently elevated ground not exceeding 5oin slope to prevent water logging and run off that would carry away seeds or cause rotting.
- Select a site near a good quality water source. This will guarantee the supply of soft water (containing less than 1400 ppm salt) throughout the year to make watering easier.
- Select a site that is easily accessible for tending the plants and for serving customers as close to their fields as possible.
- Locate the nursery in an area where there is a demand for plants.

A scion orchard is also used as a cashew gene bank for in-situ conservation of the materials. Since scion orchards are mainly for scion production, there is no need to use wider spacing as it will constitute a wastage of land. A spacing of 6m x 6m is recommended. Subsequently, thinning can be done to increase the spacing to 6mx12m and finally to 12m x 12m as the trees increase in size. Each selected clone/variety or improved planting material must be planted in double rows. This is to allow thinning to take place without losing any of the clones/varieties during thinning.

6.1 Management of cashew scion orchard

The area occupied by a cashew scion orchard is usually a large area which needs to be maintained throughout the year. Grasses must be slashed or weeded to avoid fire outbreaks.

In the dry season strip/ring weeding is compulsory even if slashing has been undertaken.

6.1.1 Formation Pruning/Tree Training

As a general recommended practice in planting cashew trees, two major operations are to be undertaken. The first one involves a continuous removal of shoots below the graft union to ensure that no shoots are allowed to grow. This is because shoots growing below graft union are from the rootstock and not the grafted scion of the desirable parent. If they are allowed to develop they will suppress the growth of the grafted scion and eventually take a lead in canopy formation. As a result, the tree formed will have the characteristics of the rootstock (not of the selected or intended mother tree).

The second operation involves formation pruning which is an agronomic practice of paramount importance because it gives the cashew trees an umbrella shaped canopy which allows easy collection of the scions.

6.1.2 Mulching

Mulching is important to conserve moisture in the soil, but it can only be done when the rest of the field is clean and does not have crop residues or huge dry vegetative materials which can easily catch bush fire. On the other hand, care must be taken to monitor and control termites particularly in the dry season. Termites can easily kill young cashew trees up to the age of five years and even older.

6.1.3 Removal of first flowers

Cashew trees which have been vegetatively propagated can flower six months after planting but will not give an economic crop. Therefore, it is recommended to remove the flowers. Removal of the flowers will increase plant vigor, which is important for scion production and will result in higher yields the following year.

6.1.4 Pest control

Most young cashew trees are prone to sucking pests due to the succulent nature of the growing young vegetative shoots. The control of sucking pests, particularly Helopeltis spp, Pseudotheraptus wayi (coconut bug) and Anoplocnemis curvipes (aeroplane bug) at the early stages of tree development, is therefore very important to ensure proper growth. In the dry season, sucking pests may attack cashew because alternative host plants may have matured/dried. The recommended insecticide for the control of sucking pests (except Mealybugs) is Lambda cyhalothrin (common name) which is available under different trade names. The rate of application is 5mls per one litre of water. This needs to be applied when symptoms of attack are seen and should be repeated two weeks later. Thereafter, it will be applied again if symptoms of attack are observed. Avoid some broad- spectrum insecticides like organophosphates (e.g. Sumithion) as it may lead into an outbreak of red spider mites (that kill natural predators). Red spider mites are difficult to control as they are resistant to most insecticides except Sulphur Dust.

In case of an outbreak of mealybugs, Profenofos (an insecticide) can adequately control the pest. The application rate is 7.2mls per litre of water, applied only when the pest attack on the cashew trees is heavy and when the attack is occurring during the fruiting period.

6.1.5 Fertilizer application

Fertilizer application in cashew is one of the most controversial issues in the cashew industry worldwide in terms of rate and frequency of application. This is partly due to the fact that cashew grows in different soil types—from wastelands to fertile lands. In most African countries cashew is grown without fertilizer application. Most fertilizer trials in many countries have not been concluded and do not provide the required information due to differences in soil types and genetic variation of cashew trees raised from seeds.

In Tanzania several fertilizer trials have been carried out on trees of less than 10 years old. Where nitrogenous fertilizers were used, tree growth was observed to be rapid and resulted in early canopy overlaps at a spacing of 12m x 12m. The nuts from these trials were extremely large compared to trees of the same clone which were not fertilized. This may probably indicate that fertilizers improve nut quality but the rate remains to be determined. Indeed there is a need to critically continue to undertake fertilizer studies in cashew. Such trials should be extended to cover mature cashew trees of about 10-15 years old in which vegetative growth is slow or stunted. In view of this, it has been recommended to fertilize the intercrop only, knowing that the cashew trees will benefit from the fertilizer applied. This way, the cost of fertilizer is taken care of by what is applied to the annual crop.

7 Establishment of Polyclonal Seed Orchards

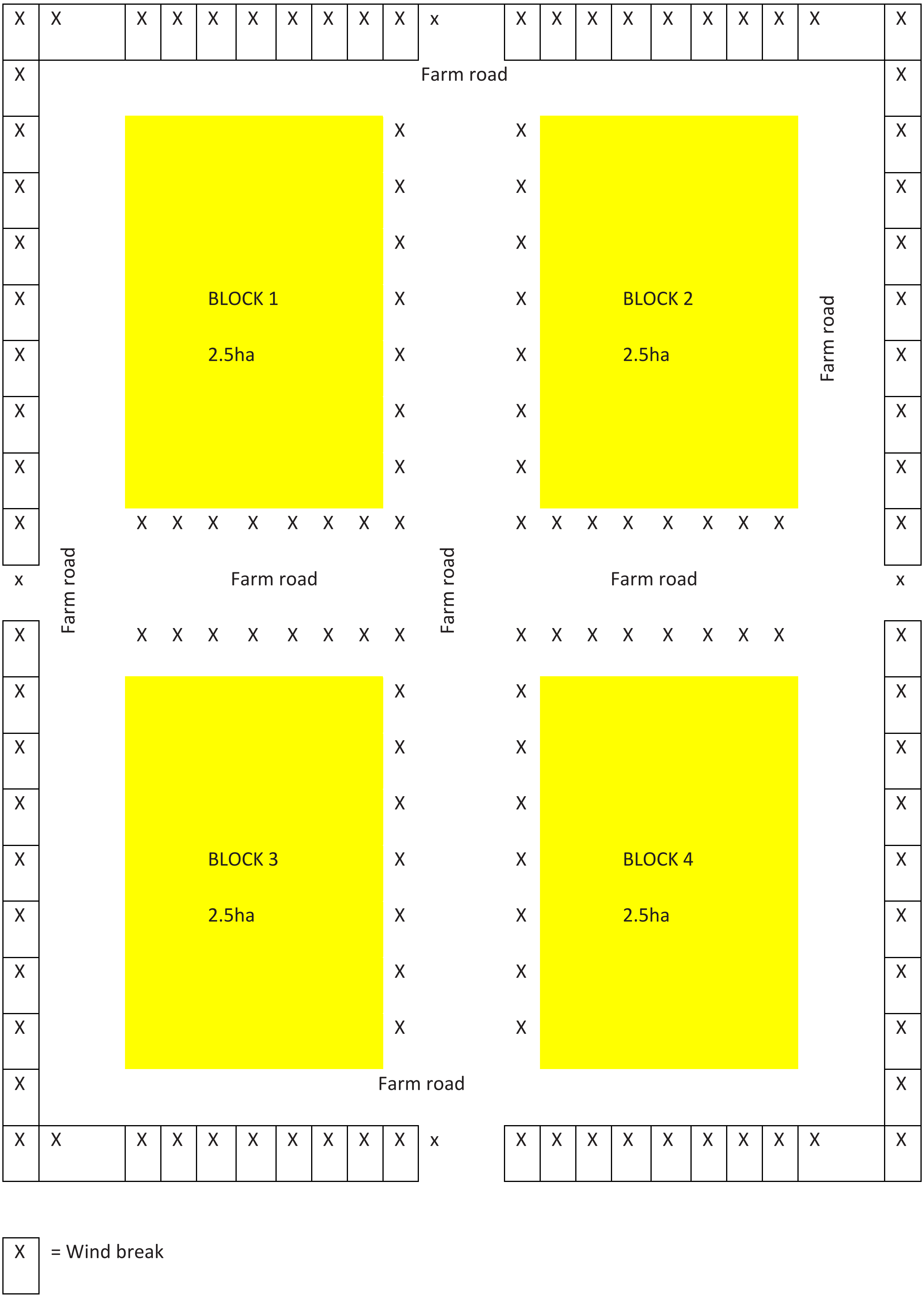
The polyclonal seed orchard is established using cashew varieties obtained after evaluating selected mother trees in a genetic trial. Polyclonal seeds continue to be the main source of planting materials in Africa as other methods of vegetative propagation (excluding tissue culture which is yet to be commercialized) are slow, cumbersome and cannot meet the demand of planting materials in any country. An additional advantage of polyclonal seed is that it will be used as a potential source of seed for farmer-managed nurseries.

7.1 Field layout

The polyclonal seed orchard will be made up of four blocks of grafted clones of approximately 2.5ha for each site (Design 1). The orchard will be formed by, for example, ten (10) selected cashew clones/varieties. The planting will be at a spacing of 12m x 12m in a triangular planting pattern. The design will be a systemic design or next neighbor design. In this type of design each individual cashew clone/variety is surrounded by seven different cashew clones/varieties.

Each block needs to be separated by a wind break of preferably fast growing trees available in each country (except Acacia amarella or Eucalyptus which have been shown in Tanzania to be not suitable due to its high competition for water or moisture in the soil). Blocks are separated by farm roads of about 12-15m and wind breaks of 3m wide.

Design 1: Field plan for blocks of polyclonal seed orchard



Design 2: Field layout of one block of polyclonal seed orchard comprising of 10 varieties

1		2		3		4		5		6		7		8		9		10	
	5		6		7		8		9		10		1		2		3		4
8		9		10		1		2		3		4		5		6		7	
	1		2		3		4		5		6		7		8		9		10
4		5		6		7		8		9		10		1		2		3	
	8		9		10		1		2		3		4		5		6		7
1		2		3		4		5		6		7		8		9		10	
	5		6		7		8		9		10		1		2		3		4
8		9		10		1		2		3		4		5		6		7	
	1		2		3		4		5		6		7		8		9		10

Note: Varieties are represented by numbers 1 to 10

7.2 Polyclonal seed and planting material certification

Cashew polyclonal seeds (PS) do not need to be certified as improved planting material as they are different from those of annual crops. Each cashew seed on the same tree is genetically different, however, trials established in Tanzania have shown that a greater percentage of polyclonal seeds are very high yielding and some give higher yields than most parents in the orchard. There is no single country in Africa that has certified cashew seeds. In most cases, the custodian of the improved planting material is a cashew breeder and not a seed certification institute or agency.

On the other hand, cashew produced by vegetative propagation does not need certification as they are true to type. However, as grafting is adopted in most of the African countries, standards and measures need to be put in place to ensure the quality of grafted seedlings produced and distributed in these countries.

8 Cashew Hybridization

Cashew hybridization usually takes a long time due to the fact that the flowering period lasts for more than six months. The stages for hybridization include selection of parents to be used in hybridization (i.e. male and female), care of the field/parental trees, preparation of pollination bags and hand pollinators. Apart from yield, important characters to the cashew industry are nut quality and in some cases tree size. The quality of the nuts takes into account nut size, nut weight, percentage kernel out-turn, easy peeling of the testa and recovery of wholes at processing. Other useful character traits such as percentage of oil content in the shells—"Cashewnut shell liquid" (CNSL)—is yet to be exploited because there is lack of research on it. Hand pollination in cashew trees is labor intensive and, in general, one person is able only to effectively do one crossing per season. Where the selected parent plants are in close proximity to each other however, two to three crossing can be done by one person in a season.

8.1 Identification of parents

Cashew cultivation is a long term investment therefore care must be taken during the selection of parent trees to be used in hybridization programs to ensure that only useful and contrasting characters are combined. If mistakes are made at the beginning, the effects can only be seen after five to six years of field evaluation and this will be very expensive in terms of lost time, money and effort. It is therefore important to carefully select parents with desirable characters which, in most cases tend to be contrasting characters, to be combined. The direction of crossing is very important since some elements of maternal effect have been reported in cashew (Masawe and Caligari 1998). Some observations have shown that good results are obtained when a female parent has the characters required to be improved (Masawe and Caligari 1998). Research results have indicated that performance of crossings and reciprocal crossings are different, particularly in the size of the nuts (Masawe et al., 2010). It was noted that where a female parent had small nuts and was crossed to a male with big nuts, the chances of getting more hybrids with big nuts were high compared to the reciprocal crossing (Masawe et al., 2010).

8.2 Pollination procedures

The cashew parent trees to be used in cross pollination may be located in difference plots, areas and sites with distances varying from a few meters to several kilometers between them. A signboard must be erected or hanged under cashew trees selected as parents showing both male and female parents to be used in the crossing. For easy identification, the signboard must be visible from afar by anybody approaching the trees. The signboard of the male parent should bear the name of the variety/clone e.g. TDC . However, the signboard of the female parent must show the name of both parents, e.g. AMOZ x TDC , where AMOZ is the first parent, which must always be a female, and TDC is the second parent, which must always be a male. This is very important in data recording and identification of parents for future reference where necessary.

The branches of the canopy of both male and female parents are pruned to ensure that they do not touch nearby cashew or any other trees and also that the branches do not touch the ground. This is very important to prevent crawling insects, especially ants, from reaching the pollination bags. It may be necessary for wooden poles to be erected within the tree canopy (for young and smaller trees) so that the cashew branches can be firmly tied to them using sisal twines to avoid damage by wind during the windy season. The wind often causes severe damage to cashew flowers, young and mature nuts as well as the mature cashew trees. Branches tend to break off and even whole trees may be uprooted depending on the strength of the wind. Since crawling insects can reach the pollination bags via wooden poles or the trunk of the cashew tree, the following precautionary steps need to be taken:

- Paint a band of grease (6-12 cm wide) around the trunk of the cashew tree at approximately 30 cm above the ground
- Spray the whole tree with insecticide (for example Lambda- cyhalothri or cypermethrin) to kill crawling insects that are already on the cashew tree. This will also control sucking bugs like Helopeltis species and pseudotheraptus wayii.

Cashew diseases, if present, should also be controlled using appropriate fungicides. Remove all grasses underneath the cashew tree canopy and between and within the rows by mowing, hand slashing or weeding throughout the flowering season. This is important to keep the ants or other crawling insects from reaching the cashew tree and hence the pollination bags.

8.3 Selection of panicles

New emerging flowering panicles need to be targeted. They should be healthy i.e. free from diseases and insect pest attack. Panicles of both male and female parents should be bagged and labelled. The selected panicles should be bagged before the flowers open. Where few flowers on the panicle have opened they should be carefully detached using a watch maker's forceps before the panicle is bagged. Use polyester crossing bags (commercial pollination bags) to bag panicles. If these are not available, locally made paper bags (wide newspapers) or book wrapping papers can be used to bag the panicles. Newspapers are not durable and require frequent replacement, however, they are much cheaper than polyester bags. Normal transparent polythene bags are not recommended because they scorch leaves and the flowers. In addition, they accumulate a lot of moisture (from transpiration) which is not desirable for the growth and development of the flower.

8.3.1 Emasculation and pollination

On a daily basis, open each bagged panicle of the female parent between 7.30 a.m. and 10.00 a.m. Remove all male flowers (female parent bags) using a fine watchmaker's forceps such that only hermaphrodite flowers are left. It should be noted that bags of male parents should not be emasculated. Harvesting of the male flowers should be done between 10.00 a.m. and 11.00 a.m. every morning. The male flowers should be wholly detached from the cashew tree using a fine sterilized watchmaker's forceps and kept in covered Petri dishes ready for use. To pollinate, open the bag of the female parent and using a new sterilized watchmaker's forceps use the anther of the male flower to touch the stigmas of several flowers in the bag. Where necessary, two or more male flowers should be used per each bagged panicle of the female parent. Reseal the pollination bag using either office pins or table clips. The exercise should be repeated daily until there are no more flowers to pollinate in that bagged panicle or there are already more than six successfully set fruits. If insects are found in the pollination bags apply insecticide using a hand spray. However, the whole tree has to be sprayed at intervals of three weeks. Successful pollination is indicated by a swollen ovary of the female flower. In cases of unsuccessful pollination, the flower will die. After a month or two, nuts will be big enough therefore bags should be opened and the nuts labelled by paint spray or by a marker pen.

Pollination should be carried out at the beginning of the opening of the panicles. It should be noted that not all successfully pollinated flowers will produce mature nuts. There are always immature nut drops probably due to physiological factors or mechanical damage from wind, insects, birds and animals. Nut maturity will take about 90 days depending on the temperature because low temperature delays maturity (Masawe et al.,1996)

9 Challenges in Cashew Hybridization

Cashew hybridization in Africa is confronted with several challenges. These include: pollination bags, weather conditions, genetic variability of the crop, and location of parent trees for hybridization.

9.1 Pollination bags

Commercial pollination bags are not easily available in many countries in Africa. When imported, they become quite expensive and therefore not easily affordable on a sustainable basis. In view of this, several local pollination bags have been adapted from sources such as newspapers and book wrapping papers and used in place of commercial pollination bags (Anonymous 2009).

9.2 Weather conditions

Cashew normally produces flowers in the dry season. This is the time when winds (harmattan winds) are also strong in West Africa. The presence of strong winds during fruit setting can cause physical damage to successfully pollinated nuts. In most cases, hand pollination comes up with few nuts. Masawe et al., (1996) found that nut set ranged from 0-20 nuts per tree. Millanzi and Masawe (1997), investigating difficulties in controlled hand pollination, found that the nut set was variable even between the same varieties suggesting that there are other factors responsible for poor success in nut set. However, poor nut set could partly be due to differences in time of flower opening. Since pollinators are trained to stop pollination at mid-day, clones that are late in flower opening would appear to have low number of fruit sets. Other problems include pollination by flying insects in situations where pollination bags are damaged mechanically or by wind.

9.3 Genetic variability

Cashew trees vary in their time of flowering and fruiting and in the duration of both (Masawe et al., 2009). When cross pollinating early flowering and late flowering tree types, the percentage success in most cases appears to be low. This is due to the fact that if the late flowering tree is used as female, hermaphrodite flowers on that tree will open more lately than the male flowers in the male tree which normally flower early. As a result, few flowers will be available for cross pollination. It is known that late flowering types can be forced to flower earlier by disturbing the trees physiology through irrigation. However, studies have not established the rate and frequency of water application, although drip irrigation would be the most likely.

9.4 Location of parents

Since hybridization is aimed at combining parental characters, the location of parent trees play a substantial role in the cost and time of cross pollination. The location of parents can be close or far apart, ranging from trees located in the same block to trees located across farms or in locations varying from a few meters to several kilometers. When trees are located at considerable distances from one another, transport, which might be quite expensive, is required to collect the pollen from the male parents and transport them to the female parent.

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