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Chapter
Production of Potato Quality Seeds in Mountainous Region of Central Africa
Nyamangyoku Ishibwela Obedi

Abstract

Potato production in the mountainous region of Central Africa (CA) remains very low (10–15 T/ha), while the commonly cultivated varieties have a genetic potential to reach more than 40 T/ha. This low productivity is due, among other reasons, to a low quality of propagation material (seed tubers). Certified potato seed tubers are not only expensive but also not sufficient on the market to cover the needs of potato producers, leading them to use year-to-year seeds potatoes already infected by diseases and totally degenerated. Due to constraints of getting appropriate facilities for good Potato seeds production among producers, various cutting methods to obtain quality potato seeds have been developed. Indeed, in several experiments carried out in Rwanda and in other countries, the use of good healthy propagation material has increased yields by more than 35%. Since this mountainous zone of Central Africa is very suitable for the cultivation of potatoes for its climatic conditions, the methods developed in this chapter for producing quality potato seeds and appropriate agricultural practices (crop rotation, good fertilization, disease control and pests) will make it possible to significantly increase yields, and thus allow the varieties grown in Central Africa to express their genetic potential of more than 40 T/ha.

Keywords: potato tuber seeds, Central Africa, cuttings methods, yield, potato varieties

1. Introduction

The mountainous region of Central Africa where the potato crop is cultivated at more than 1800 m altitude and covered by this chapter concerns four countries, namely Burundi, DRC, Rwanda and Uganda. Figure 1 shows the mountainous zone suitable for potato crops in Central Africa.

In Burundi, potatoes are grown everywhere except in areas of low altitudes (Bujumbura and Rumonge) [1]. While in the Democratic Republic of the Congo, the potato is grown mainly in the North Kivu and South Kivu provinces. Potato is cultivated across Rwanda and growing in popularity. But the majority of the crop is produced in the northwestern region of the country in the districts of Burera, Musanze, Nyabihu and Rubavu [2]. The Main potato producing districts in Uganda...
are Bushenyi, Isingiro, Kabale, Kabarole, Kapchorwa, Kisoro, Kyenjojo, Masaka, Mbale, Mbarara, Mubende, Nebbi and Sironko [3].

The potato is a staple food source for many people around the world, particularly in Central Africa, it is cultivated for the following reason: It is an important crop, ranked 4th after wheat, rice and corn; takes less time to mature; a source of income in high altitude regions in Africa; job offer; source of raw material if industrialized; takes less cooking time compared to cereals; competes well in nutritional value compared to cereals; has a higher yield per unit area and in a given time; crop assuring food security in many rural areas and can be used in rotation with cereals. The nutritional value of the potato is given in Table 1 [4].

Despite its nutritional importance and the favourable climate for its production in the mountainous zone of Central Africa, potato productivity is still low (Table 2), notably for the following reasons: (1) Low soil fertility, (2) Seed degeneration and low potential of existing varieties, (3) Inadequate cultivation techniques, (4) Short rotations and no intensive crop system, (5) Crop attacks by diseases (mainly late blight, bacteria and viruses) and pests, (6) Shortage and poor seed quality, (7) post-harvest losses, (8) Non-structuring of the potato sector, (9) Insufficient technology transfer, and (10) Insufficient training and technical information [1–3].

Figure 1. The mountainous area of Central Africa where potatoes are cultivated, comprising Burundi, Democratic republic of Congo, Uganda and Rwanda countries.
However, with good quality seed, and the use of fertilizers, the yield can reach more than 40 tons per hectare. Reason why it is important to focus more attention on good quality potato seed production and develop multiplication methods that could be applicable and affordable by potato seed multipliers.

2. Organization of the potato seed chain in mountainous region of central Africa

2.1 Potato seed production in Central Africa

There are three recognized potato seed systems in Central Africa: formal, informal, and semi-formal, as elaborated below [6, 7]:

2.1.1 Formal seed system

The formal seed system involves a chain of activities leading to certified seeds of officially released varieties. This is guided by scientific methodologies for plant breeding. Multiplication is controlled and operated by public or private sector specialists, with significant investments having been made throughout the process. In the formal system, production of basic seeds is mainly a responsibility of public research institutions [8, 9]. The basic seed is then passed on to public and private sector seed multipliers for bulking and distribution as certified seed. The regulator is responsible for the inspection and certification function.

2.1.2 Informal seed system

The informal seed system in CA context is defined as seed production and distribution practices where there is no legal seed certification. The system constitutes many individual small-scale farmers, who save or exchange seeds at the local level (Figure 2).

Table 1. Potato chemical composition based on fresh weight.

<table>
<thead>
<tr>
<th>Component</th>
<th>Content (% or mg/100g)</th>
<th>Component</th>
<th>Content (mg/100g)</th>
<th>Component</th>
<th>Content (mg/100g)</th>
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</thead>
<tbody>
<tr>
<td>Dry matter</td>
<td>15–28</td>
<td>Asparagine (free)</td>
<td>110–529</td>
<td>Vitamin C</td>
<td>8–54</td>
</tr>
<tr>
<td>Starch</td>
<td>12.6–18.2</td>
<td>Glutamine (free)</td>
<td>23–409</td>
<td>Vitamin E</td>
<td>0.1</td>
</tr>
<tr>
<td>Glucose</td>
<td>0.01–0.6</td>
<td>Proline (free)</td>
<td>2–209</td>
<td>Folic acid</td>
<td>0.01–0.03</td>
</tr>
<tr>
<td>Fructose</td>
<td>0.01–0.6</td>
<td>Other amino acids</td>
<td>0.2–117</td>
<td>Potassium</td>
<td>280–564</td>
</tr>
<tr>
<td>Sucrose</td>
<td>0.13–0.68</td>
<td>Polyphenols</td>
<td>123–441</td>
<td>Phosphorus</td>
<td>30–60</td>
</tr>
<tr>
<td>Fiber</td>
<td>1–2</td>
<td>Carotenoids</td>
<td>0.05–2</td>
<td>Calcium</td>
<td>5–18</td>
</tr>
<tr>
<td>Lipid (fat)</td>
<td>0.075–0.2</td>
<td>Tocopherols</td>
<td>Up to 0.3</td>
<td>Magnesium</td>
<td>14–18</td>
</tr>
<tr>
<td>Protein</td>
<td>0.6–2.1</td>
<td>Thiamin B</td>
<td>0.02–0.2</td>
<td>Iron</td>
<td>0.4–1.6</td>
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<tr>
<td>Nitrogen (total)</td>
<td>0.2–0.4</td>
<td>Riboflavin</td>
<td>0.01–0.07</td>
<td>Zinc</td>
<td>0.3</td>
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</table>

Vitamin B6 0.13–0.44 Glycoalkaloids < 20
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<tbody>
<tr>
<td>Burundi</td>
<td>14</td>
<td>20</td>
<td>27</td>
<td>54</td>
<td>30</td>
<td>146</td>
<td>205</td>
<td>303</td>
<td>376</td>
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<td>DRCongo</td>
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<td>Rwanda</td>
<td>106</td>
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<td>Uganda</td>
<td>32</td>
<td>39</td>
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<td>171</td>
<td>299</td>
<td>327</td>
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(FAOStat 2022 [5])

It also includes development agencies and projects supporting community seed production with no regulatory oversight. It is considered the most flexible system and it involves the use of both local and improved varieties. The seed production and distribution processes are not monitored or controlled by government policies and regulations but rather by local standards, social structures and norms.

2.1.3 Semi-formal seed system:

Semi-formal seed system has overlapping features with both the formal and informal seed systems. The major actors in this system are groups (of farmers) engaged in community-based seed production and marketing. Seed producers do not necessarily go through formal channels to get planting materials or through the formal certification process. The intermediary seed system also includes the production and marketing of seed by local farmers under financial and technical support from NGOs and breeding centres. Seed potato producers in the semi-formal system produce two different types of seed: (1) clean seed and (2) positively selected seed.

1. Clean Seed or QDS: This comprises seed multiplied at the farm level which originates from certified seed. It is produced using Good Agricultural Practices (GAPs). Most guidelines used in production of certified seed are also used in clean seed production. However, sampling, testing and certification by the
regulator are omitted or where involved, less rigorous as for the case of QDS. Quality declared seed is officially recognized in Uganda and Rwanda by law and can be legally sold through formal market channels but for localized areas only.

2. Positively Selected Seed: These are seed potatoes produced from farmer seed through a process of selecting the best-looking plants during vegetative growth by farmers trained in seed selection and management. Although the process of production lacks stringent procedure and inspection by the regulator it offers an opportunity for farmers to control diseases and improve their yields by an average of 30% per season.

2.2 Formal seed potato multiplication

Formal seed potato sources include public institutions, private seed companies, and registered individual seed growers. There are three main types of formal seed production systems [2]:

- **Public formal seed system**: Here, the public sector undertakes all activities involved in variety development, seed production and marketing.

- **Public-private formal seed system**: This involves the partnership of the public and private sector from variety development and seed production up to seed marketing. The public institution conducts research and breeding while the private sector multiplies the seed under the supervision of the regulator and distributes the seed to farmers.

- **Private formal seed system**: These are systems that are entirely performed by the private sector from variety development to seed multiplication and distribution. There is minimal government involvement except in seed quality control and certification.

There are three main business models used to produce seeds as described below.

- **Multiplication from breeder seed**: Licensed local or international, public or private seed producers grow seed from mini-tubers to the second stage of certified seed (C2).

- **Multiplication of imported basic seed**: In this case, basic or certified seed potato tubers are imported (under specified conditions) for further multiplication as certified seed by local seed companies and multipliers.

- **Multiplication of Clean Seed**: Seed potatoes are sourced from certified seed producers which are then multiplied by farmer groups and cooperatives with the support of the extension services.

2.3 Sources of seed potato

The sources of formal seed in CA are public institutions and private seed companies and registered individual seed growers. Such seeds must undergo certification by the regulator.
Sources of basic seed: The official source of basic seed for public bred varieties are research institutions and private seed producers. Basic seeds can only be produced upon the assurance that the breeder materials are free from all major diseases and pests. Basic seed production begins with tissue culture where meristem tissues are multiplied in a controlled environment to produce in vitro plantlets. These plantlets are transferred to the glass house for hardening. Afterwards, they are then planted in pots, aeroponics or hydroponics to produce mini-tubers. The mini-tubers are planted in the field through a number of generations to produce pre-basic seeds and basic seeds. The basic seed is then supplied to authorized seed multipliers for production of further classes of certified seed.

Sources of certified seed: These are mainly the authorized seed multipliers and seed companies that source basic seed either from public institutions or private basic seed producers to produce certified seed. Provided the seed meets the quality standards, the certified seed can be further multiplied up to two cycles for production of ware potato by growers.

3. Production and management of quality potato seeds

The usual way to spread potatoes all over the world is by vegetative way through whole or fragmented tubers. The latter is only practised in a few European countries and in North America [3, 10]. Through this vegetative production from generation to generation, seed tubers can be infected with a high number of viral, bacterial and fungal diseases, and thus seriously affect the growth and production of the plantation. This is the reason why the production of quality seeds, storage and related legislation are discussed in the following pages.

At the harvesting time, the seed tubers are usually dormant and do not present growing buds even if the ecological conditions are favourable.

3.1 Characteristics of potato quality seed

Many factors determining yield are affected by seed quality. Good quality seed is obtained when the seed tubers are harvested on a seed field in good condition, dry before the formation of the tubers has been naturally completed and harvested shortly after dehauling. Quality tuber seed should be able to produce healthy and vigorous plants within the growing season. Seed quality is determined by the following parameters [6, 10]:

a. Variety: seed must be true variety and should not have different varieties or mutants;

b. Physiological maturity: At planting, seeds should be physiologically mature with multiple vigorous sprouts. This kind of seed tubers germinate rapidly and develop several stems.

c. Size: The size of a seed lot will need to be homogeneous to ensure consistent germination and development.
d. Healthy tuber: tuber seeds must be free of disease and the percentage of infected tubers in the seed lot must be below locally accepted standards. Seeds devoid of diseases and parasites are obtained from tubers that themselves were devoid of them.

e. Physical defect: Seeds must be free from external damage that could occur during harvesting or during post-harvest treatment that could make tubers vulnerable to bacteria, fungi and parasites, and thus increase the risk of low germination and growth. Seeds should also be free from any internal damage caused by poor growing and storage conditions. This can increase vulnerability to diseases.

3.2 Dormancy

Like other plant organs, the tuber goes through a phase during which its buds do not show significant growth. It is a period of any vegetative growth, during which the tuber is unable to germinate, even when it is placed in optimal conditions for germination, such as optimal temperature and humidity. Influence of different factors on dormancy:

3.2.1 Tuber-related factors

- The size of the tuber: The sprouts of small tubers take longer than the sprouts of large tubers to reach a certain length (3 mm).
- Genotype: the dormancy time depends in particular on the genotype.

In general, most early varieties have a rather short vegetative dormancy.

3.2.2 External factors

In general, environmental factors would have a very limited impact on dormancy. However, the effects of nitrogen, temperature and light were reported in the experiments. Nitrogen fertilization and relatively high temperatures would shorten the dormancy time. Whereas the light effect would have no significant impact.

The agricultural calendar for potato seed production should take into account the calendar for potato consumption production, the dormancy of tuber seed and the fact that tuber seed is generally earlier harvested when the tuber is still small. Therefore, three examples of calendars are given considering the dormancy duration of Potato varieties in CA countries (Figures 3–5), and where very early varieties, early and late ones cannot be scheduled in the same ways.

3.3 Production of quality seed plants/tubers

The production of potato plants requires considerable agricultural practices. This involves the vegetative production of tubers which do not deviate in any way from the original characteristics of the variety and which free diseases.

Although “True potato seed” regeneration was initially the only means available to producers a clonal breeding model was then developed at the beginning of the 20th century in order to preserve the intrinsic qualities of the cultivars produced [11–13].
Figure 3. Agricultural calendar for very early varieties (CIP 720118, CIP 381381.20 and Rw 8201-19).

Figure 4. Agricultural calendar for Early potato Seed Varieties (CIP 386003-2, CIP 393077-54, CIP 393371-50).

Figure 5. Agricultural calendar for Late potato Seed Varieties (CIP 800949, CIP 381391-13, CIP 381395-1, CIP 383120.14, CIP 387233.24).
The development in the recent past of in vitro potato micropropagation techniques combined with new quality control techniques (ELISA, PCR, etc.) has led to a significant increase in the overall quality of production. Micropropagation has also provided more flexibility and speed in plant production processes. These two methods will be developed below.

3.3.1 Traditional Inbreeding and clonal selection

This method includes the application of techniques that maintain the preservation of good health over time, namely [4, 6, 13]:

1. Selection of mother tubers on apparently healthy plants,
2. Tuber growth in areas of unfavourable climate for viral infections;
3. Isolation of propagating crops from infected consumer crops;
4. Severe mass selection in propagating crops;
5. Early dehaulming to remove leaves from plants and prevent them from infections.

3.3.1.1 Selection of mother tubers on apparently healthy plants

It is essential, before multiplying a potato clone, to ensure that the seed tuber is free from any disease, including virus-borne diseases. The tuber is chosen from the healthy batch (varietal collection, family field, etc.) and then undergoes a series of various tests (ELISA, visual checks, etc.) to verify the absence of any infection.

Sometimes there may be no healthy tubers (old varieties chronically infected with one or more viruses). Since viruses are mostly absent from seeds and meristem, regeneration from meristem and thermotherapy can help to cure these diseases and thus obtain a healthy starting material.

These very fine techniques have proven their effectiveness for a long time. Meristem culture consists of growing in vitro a very small fragment of the apical shoot which is generally virus-free. This technique gives very good results, provided that only the strict meristematic zone is sampled (of the order of 0.3 to 0.5 mm).

3.3.1.2 Tuber multiplication in unfavourable climates for viral infections

Except for the generation F0 production or subsequent in vitro propagation and micro-cuttings, the majority of subsequent multiplication is done in the field and the impact of the environment is then essential to producing good quality plants. Indeed, zones with a climate unfavourable to the propagation and dissemination of aphids (cool and humid regions, with frequent winds) make it easier to maintain a good sanitary condition of the crops. Following methods can be applicable:

3.3.1.2.1 Removing diseased plants

In addition to these environmental precautions, it is also necessary to eliminate the sources of inoculum that are infected virus plants themselves inside the crops.
This cannot be done before planting, as the tubers infected by virus generally do not show symptoms, with the exception sometimes of some discoloration on the sprout.

On the other hand, the foliage of contaminated plants expresses various specific symptoms of the virus notably, leaf roll, mosaics, curly, stunted, etc. These symptoms may be more or less easy to observe depending on the varieties, vegetative stage and climatic conditions and laboratory techniques may be required in addition to visual examination. The knowledge of these visual symptoms helps to eliminate diseased plants (purification) in a continuous way during the period of growth of the foliage.

3.3.1.2.2 Removal of regrowth and other sources of viruses

Another source of contamination is regrowth, plants from small-scale tubers left on the ground after harvest. The number of these tubers can exceed one hundred thousand per hectare, there is no effective means against this regrowth except the respect of a certain rotation time.

3.3.1.2.3 Limiting passages

In order to limit the spread of contact-transmissible viruses (PVX and PVS), it may be useful to limit the passage of tools, machines and humans.

The cultivation operations will also be done always starting with the healthiest plots, to avoid contaminating them hard to pass into the affected plots.

3.3.1.2.4 Protective treatments

Control of vector aphids is first carried out by chemical means. It is especially effective in preventing the spread of so-called persistent viruses (PLRV) whose particles are infectious only after a certain period of residence inside aphids. So, we can destroy the aphids first. The spread of non-persistent viruses, among which PVY is particularly important, is much better contained by the application of mineral oils. These nevertheless have some disadvantages: by maintaining moisture on the foliage, they may promote the development of Late Blight and make it more difficult to purify certain varieties whose leaves may deform as a result of phytotoxicity.

3.3.1.3 Isolation of propagating crops from infected consumer crops

An important factor is a distance from external sources of contamination represented by consumer potato plots and regrowth in other crops. It may be interesting to exclude some crops from plant production areas as they may be a source of vector aphids. The standards for isolation are:

- Plots with pre-basic material of one or more varieties must be isolated at least 50 meters from any other potato crop;
- Plots for the production of basic plants are separated by at least 10 m from any other potato crop;
- Plots intended for the production of certified plants are isolated by at least 10 m from any consumption potato crop;
Breeding plots of different varieties are separated by at least two empty rows;

When the presence of regrowth is observed in the separation interval, these are considered as not isolated;

In cases where the production plots of basic or certified plants are adjacent to another plot which, during the vegetative stage, presents a danger of contamination, this one shall be cleaned up on a contiguous strip with a minimum width of 10 m.

3.3.1.4 Severe mass selection or varietal treatment in propagating crops

Selection is mandatory from the beginning of the vegetation until the beginning of yellowing of the leaves (early maturity).

It consists of the removal of foreign and nonconforming plants, regrowth and plant with virus diseases as soon as symptoms appear, severe rhizoctonia and verticillium.

3.3.1.5 Early dehaulming to remove leaves from plants and prevent them to infections

Potato plots are systematically removed early, meaning that the foliage is reduced before ripening. This practice removes vegetation from aphid flight and prevents virus migration to the tubers (in the case of late contamination). The follow-up of aphids allows knowing whether or not to advance the dates of dehaulming.

By limiting the life of the foliage, removing old leaves also helps to limit the growth of the tubers. This is one of the ways to obtain a suitable proportion of small and medium-size tubers corresponding to the regulation of plant trade.

3.3.2 Pre-base seed production

3.3.2.1 Production of quality plants by in vitro micropropagation

In the in vitro system, parts of plants are propagated and regenerated into whole plants or tubers under sterile artificial conditions. For rapid multiplication, three types of material can be used: (a) Node cuttings, (b) Apical cuttings and (c) Micro-tubers [14]

Apical cuttings are not frequently used because they are not widely available. To do this, we will focus our attention on node cuttings and micro-tubers.

3.3.2.1.1 Node cuttings

When a large quantity of seedlings with high genetic quality and a maximum sanitary condition is desired, rapid multiplication is done by node cutting. The various steps are as follows:

1. Source plant selection and treatment

Three types of plant material are used:

- Tubers; where the tubers are used as starting material, they must first be pre-germinated, after which the buds are harvested. This step can take 2 months.
• Stems; stems can be harvested directly from the field or from greenhouse plants.

• Seedlings in vitro

These materials must conform to the cultivar and be viral tested (mainly PVX, PVS, PVY, PVA, PVM, and PLRV), bacteria (stem rot, brown rot and those caused by Erwinia spp) and other diseases.

2. Disinfection of stems

The leaves must be removed from the stems, after which the stems are disinfected for a few seconds into alcohol 70–96%, followed by a few minutes in a solution of sodium hyperchlorite 10%. After disinfection, rinse with sterile water (distilled water).

3. The first in vitro culture

The cuttings are cut into pieces including an axillary bud. They are then placed in the culture medium, with the base pushed into the medium. The test tube must be closed. After 4 days, the bud could start to grow into a stem.

Throughout the in vitro development stages (Steps 3 and 4), only 1 medium type is used. The Murashige and Skoog growing medium contain a wide range of nutrients including the auxin hormone that induces root development. Consequently, the use of this growing medium during stages 3 and 4 leads to the production of seedlings [15].

The composition of the culture medium

<table>
<thead>
<tr>
<th>Composition of the medium</th>
<th>Growing conditions</th>
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<tbody>
<tr>
<td>Agar 80.0 g/l</td>
<td>Light duration 16 h</td>
</tr>
<tr>
<td>Murashige &amp; Skoog 4.2 g/l</td>
<td>Light intensity 800–500 lux</td>
</tr>
<tr>
<td>Sucrose 25.0 g/l</td>
<td>Temperature 20–23°C</td>
</tr>
<tr>
<td>Alar 85% 0.001 g/l</td>
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</table>

4. Multiplication

Seedlings produced in Step 3 are cut into pieces with an axillary bud and leaf. These individual pieces are placed in a new tube medium, with the bud just above the nutrient medium. This multiplication step can be repeated every 4 weeks, resulting, on average, in 5 new vitro-plants from a single initial vitro-plant.

5. Acclimatization

After the desired number of vitro-plants is produced, they must be fortified for later uses in greenhouses, under shelters or in fields. For acclimatization, the vitro-plants are planted in small pots containing the soil, then the temperature is reduced from 20–23 to 18°C in the greenhouse.

If the micro-tubers are produced directly in a greenhouse, the vitro-plants have no interest in being fortified (physiological maturity), they can be used as such.
3.3.2.2 Production in a protected system or in a well-controlled environment

The semi-in vivo environment refers to sterile (aseptic), artificial (in vitro) and natural (in vivo) conditions. An example of a semi-in vivo environment is the greenhouse or under-shelter. The semi-in vivo propagation systems are: (a) Bud cuttings, (b) Stem cuttings, (c) Leaf bud cuttings, (d) Single node cuttings and (e) Micro-tubers

3.3.2.2.1 Bud cuttings

The bud cutting is a rapid propagation method [16, 17] which requires following steps (Figure 6).

1. Tuber selection

The tubers selected are those that have passed the dormant stage and are healthy systemic pathogens.

2. Treatment of tubers

After breaking of dormancy, a vigorous bud is stimulated by the transfer of tubers every 7 to 10 days from the dark medium to the light (indirect) medium and back. Darkness promotes the growth and development of the internodes, while indirect light improves the vigour of the buds and induces short internodes. After treatment with dark and indirect light, when the buds are 3 cm long, the apical part is sectioned by a very sharp knife. This stimulates the formation of lateral buds and consequently the increase in the number of cuttings. After removal of the apical part, the tubers with their buds are submerged for a maximum of 10 minutes in a solution of

![Figure 6.
Bud cutting technique (Stapes to follow).](image-url)
gibberellic acid of 1–2 ppm in order to improve the growth of the buds. After which the proper distance of the internodes is regulated by placing the tubers in darkness or under indirect light. Root formation can be stimulated by high relative humidity.

3. Cuttings

A small portion of the buds will have to remain on the tubers if another harvest of the bud cuttings is expected. Two to three bud harvests can be taken from each tuber if they are physiologically young.

If the tuber is to be planted, at least a harvest can be made. After removal of the tubers, the buds are sectioned into pieces of one or more nodes. Cuttings should have at least one apical bud and two small roots to ensure good growth of the new seedling. A single tuber can produce up to 40 buds, depending on the size of the tuber, the number of eyes and the management of the buds.

4. Planting Bud Cuttings

The bud cuttings are planted on a well-drained substrate (fine sand 1 mm) in tray. The apical bud should be slightly higher above the sand after first watering. Terminal cuttings grow very quickly and should therefore be planted separately from those from the base.

5. Transplantation

After about 15 days, the cuttings will have formed roots and are thus ready for transplantation. Two days before transplant a foliar application of fertilizer is desired. The transplant can be done directly in the field or in pots in the greenhouse.

- **In the field:**

  The soil-cuttings contact must be optimal. At least one leaf node must be underground; this is best done by watering after transplantation. Good results are obtained when the fertilizer solution is made of a concentrated mixture of P₂O₅ and water.

  Two to three weeks after transplant, cuttings are treated as normal potato plants. Early earthing-up must take place to maximize tuber production. The average yield of 500 gr per plant can be obtained.

- **In the pots:**

  Cuttings planted in pots can be considered mother plants for the production of node cuttings. If 3–4 cuttings are transplanted into a large pot, they can be used for future propagation of stem cuttings, leaves or for tuber production.

3.3.2.2.2 Stem cuttings

Stem cuttings used as rapid propagation can produce 20 to 60 cuttings from each parent plant. The advantage of stem cuttings is that non-systemic diseases and nematodes can actually be eliminated because only the top part is used for propagation [18, 19]. The procedure is as follows (Figure 7).
1. Management of mother plants

Mother plants are grown in pots in a greenhouse from the best buds of tubers or cuttings with disease free. For optimal use of the greenhouse space, plants with 3 or 4 stems are preferable, depending on the size of the pot and the cultivar.

When tubers are used to produce mother plants two methods of planting exist:

- The tubers are planted in the pot and lightly covered with the soil. The shoot emerges together with the aerial stolons.

- When tuber production is desired in pot, the earthing-up must take place early. Aerial stolons are harvested as cuttings. When mother plants are 25–30 cm tall, each stem is decapitated. This eliminates apical dominance and stimulates the development of lateral branches from the axillary buds of each leaf. After 15–20 days, the cuttings are ready for harvest.

Mother plants must be fertilized with nitrogen for rapid growth and phosphorus for rapid root development. Liquid fertilizer is desired after beheading and after each harvest of cuttings. A suitable solution is obtained when 5 gr of 12-14-12 fertilizer is dissolved in 1 litre of water.

2. Cutting

When the lateral branches (cuttings) are 12–15 cm long, they are cut with a sharp knife. The section must be made near the new axillary bud that will produce the branch, which will produce cuttings. After the first harvest, additional harvests are made at intervals of 12–15 days. These have cuttings yield of 30–60% more than that of the first harvest. In total, between 20 and 60 cuttings are obtained per mother plant.
Cuttings should preferably have a stem 4–5 cm below the node of the first leaf. If cuttings cannot be planted immediately, they can be stored in the refrigerator at 4–6°C for up to 2 days.

3. Culture of cuttings

The cuttings are planted at 5 × 5 cm spacing, on tables (bins) containing a well-drained substrate, of washed sand (size 1–2 mm). If necessary, cuttings can be dipped in a hormone-containing solution (auxin) to activate root formation for 2–3 days. When cuttings are planted, the lowest leaf node should be below the sand and the roots should have good contact with the soil. If the hormone has been used, irrigation should be done at least in 2 hours to allow its impregnation. Plants must be grown under shade.

4. Transplantation

Fourteen days after the extraction of mother plants, plants are ready for harvest if they have been well rooted. The plants can be transplanted in pots or directly in field.

- Pot transplants are made to produce new mother plants or tubers. Plants should be put under the soil as for tubers (see point 1). One or more nodes should be covered with soil.

- When transplanted in the field, the plants are placed at a uniform distance with one or more leaf nodes under the ground. Liquid fertilizer with a high phosphorus concentration will need to be applied to improve root development. This should be done early and lightly.

3.3.2.2.3 Leaf bud cuttings

As with stem cuttings, the use of leaf bud cuttings as a rapid propagation technique eliminates non-systemic pathogens from the soil and tubers [20, 21]. The procedure is as follows (Figure 8).

1. Selection of the mother plant

The first step in the production of leaf bud cuttings is to choose a healthy and suitable mother plant. The mother plant should be cultivated under the conditions of a long photoperiod (long days) and then kept for 10 to 15 days in short photoperiod (short days) before cutting to induce tuberization. A plant that begins senescence (when the basal leaves are mature) is ready to cut the cuttings of leaf buds.

2. Cutting

The best cuttings yield comes from the central part of the plant. Those coming from the lower part of the plant produce smaller micro-tubers, the cuttings of the top parts produce few micro-tubers and tend to produce aerial roots and buds.

After removing the stems from the base of the plant, they are cut (main stems) into cuttings of leaf buds of 1–3 cm, depending on the cultivar. In the centre of the
cuttings, a node should be present with an undifferentiated bud and a leaf. Approximately 70–100 cuttings can be produced per plant.

3. Cultivation of cuttings

Leaf bud cuttings are planted with part of the stem in a well-drained substrate (fine sand, 1 mm), with the bud below and the leaf above the surface. The cuttings are planted in line 5–7 cm apart, depending on the size of the leaves, and their leaves should be covered with sand more or less completely. Cuttings and sand substrate should be well in contact. Irrigation should be done carefully with very fine water droplets. When the light intensity is high, shading can be provided. The temperature in the greenhouse should be relatively low, about an optimum 20°C.

4. Harvest

After one or two weeks, the germs begin to develop. When all the leaves have died (4–6 weeks after planting, depending on the cultivar and temperature), the micro-tubers are harvested. Generally, 1 micro-tuber is harvested by cutting, but sometimes 2 can be obtained. As a result, 80–120 tubers are harvested from a single-parent plant. The typical size of tubers produced in 31 days is between 0.5 and 1.0 cm (0.2–1.0 gr).

By the technique of leaf buds, more than 1000 tubers can be produced on 3 m².

5. Storage of Micro-tubers

Micro-tubers can be stored for 4–6 months at 4°C and relative humidity of 90% after which the dormancy period is generally over.
6. Planting in the field

The spacing between the lines is usually 15–20 cm, depending on the cultivar, the soil conditions and the desired tuber size. In general, micro-tubers produce only one main stem and average yield of 500 gr each (depending on cultivar, soil and climatic and management conditions).

3.3.2.4 Single node cuttings

“Single node” cuttings should not be confused with “node cuttings”. Single node cuttings are produced under in vivo conditions, while node cuttings are produced under in vitro conditions (previous section) [17, 18]. The single node cuttings technique is often used to produce many seedlings in the first generation of the pre-basic seed production program.

When the produced plants are transplanted into the field, the yield of the tubers can be about 500 g/plant, while the produced tubers have an ideal size of the seed tubers. The process is as follows (Figure 9).

1. Mother Plant Management

The small mother plant of single node cuttings can come from the cuttings of buds, plants from the vitro-plants, stem cuttings, micro-tubers or true seed tubers. When the plants have 5–6 leaves, the cuttings are taken, but 2–3 days before this, foliar

![Figure 9](image-url)
fertilization must be applied. The stem is cut from the mother plant leaving a strong whole leaf. After each harvest of cuttings, the mother plant is fertilized with a liquid NPK fertilizer to stimulate the growth of new cuttings. An application of 5 g of a 12-14-12 fertilizer per litre of water is appropriate for each plant. A new stem is formed at the leaf node remaining at the base of the stem.

A temperature of 23–26°C and a long photoperiod stimulate rapid growth. In addition, these conditions not only stimulate growth but also do not induce the formation of tubers. The new stem is ready for harvest in 15–29 days. Each parent plant can be harvested 2–10 times and produce between 30 and 200 cuttings.

2. Cutting

After removing the stems from the mother plant, they are sectioned, each with a leaf and an axillary bud in the centre.

3. Planting

Before planting, cuttings are brought into contact with a rooting hormone. Single node cuttings are either planted individually in a pot to produce more mother plants, or they are planted together in a well-drained rooting substrate made of 1 mm of sand. The latter cuttings are planted in the soil. The plants will be transported to the field in the next phase. Cuttings should be put deeply in the soil, so the node and stem are covered with sand.

4. Culture of cuttings

Temperatures of 20–23°C (rooting optimum) and 23–26°C (shooting optimum) are ideal. Irrigation must be done by a fine droplet sprayer, 2–3 hours after planting to allow the hormones to penetrate the plant tissues. Usually, 15–20 days are required to produce a seedling, which can be transplanted. The seedling thus has adequate roots and 3–4 leaves.

5. Field Transplant

Single node cuttings could be planted in the field in narrow, spaced lines. Yields can be around 500 gr per plant. The tubers are ideal for use as seed tubers.

4. Plant selection and elimination

Plant selection and elimination are done to remove off-type plants, remove sources of infection such as virotic plants, and thus prevent the spread of diseases. Viral diseases as well as those caused by bacteria and fungi are, especially controlled by this approach. These practices also have long-term effects because they reduce the number of infected tubers entering the stock, where the infections could spoil the entire seed lot. These practices also reduce the level of inoculum and spread of virus infections. Plant selection and elimination can only be effective under the following conditions:

- Timing: should be done as early as possible to avoid possible spread of disease;
- Frequency: repeat operations regularly;
• Extended throughout the field;

• Carefully remove plants to avoid dispersal of vectors by more movement.

In fact, this negative selection (removal of infected plants) does not guarantee that all remaining plants are healthy. It could only have effects if the majority of plants are healthy.

Positive selection is also possible. In this case, apparently healthy plants are harvested only if they are surrounded by other apparently healthy plants.

4.1 Dehaulming, harvesting and post-harvest work

Another protective measure that is often needed in potato seed production is shoot elimination (dehaulming) [22]. It allows for:

• Prevent the spread within the crop (from plant to plant) of the main fungal diseases of aerial origin and even some of the soil;

• Stop the production of fungal spores that could attack tubers (e.g. *phytophthora infestans*);

• Prevent viral infections when vector populations become very important or stop the spread of viral diseases from the air to the forming tubers;

• Stop growth and thus allow the tubers to resist adverse climatic and edaphic conditions (drought, cold, heat);

• Stop the growth of the tubers in the formation when they have reached the desired size and initiate their maturation and skin colouring.

• Removing shoot can also influence tuber dormancy.

• The time between removing shoot and final harvest is important. It seems that the long period (more or less 3 weeks) between removing shoot and harvest could lead to attacks of various diseases and parasites.

• Depending on the temperature of the soil, about 10 to 20 days are required for the tubers to acquire a beautiful skin, so the harvest can be done without too much damage, due to the spread of diseases. The harvesting of tubers must be done with great care and avoid as much as possible injuring the tubers with the tillage instruments.

After harvest, tuber seeds will need to be dried cleanly to further prevent the development and spread of diseases. Initially, storage temperatures will need to be relatively high (15°C) to allow more firmness and skin coloring. Once this process is completed, the temperature should be lowered to a temperature that allows physiological development during the storage phase, with minimal loss of dry matter and water. Good ventilation is essential. Heat and cold shocks can be applied to advance the physiological maturation of the tubers.
5. Potato seed certification

5.1 Types of seed

Following are categories of types of seeds [14, 23]

a. Breeder Seed

- It is a class in seed certification;
- They are produced by the breeder, owner of the variety;
- They are controlled by the person or research institutions;
- This is the source of production of pre-basic seeds;
- They are generally in very small quantities.

b. Pre-basic seeds

It is a seed generation that is still under the control of the breeder or the research institution.

c. Basic seeds

It is a seed class that constitutes the last step of multiplication of initial seed and which plans for the production of certified seed. This category is generally given to multiplier farmers.

d. Certified seed

It is a seed generation from basic seed that has been certified to meet the standards of genetic purity established by the certification agencies

e. Standard seed

It is seed of lower status that is subject only to varietal conformity, purity and laboratory tests.

5.2 Seed certification process

Quality control objectives are two: (a) Ensure that farmers receive quality seed in terms of input to maximize their production at harvest, and (b) Ensure farmers are not at risk of receiving low-quality seed (inputs) from fraudulent traders [24].

The Seed Certification process involves the following steps: Field inspections, Seed Treatment; The seed test, Label and seal, Post controls, and Post Certification Survey
5.2.1 Field inspections

This is the first step in the certification process. It consists of:

- Registration of the field;
- Provide proof of origin from parents;
- Observe the minimum isolation distance.

The inspection is conducted to ensure that harvested crop is the true type, it has no contamination, and culture is healthy (disease free/pest free).

5.2.2 Seed treatment

Tuber seeds are harvested and treated to remove the surrounding soil, wash and then categorize (calibration) to have homogeneous seed tubers. The categories are as follows:

- Grade No. 1: Are tubers retained by a sieve with a diameter of 35 mm mesh. They correspond to the largest size of seed tubers.
- Grade No. 2: Are tubers retained by a sieve with a diameter of 25 mm of mesh. They correspond to the large calibre of seed tubers.
- Grade No 3: Are tubers retained by a sieve with a diameter of 15 mm of mesh. They correspond to the medium size of the seed tubers.
- Grade No 4: Are tubers retained by a sieve with a diameter of 10 mm of mesh. They correspond to the small calibre of seed tubers.

5.2.3 The seed test

Laboratory tests are useful for determining purity, dormancy, tuber recovery capacity, moisture content and health status of seed lot.

5.2.4 Labelling and sealing

Each seed lot is labelled with a label and a mark.

5.2.5 The Post-test checking

Post-test checking is intended to show that the measurement of the previous control was effective. They ensure that varietal traits remain unchanged during multiplication.

5.2.6 The post-certification surveys

This is done by all provincial offices across the country. This ensures that all seeds are well planted and on time. Samples are taken at the selling point and from farmers and are planted along control strips for comparison. Low-quality plants are therefore easily checked.
6. Conclusion

Potato is ranked as the fourth most important staple food crop and the number one non-grain food commodity as per the Food and Agriculture Organization of the United Nations (FAO) (2018). It has increasingly become an international commodity cultivated across the world. In Central Africa, Potato is cultivated in mountainous regions where climatic conditions are favourable. However, its productivity is still very low (5–10 tons/ha) due to the use of degenerated potato seeds and poor agricultural practices by farmers. Limited use of quality seed potatoes, by less than 4% of farmers is due to lack of appropriate facilities, in vitro laboratory, which cannot be affordable to potato seed producers. So, in this chapter different techniques of cuttings that could be applicable to farmers are developed by using meristematic tissues which are considered free diseases and restore the genetic potentiality of cultivated varieties.

It was proved that the use of good quality seeds increased the productivity of potatoes by more than 35%. In order to make them available during cropping seasons, it would be necessary to take into account the variable dormancy of the different varieties and to establish an appropriate agricultural calendar the potato seed production, which examples have been given in this chapter.

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