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Ecophysiology and Production Principles of Cassava (*Manihot* species) in Southeastern Nigeria

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Abstract

Cassava (*Manihot* species) is a crop of the humid tropics that belongs to the family *Euphorbiaceae*. Cultivated forms belong to the species "*Manihot esculenta* Crantz" and "*Manihot utilissima* Pohl." Africa produces about 50–80 million tonnes of cassava annually; this translates into an average of more than 300 calories per day for more than 200 million people. Cassava can grow on relatively marginal soils and erratic rainfall conditions in southeastern, Nigeria. It quickly adapts and integrates into the traditional farming system, is easy to cultivate and process and it is available all year round acting as a buffer against crop failure. These characteristics make this root crop a necessary component of the farming system in many areas of Africa south of the Sahara. Some of the principal recommended cultivated varieties in Nigeria include; TME 419, TMS 90257, TMS 91934, TMS 81/00110, TMS 82/00661, TMS 30001, TMS 30555, TMS 30572 and local cultivars—*Nwugo*, *Nwaiwa*, *Ekpe* and *Okotorowa* that are popular in southeastern Nigeria. Cassava is expected to play increased role in Africa's struggle to attain food and nutrition security through increased production and utilization. This paper examines the ecophysiology, production principles, pest and disease management, uses and constraint hampering cassava production in southeast Nigeria.

Keywords: cassava (*Manihot* species), production, yield, edaphoclimatic requirements, uses, constraints, Nigeria

1. Introduction

Cassava (*Manihot* spp.) belongs to the family *Euphorbiaceae* and is the most important root crop grown in the Tropics. The plant probably originated from South America and was first introduced into Central Africa during the last part of the sixteenth century, into West Africa in the early eighteenth century and into East Africa in the early nineteenth century [1]. Cassava

is thus a relatively new crop to African Agriculture. Hahn et al. [2] postulated that farmers rapidly adopted cassava and integrated it into the traditional farming practice because the plant quickly adapts to local farming conditions. The crop is easy to cultivate and process, and it is available all year round thus acting as a buffer against crop failure. Cassava requires minimal input for cultivation and yet produces relatively good yields with little labor input.

Although the crop grows in every country of the sub-continent (sub-Saharan Africa), cultivation is concentrated in the humid tropics [3]. Africa produces about 50–80 million tonnes of cassava annually; this translates into an average of more than 300 calories per day for more than 200 million people [4]. Africa has 7.48×10^6 ha of land under cassava and this account for 52% of the world's area under this crop in 1984 [5]. Four African countries (Mozambique, Nigeria, Tanzania, and Zaire) are among the 10 largest cassava producers in the world.

According to [3], cassava's ability to adapt to biotic and abiotic stress hampering crop production, poor edaphic condition, irregular rain fall, high yield per unit of area of land and labor requirements make cassava a primary component of the farming system in many parts of Africa south of the Sahara. Cassava has the potentials for eliminating food crisis and famine. Cassava is commonly blamed for malnutrition because the roots contain little protein and an anti-nutritive factor (hydro cyanogenic glucoside) which is removed during processing. The absence of cassava in the farming and food systems of Africa would lead to catastrophe. Cassava deserves a primary position as a crop that has saved many lives in Africa. This paper provides detailed information on cassava—growing conditions, production systems, and processing methods in Southeastern Nigeria.

2. Classification

Cassava is a dicotyledonous plant of the Spurge family *Euphorbiaceae*. All cultivated forms belong to the species "*Manihot esculenta* Crantz" and "*Manihot utilissima* Pohl". There are many cultivars of cassava, and these may be distinguished based on many criteria relating to the structural features of the plant. Other features such as tuber shape, earliness of maturity, yield and its content of cyanogenic glycoside (HCN) are characteristics employed in distinguishing the different varieties of the plant. *Manihot utilissima* Pohl or sweet and *Manihot aipi* Pohl are two edible species reported to have high and low cyanogenic glucoside concentrations respectively. Cassava has $2n = 36$ ploidy number. Many closely related species are present in the tropical and subtropical Americas that can be crossed with *M. esculenta* [6].

A current study by IITA revealed that about 4000 local varieties are in 17 major cassava-growing countries in Africa. The research programmes on cassava improvement of the countries surveyed released a total of 206 improved cassava varieties between 1970 and 1998 [7].

Some of the important recommended cultivated varieties in Nigeria include; TME 419, TMS 90257, TMS 91934, TMS 81/00110, TMS 82/00661, TMS 30001, TMS 50395, TMS 84537, NR 87184, NR 41044, NR 8082, NR 8083, NR 8212, NR 83107, TMS 30211, TMS 30555, TMS 30572, U – 41044, U – 7706 and U – 60506 – 2(4) TMS 419, TMS 30001, TMS 300017, TMS 30110, TMS

30337, TMS 4(2)1425, UMUCASS 42, UMUCASS 43 and local cultivars—*Nwugo*, *Nwaiwa*, *Ekpe* and *Okotorowa* that are popular in southeastern Nigeria. The best cassava varieties possess short growth cycle, high yields, withstand biotic and abiotic stress, early maturing, give high root yields (fresh and dry) and meet end-users quality characteristics, and store well in the soil for more than 18 months.

3. Edaphoclimatic requirements

Cassava is a crop of the humid tropics. It is warmth – loving plant and performs optimally at a temperature between 25 and 29°C but cannot perform well at temperatures below 10°C. Cassava requires some amount of moisture, and an annual rainfall of 1000–2000 mm is adequate for its growth. Since it is a moderate drought tolerant plant, its cultivation is possible with only 500–750 mm of rainfall. During drought, cassava growth ceases or slows down considerably, the length of internodes shorten, and tuber enlargement stops. The crop, however, cannot tolerate drought a few weeks after planting. The optimal soil for cassava can be described as well drained, light textured, deep and fertile soil. Onwueme and Sinha [8] pointed out that cassava does best on light sandy loam soil with high but not excessive fertility. Excessive fertility, especially in soils with a preponderance of nitrogen content, cause the plant to produce more shoot at the expense of root growth. The crop performs poorly on stony soils, saline/alkaline soils (with pH above 8.0, above 2.5% soil sodium saturation, and above 0.5–0.7 dSm⁻¹ electrical conductivity [9] or soils with hardpan and poor drainage that restricts root growth and enhances tuber rot. According to [10], soil physical status often gets less attention although it usually controls the chemical and biological functions of soils concerning crop production. Poor soil structure and acidity are attributes of long term effect of the continuous application of chemical fertilizer. In many heavily weathered soils, subsoil penetration by roots and water percolation are impeded by chemical and physical barriers [11].

Hahn et al. [2] noted that African soils under cassava are over cultivated and have low fertility, high acidity and aluminum levels, low organic matter, are shallow and highly compacted, retain little soil moisture and are high in the soil temperature at certain times of the year. In these soils, with poor fertility, cassava gave 79–80% of the maximum yields after liming while sorghum and maize gave only 9.5 and 52% of their maximum yields respectively. This indicates that cassava performs better than any other food crops on soils of low fertility and high acidity.

4. Crop physiology

Cassava is a woody perennial that can grow up to 5 m in height. The leaves are large, spiral and lobed. Several tubers are produced at growth stage which contains 35% starch and weighs up to 40 kg. The male and female flowers are in clusters, and the plant also produces a non-fleshy fruit capsule [12]. Cassava can be propagated by stem cutting or by seed. Propagation

by seed is often slow, and some of the seeds may require to be scarified before germination can take place. However, stem cuttings germinate readily, and this is the usual method of multiplication or establishment.

Germination, shoot expansion, and root spread occurs within the first few weeks after emergence or sprouting. At the early growth stage, the adventitious roots are formed first from the nodes at the base of more than one axillary bud (nodal roots) 5–7 days after planting, which is then followed by the formation of rootlets from a recently formed callus at the base of the cutting (basal roots) [13]. The buds also begin to sprout and enlarge 5–8 days after planting, with the first leaves appearing by 10–13 days. Sprouting is faster at a soil temperature around 28–30°C but ceases at temperatures higher than 37°C and lower than 17°C [14]. The maximum leaf area is reached in 4–5 months after planting. Flowering starts from the first 6 weeks and continues throughout the growth period of the crop. Tuber initiation starts from the 8th week after planting but depends on the variety and environmental conditions. Most of the fibrous roots will develop into tubers but after 6–9 months no fibrous roots will grow into tubers.

The fibrous roots (ranging from about 3 to 20 roots, depending on cultivars and growing conditions) initially penetrate the soil as thin fibrous roots, after that, they undergo secondary thickening and starts swelling from the proximal end where the fibrous root is attached to the stem. The feeder roots grow vertically into the soil to a depth of 1 m, thus the reason for its ability to tolerate drought and low soil fertility [9]. Mature roots which contain 20–30% starch extend 60 cm down into the soil and are around the base of the plant. Fresh root yield at harvest under the most favorable conditions is about 90 t/ha while average world yields from mostly subsistence agricultural systems are 10 t ha⁻¹ [15, 16]. The cassava tuber is physiologically inactive and thus cannot be used to propagate the crop. Studies have shown that shoot development takes pre-eminence during the first 3–5 months of the development of the plant whereas root bulking occurs during the subsequent period of the growing season. This may be because the plants mobilize photosynthates to the shoots early in the growing cycle and supply the roots more photosynthates during the later part of the growing cycle. This may, however, depend on critical eco-physiological conditions such as soil and water conditions, temperature regimes and photoperiodism [13, 17–19]. In general, cassava does not have specific water stress sensitive growth stage beyond crop establishment, and the crop tolerates prolonged drought and erratic precipitation [13]. The ability of cassava to tolerate elevated temperature, drought and increased concentration of atmospheric carbon dioxide, places it as a crop that can adapt to climate change impacts.

5. Cultivation of cassava

The planting period, planting density and the position of the cuttings are three primary factors that are important in the growing of cassava [12]. Cassava cultivation starts with the selection of a suitable site. Selection of a good site is a desideratum for production of high yields. Factors such as edaphic condition and land use history, vegetation, topography and specifically soil physical properties should be considered. Although cassava tolerates a broad

range of soil conditions, it grows well in well-drained soil of medium texture (loamy soils) with high organic matter content. Soils that are water-logged or imperfectly drained should be avoided as tuber rotting proliferates after more than 10 days of continuous inundation in water. Similarly, cassava will not give good yields in soils that are stony, compacted or soils with hard pans or indurated layers. If it is possible, a site that has been over cropped (used for continuous cultivation for 3–5 years without appropriate fertilization) should be avoided. Land with gentle or rolling slope is preferable to soil on steep slopes for cassava production.

Land preparation for cassava planting usually starts with clearing, stumping and sometimes burning. The cuttings may be planted on unploughed land using minimum tillage technique. Similarly, cassava may be planted on mounds, which are 30–60 cm high and 1–2 m apart, or on large mammoth mounds up to 1 m high in poorly drained soils. The choice of the land preparation method largely depends on soil type and the depth of water table.

In modern agriculture, the land is plowed and harrowed, thereafter cassava cuttings may be planted on the flat or on ridges that are 1–1.5 m apart depending on cultivars. Ridge and mound planting are suitable on heavy soils. This prevents water logging which leads to root rot.

6. Planting material

Cassava is propagated by the use of stem cuttings. The cuttings measuring 15–30 cm long with 4–6 nodes are used for planting. Such cuttings make it easy for mechanization, transportation and handling of large quantities of planting material. However, longer cuttings have been found to produce higher yield because they produce greater number of roots and shoot and contain larger stored food reserves that the plant can utilize before it becomes self-sufficient. The ripe wood (mature cuttings) taken from the middle of the stem is normally preferable to cutting from either the plant tip or base. It is a normal practice to cut cassava stems 2–3 days before they are cut into final planting lengths and planted. This allows the stems to develop callus (auxins), which promote early sprouting and development. Before planting, healthy cassava stems are selected. They are cuttings usually procured from mature plants 8–10 months old and preserved under the shade for a few days before cutting and planting. It is important to place the distal end of the stems on the soil and moisten it regularly making sure that the surroundings are kept weed free [20]. This will make the stems sprout faster than when they are planted freshly cut from the field.

Cassava cuttings are planted in different positions in various countries. They may be planted upright in a vertical position, inclined at an angle of 30–40° or planted horizontally at about 10 cm beneath the soil surface. When cassava sticks are planted vertically, they sprout and acquire healthy foliage slightly more rapidly and produce deeper lying tubers than inclined or horizontally planted ones. Probably, planting in an inclined position, at an angle of 45°, is best. If the cuttings are planted inclined or vertically, the cuttings are buried in the soil with one-third above the ground surface with the buds pointing upwards. This is not necessary for horizontal planting. The planting depth can be 5–15 cm. Vertical or angular planting is recommended in areas of high rainfall whereas horizontal planting is better in dry areas.

Timeliness in planting operations ensures healthy sprouting, good crop establishment, and growth. Dry season planting is not recommended in areas of low rainfall and where water table is low because soil moisture content influences stem sprouting and survival [20, 21].

Cassava is usually planted when there is adequate moisture in the soil. This is important because young plants do not tolerate drought, unlike older plants. The crop is planted one cutting per hole/hill and sprouts within 7–14 days. It can be planted manually or with newly developed mechanical planters. The standard spacing is between 80 and 100 cm apart on ridges, mounds or flat which are 100–150 cm apart depending on cultivars and environmental conditions. When cassava is intercropped with other crops, a much wider spacing is adopted depending on types and number of plants as well as the kind of inter-cropping used. In intensive cultivation, it is recommended that the crop should be alternated with a legume cover crop at rest period. At times intercropping cassava at the end of rotation help conserves soil fertility [12].

7. Weed competition in cassava

Weeds reduce cassava yield if not controlled properly. In cassava fields where weeds are not adequately managed, yield reduction of between 50 and 80% is observed. Weed competition at any stage of growth after rooting reduces yield but the most damaging effects of weeds on yield occur during early canopy formation and tuberization. This starts from planting to 90–120 days. Optimum yield can be achieved if cassava is kept free of weeds during this time. The period, 90–120 days is referred to as the critical duration of weed interference. However, weed competition from 8 to 12 weeks after planting was found to cause the greatest reduction in tuber yield. This period (8–12 weeks after planting) is referred to as the critical period of weed interference in cassava. Thus if there is limited labor for weeding, the farmer must choose to weed at 8–12 weeks to obtain satisfactory yield. Weed control takes up to 60% of the labor and more than 40% of the total cost of growing cassava in sub-Saharan Africa [20].

Two properly spaced weeding at 30 and 60 days after planting could produce a satisfactory yield up to 77% of maximum yield. After that cassava is weeded periodically (every 6 months) especially if the crop is to spend up to 2 years in the field. Cassava can be weeded using hand held hoes (manual method). This method is effective if it is done at the right time but the method may damage plant parts especially the tender superficial roots. Chemical weeding using herbicides is another good option for weed control in cassava farms. Herbicides may be applied as pre-emergence or post-emergence herbicides. Some herbicides used in cassava farms are:

Pre-emergence herbicides

- Atrazine applied at 1.5–3.0 kg ha⁻¹
- Fluometuron applied at 2.0–3.0 kg ha⁻¹
- Premextra applied at 2.5–3.0 kg ha⁻¹
- Diuron applied at 1.5–3.0 kg ha⁻¹

Post-emergence herbicides are:

- Paraquat or Gramoxone applied at 0.5–1.0 kg ha⁻¹

Lower rates of these herbicides are recommended for light soils whereas higher rates are recommended for heavy soils. Most post-emergence herbicides are non-selective and therefore must be directed to the weeds only.

Weeds can also be controlled in cassava using the cultural method, for example, the use of increased plant population and optimal fertilizer use to check weed growth. Similarly, an integrated approach (integrated weed management) can be employed, and this involves the use of a combination of methods to achieve desired results, e.g., use of a pre-emergence herbicide which is followed up by one hand weeding later. Early weeding prevents weeds from competing with the crop for nutrients, water, light, and space. Melifonwu [22] recommended a combination of different cultural practices to control weeds control weeds in small scale farms in Nigeria. These include but not limited to:

- a. Removal of weed rhizomes, stolons, and tubers during land preparation.
- b. Mulching of cassava seed beds with live or dead mulch materials to reduce weed problems and improve soils.
- c. Growing cassava varieties with early, low, and much branching habit; these will suppress weed growth better than varieties with late, high, or no branching habits.
- d. Intercropping cassava with appropriate crops to reduce weed problems and improve soils.
- e. Using the improved fallow plant as “live mulch” on land for planting cassava.
- f. Hand weeding three times within 3 months after planting cassava; this will reduce weed competition with cassava for nutrients.
- g. Combining the most appropriate weed control practices for more efficient control of the weeds.
- h. Using an appropriate herbicide to control weeds in cassava farm.

8. Fertilization

Cassava grows well in fertile soils. Fertilization can be in the form of organic manure and inorganic fertilizer. Different fertilizer rates and types can be used such as NPK 12:12:17 or NPK 15:15:15 depending on:

- a. The nature of the soil, previous cropping history of the field, cultivar of the crop grown and planting density. If a location were previously planted with cowpea or other legumes, that location would need less fertilization than a place that was cropped with other grains continuously for a longer period.

- b.** The amount of rainfall prevalent in a particular location. It is possible to apply fertilizer at the time of land preparation, especially in low rainfall areas. Under inter-cropping, the fertilizer may be applied at 4 weeks after planting, and in areas with very high rainfall, it is possible to apply fertilizers in split doses at 4 and 8 weeks after planting. This is to prevent most of the fertilizer from being washed away or leached out of the soil solum.

Cassava requires a moderate supply of potassium fertilizer to produce a high yield of tubers. It is usually preferable to apply potassium sulfate instead of muriate of potash (potassium chloride) because potassium sulfate also meets the plant demand for sulfur. Potassium (K) is essential in the absorption of N and P in the soil. One way of adding K to the soil is through bush burning during land preparation. This cultural practice can increase yield if planting is done immediately after burning. Nowadays farmers are not encouraged to use this cultural practice (bush burning) because the disadvantages often outweigh the gains for using it [23].

Cassava needs a moderate supply of nitrogen, as excessive N application will increase shoot to root ratio and also increase the level of hydro cyanogenic glucoside (HCN) in most varieties. The best management practice would be to carry out soil tests before fertilizer application in a particular year. This will help the farmer to know what is lacking and what is to be applied. Soil tests are carried out and interpreted by soil scientists. Cassava can grow in all types of soil but best grown in a well drained sandy loam soil of average fertility. There is every need to adopt the most suitable cultural practices and method that will boost the yield of cassava. Even though cassava is said to have the ability to produce under low soil fertility, the relative yield is higher under high soil fertility, hence the need to improve soils for better yield. Soils in southeastern Nigeria are characterized by kaolinitic clay mineralogy. They are often degraded and are characterized by low fertility and high acidity which may be caused by over exploitation, erosion or leaching. Farmers in attempt to overcome this challenge adopted the strategy of chemical fertilizer application. The approach of farmers toward chemical fertilizer usage has posed a threat to soil physical quality status [10]. Various soil amendments are used by farmers to improve the productivity of soils. For example, the use surface applied gypsum, lime, and organic manures especially poultry droppings, cow dung, etc. in ameliorating chemical and physical barriers associated with improving soil productivity are promising technologies. The effect of these improvements on soil physical condition is attributed to the flocculation and aggregation effect of these amendments on the soil properties [11, 24].

Anikwe et al. [25] found that soil application of a combination of 5000 kg ha⁻¹ of lime and 2500 kg ha⁻¹ of gypsum increased soil exchangeable Ca²⁺, soil percent base saturation, soil total porosity, soil water transmissivity and decreased soil dry bulk density in the unamended control plots. The changes in soil conditions increased mean plant height of cassava and fresh tuber yield by 30–36%. They concluded that lime and gypsum influenced the soil physical and chemical properties through the addition Ca²⁺ that helped to flocculate soil particles, promoted nutrient uptake, proper moisture infiltration, aeration, increased exchangeable P and optimum pH for growth of cassava. Odedina et al. [26] postulated that cost, availability and technical reasons constrain the use of chemical fertilizer input in Nigeria. Animal manure, an

alternative to mineral fertilizer is cheap, but the disadvantage in its usage is that there are not available in the required quantities needed for bountiful crop growth. Essential nutrients such as N, P and K are often low. They studied the effect of an integrated use of organic manures and inorganic fertilizer on cassava production and soil parameters and found that the highest crop responses were observed in plots amended with organic manures with no productivity gaps when compared with scenarios where the recommended fertilizer and manure rates were used. They found more plant-available nutrients in plots where a combination of organic and inorganic manures was used. The study also found that whereas root yield was higher in plots where organic and inorganic fertilizers were used together, stem yield was greater in inorganic fertilizer managed plots. The lowest crop yield responses were found in unamended plots. The productive capacity of soils could be maintained by the use of integrated nutrient management techniques.

Howeler [27] observed that a combination of good agricultural practices that do not harm the environment with the right mix of inorganic fertilizers is recommended for sustainable crop production. They noted that cassava could endure acid soils and in symbiotic association with soil fungi intertwined with cassava roots, the crop can absorb nutrients especially phosphorus which they use in the production of photosynthates. Most nutrients absorbed by the cassava plant are mobilized to the leaves and stems, and this gives the plant the advantage of recycling nutrients within the plant-soil system. Although cassava has been reputed to produce well in soils of marginal fertility, many trials as shown by FAO imply that cassava responds favorably to mineral fertilizers especially in soils of low fertility.

9. Harvesting

Cassava tubers should be harvested when the tuber has not become fibrous or woody (when the starch content is at its peak). It should be harvested at 7–15 months after planting depending on the cultivar. The sweet types are harvested around 7 months while the bitter varieties are harvested at about 12–15 months after planting. It is typically recommended that mature cassava should be harvested before the dry season starts to reduce the loss of tubers during the dry season when the soil is hard and dry. Cassava is usually harvested piece-meal over a period after maturity. This means that you harvest, as you need since the keeping quality of cassava after harvesting is poor.

The crop can be harvested manually or mechanically using mechanical harvesters. For manual harvesting, cassava is mostly harvested by hand. In this process, the stem of the plant is cut off usually by using machetes, then the remaining lower part of the stem is lifted out of the ground by hand. Levers and ropes can be used to assist harvesting. A mechanical harvester can also be used. Mechanical harvesters, like those developed in Brazil, would grab onto the stem and lift the roots from the ground [16, 28]. Low productivity is caused by an inappropriate or near absence of mechanization, farming tools and limited market opportunities in southeastern Nigeria. This scenario encourages drudgery and delay in farm operations. Thus, with mechanical harvesters, cassava harvesting time frame is reduced from approximately 8–10 days per hectare to about 6 h [28].

Mechanical harvesters are less cumbersome but can damage the tubers, leave some of them buried in the soil and make separation of the tubers from soil and plant residues difficult. Thus, developing a labor-saving technology for cassava harvesting is the most critical challenge for cassava farmers and a limiting factor to cassava production in Africa. This challenge is more urgent than further increases in cassava yield [29]. This is because current harvesting methods are cumbersome, i.e., labor intensive. There is a need to develop seamless mechanical harvesting methods that can enhance harvesting of vast hectares of land. The bane of commercial production of cassava is mostly caused by manual harvesting reflecting drudgery and time consumption, especially in dry season. As enunciated by [30]. Africa is the highest producer of cassava in the world, but lack of access to appropriate mechanization to support production and processing of cassava is impeding the development of the cassava market in Africa. This challenge has limited the capacity of the farmers to increase production. Africa utilizes more than 90% of the cassava it produces for food whereas in Asia and Latin America, only about less than half of its cassava production is consumed.

The unavailability of equipment for cassava mechanization is a major problem militating against the expansion of output and utilization of cassava in Africa.

Frimpong [31] reported that the Agricultural Engineering Department of the Kwame Nkrumah University of Science & Technology (KNUST) in Ghana recently developed a unique cassava harvester designed to enhance the mechanization of root and tuber crops cultivation, mainly cassava and yam. The device 'Tek Mechanical Cassava Harvester' (TEK-MCH) has been engineered to address the difficulty in commercially harvesting root and tuber crops. The development and use of this machine is expected to revolutionize the technology for cassava production for use as food and industrial raw material. The TEK-MCH can harvest a hectare within a maximum of 2 h. This technology will increase efficiency and reduce drudgery thus allowing many farmers especially youths to embrace cassava production. The tek mechanical harvester worked best on fields with minimal trash or weeds and relatively dry soils with moisture content from 12 to 16% d.b. and requires drafts of up to 10.33 kN with penetration depth from 23 to 29 cm. Best harvesting performance was achieved at a tractor speed of 5 km/h giving a field capacity of 1.9–2.5 h/ha. After mechanical harvesting, the field is left plowed with savings on fuel, time and cost. However, it is recommended to field evaluate the harvester in all agro-ecological zones and through a wide range of soil moisture regimes in Ghana to determine suitable areas for mechanical harvesting and to promote nationwide adoption [32]. Amponsah [16] reviewed available manual, semi-manual and mechanical cassava harvesting methods and equipment and postulated that in the traditional method of cassava harvesting traditional farm implements including machete or cutlass is used to sever the stem from the base. The hoe or mattock is used to dig a hole around the tuber and subsequently the farmer pulls the tuber out of the soil. This method is laborious especially during the dry season when soil moisture is at lower levels [33]. According to [34], manual harvesting requires about 22–62 man-days per hectare.

The International Institute of Tropical Agriculture (IITA) and the National Centre for Agricultural Mechanization in Nigeria also invented a manually operated cassava root tuber lifter and a semi-mechanized cassava harvester respectively. These implements are to be used by small scale cassava farmers [35].

The implements use mainly human efforts to operate them efficiently, and they have been tested to harvest up to 200 plants per man-hour [35].

Mechanical harvesting of cassava relies on the deployment of tractor mounted equipment to harvest cassava roots. However, human efforts are still required to collect and separate the cassava tubers from the stump [36]. Other existing mechanical cassava harvesters include the Leipzig Mechanical Cassava Harvester that is capable of digging, lifting and transporting of cassava root cluster into a windrow. This has been demonstrated under a Ghanaian condition using a prototype cassava harvester developed at the Leipzig University, Germany [36]. The equipment reduces to the minimum the heavy physical work involved in manual cassava harvesting using the hoe and cutlass, especially in the dry season.

According to [36], tests to date show that several factors are critical for the successful mechanized harvesting of fully matured cassava crop. These key factors include soil penetration resistance, maintenance of tractor speed, soil moisture content, ridge height and depth of penetration of share in the soil. Other factors include configuration of roots, stem height and diameter, and planting density, etc. Other mechanical cassava harvesters include, CLAYUCA Cassava Harvester Model P600, semi-mechanized cassava harvester prototypes developed in Brazil and the NCAM Tractor-drawn Tuber Harvester developed by the National Centre for Agricultural Mechanization (NCAM) in Nigeria. Agbetoye et al. [37] reported that most of the experimental cassava harvesters in literature are based on the elevator digger principle whereby the share cuts through the soil 0.3–0.4 m deep and 0.7–0.8 m wide and handling about 0.23 m³ or about 500 kg of soil to harvest a plant. All these unique characteristics must be appropriately considered to design an efficient harvester [16, 38]. Mechanization of cassava production using tractor drawn implements successfully improved efficiency and reduced time used for land preparation from 240 to 3 man-hours; planting from 64 to 1 man-hour and harvesting from 320 to 8 man-hours in 5500 households in Nigeria, Zambia and Uganda [29].

10. Yield of cassava

Fresh root yield of cassava under farmer's condition is about 2–10 tons per hectare, but cassava may yield up to 40–60 tons per hectare where growing conditions are best. In sub-Saharan Africa, Nweke [39] found the mean root yield per hectare to be 11.89 t, with the range from 0.4 to 67.3 tonnes in 196 cassava growing communities in Cote 'd'ivore, Nigeria, Tanzania, and Uganda. Root yield in cassava is influenced by cultivar, cultural operations like weeding, fertilization, field spacing, climate, etc.

As elucidated by [40] when food and nutrition security are considered, crop yield and nutritional quality become important factors. These prompted the efforts to develop cassava as a major cash crop in sub-Saharan Africa. Cassava varieties fortified with Vitamin A have already been developed by IITA and National Root Crops Research Institute in Nigeria and are already popular in Southeastern Nigeria.

The cassava value chain in south-east Asia already produces cassava products like industrial starch, ethanol and cassava chips for livestock feed on a large scale. From that perspective,

yield still matters, but so too do others such as dry matter content for processing into starch or high-quality cassava flour. Today we plant 10,000 plants per hectare, and each plant produces 1.5–3 kg of the root or 15–30 t/ha (tonnes per hectare) of fresh root.

11. Pests and diseases

Like other crops, cassava is susceptible to pests and diseases. These pests and diseases reduce yields drastically. In some regions, pests and diseases proliferate as a result of the expansion of land under cassava cultivation and intensification of the cultivation processes [41]. More than 30 diseases of cassava have been identified. Lozano and Booth [42] listed the important bacterial diseases as Bacterial blight (*Xanthomonas campestris* pv. *Manihotis*), Bacterial angular leaf spot (*X. campestris* pv. *Cassava*), Bacterial stem gall (*Agrobacterium tumefaciens*), Bacterial stem rot (*Erwinia carotovora* subsp. *Carotovora*), Bacterial wilt (*Erwinia herbicola*). Fungal Diseases include Anthracnose (*Colletotrichum gloeosporioides*, *Colletotrichum graminicola*), Armillaria root rot (*Armillaria mellea*), Black root and stem rot (*Scytalidium* sp.), Blight leaf spot (*Cercospora vico-sae*), Brown leaf spot (*Cercosporidium henningsii*), Cassava ash (*Oidium manihotis*), Concentric ring leaf spot (*Phyllosticta manihotae* Viegas: *Phyllosticta manihotica* Syd.), Dematophora root rot (*Dematophora necatrix*), Rosellinia root rot (*Rosellinia nec*), Diplodia root and stem rot (*Diplodia manihotis* Sacc.), Fusarium root rot (*Fusarium oxysporum*; *Fusarium solani*), Phytophthora root rot (*Phytophthora cryptogea*), Pythium root rot (*Pythium* spp.), Rigidoporus root rot (*Rigidoporus microporus*), Rust (*Uromyces* spp.), Sclerotium root rot (southern blight; *Sclerotium rolfsii* Sacc.), Superelongation (*Sphaceloma manihotica*), Verticillium root and stem rot (*Verticillium dahliae* Kleb.), White leaf spot (*Phaeoramularia manihotis*). They also listed diseases caused by viruses as African cassava mosaic caused by African cassava mosaic virus, Antholysis, Cassava common mosaic caused by Cassava common mosaic virus, Cassava frogskin, Phytoreo-like virus, Cassava green mottle disease caused by Cassava green mottle virus, Cassava symptomless infections by Cassava American latent virus and Cassava Ivorian bacilliform virus. Others include Cassava vein mosaic caused by Cassava vein mosaic virus, Indian cassava mosaic by Indian cassava mosaic virus. Other miscellaneous diseases or disorders are Post-harvest root rot, Physiologic and pathogenic deteriorations, Root smallpox disease, Microbial rotting after feeding by *Cyrtomenus bergi*.

The most dangerous of them is the African mosaic disease (AMD, a virus), and cassava bacterial blight (CBB), which is caused by *Xanthomonas* spp. The mosaic virus is spread by *Bermisia* spp.; other diseases are brown streak (virus), brown leaf spot (Fungus) and Anthracnose disease. The most important control measures for AMD and CBB are to use tolerant varieties and use of disease free planting materials. Similarly, insecticides like *vetox 85* could be used to control *Bermisia* spp., which transmit AMB.

The most important insect pests are green spider mite, red spider mite, web mite, scale insects, white flies, termites and mealy bugs. They can be controlled using one or more of the following methods:

- Early planting of high yielding and early maturing varieties
- Planting of stakes by burying at a shallow depth to obtain a clean crop.

- Fertilization.
- By use of biological agents called parasitoids e.g. *Epidinocarsis lopezi* which eat up mealy bugs and mites.
- By application of insecticides, e.g., Dimethoate and methidathion.
- By removing and burning infected plant materials
- By dipping stem cuttings in Nuvacron 40 EC for about 5 min before planting.

Other pests of cassava are mammals especially rodents, goats, and monkeys.

12. Uses

Cassava is regarded as one of the principal plants of use to man because of the important part it plays as food. It is the tuberous roots that are most important as a foodstuff, but it should be noted that the leaves may also be eaten and that they possess nutritional characteristics, which are complementary to those of the roots. However, it must be noted that cassava contains a glucoside, which must be removed by processing before the product is consumed [43].

The major cassava products include:

- Dried cassava.* Tuberous roots either peeled or unpeeled are cut into chips and dried. This can be used as animal feed. When they are crushed, sieved and reduced to flour, they serve as food for man. The flour is popular in Brazil and Indonesia and can be used to make porridges, dough or bread.
- Cassava steeped in water.* Cassava peeled, or unpeeled are immersed in water, preferably slow running water for 3–5 days after which the starch is sieved out and used to prepare 'Fufu.' This is a pleasant food called *Farinha de agua* in Brazil and *Farine* in the Central African Republic. Cassava can also be made into "cassava bread" and "cassava stick."
- Grated cassava product.* Fresh tubers are peeled and grated, then left to ferment for 2–3 days, it is then dried, broken – up, sieved and fried or cooked in hot plates. This produces 'garri' (West Africa), "Farinha de Mesa" (Brazil) or 'Melange flours' (Angola). This product is attractive because it keeps for a longer period.
- Pellets.* The industrial product, which is currently most important regarding the volume of trade, is cassava pellets. The tubers, peeled or unpeeled are cut – up, using root cutters, into chips which are dried in the sun, the chips are then pelleted in the factory by compressing chips against grids with mesh to produce uniformly sized pellets.
- Starch.* This is virtually pure carbohydrate used for various purposes in food industries (sweetened products, thickeners etc.), in textile, paper, and other industries.

Cassava is also used to produce tapioca, industrial sweeteners, and alcohol.

13. Constraints to improved production of cassava

- Lack of seed material for those high-yielding varieties.
- Price changeability of fresh tubers because of the absence of a stable market—when production is low, prices are high on the other hand when production is high, prices are too low that cost of production cannot be covered.
- Budgetary constraints—Governments are unable to mobilize extension workers and to purchase processing equipment to process cassava into chips and garri.
- Lack of resources to conduct permanent research on cassava.
- Low multiplication ratio of cassava.
- Poor storability of cuttings—They do not usually keep for more than 14 days.
- Bulky planting material.
- The rapid deterioration of tubers.

14. Solutions

- Adaptation of improved methods for increased stake production.
- Development of farmer efficiency by encouraging farmers to plant high yielding and disease resistant varieties.
- Finding new uses of cassava and its products.
- Provision of better facilities for processing cassava.
- Increased extension and research work on better methods of production, utilization, multiplication, and distribution of improved planting material.

15. Conclusion

Finally, the tolerance of cassava to extreme conditions, its biological efficiency in the production of food energy, its low production resource requirements, its availability throughout the year and its suitability for farming systems will make cassava more popular to African farmers. With improved varieties, cultural practices and processing, cassava yield and product quality (gari is one of the best-processed food) could be equaled or bettered with less land and labor. For this reason, cassava has great potential as a crop of the future in Africa's struggle to attain household food sufficiency and security through increased production and utilization [44].

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