MANIHOT ESCULENTA

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Monograph

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Introduction

One of the most important food crops around the world is cassava. In continents like Africa, *manihot esculenta* plays a critical role, because many populations depend of it and use this source as a daily diet. Though, these populations also use the crop as an economic factor, for example Nigeria, which are currently the largest cassava producers in the world. However, even though Nigeria is the greatest producer right now, they still need to increase the production of cassava but for export use. In South America the crop is cultivated in many regions, but is more common to use it as an economic income rather than for feeding, that's why the situation in Africa is differently. Furtherly, in this monograph the reader would found reliable information of the crop, starting by its importance, physical characteristics, and health benefits. Then, the next chapter would provide facts about its origin, affinities, and distribution. Moving over, the following chapter would include data about how to deal with the environmental factors of cassava, such as rainfall, climate, temp regime, geology and soils. The following chapter guidance the vegetation components, and it would give specific information of the interactions the crop has with flora and fauna. After that, the next chapter would present biological facts, including pollen, pollination, sexuality, ecophysiology, and development. Afterwards, the chapter of Propagation and Management would explain methods of germination, regeneration, sowing, grafting, storage, and how to control pest and diseases. Yet, it would demonstrate why now cassava is crucial for tending. In the last two chapters, the reader would be able to understand why cassava is also important for markets and for the medicine area. In chapter 7, the reader is going to see how cassava and its products made out of it are emerging new markets. Lastly, the reader would comprehend the importance of the crop due to its medicinal value, and all the benefits *manihot esculenta* provide.

Chapter 1: Ecology

1.1. Importance

If there is a continent that depends on root and tuber crops for feeding its population, its name is Africa. The main sources of food in Africa are : yams(*Discorea sp*), sweet potatoes(*Ipomea batatas*), and Cassava(*Manihot esculenta*). For example in Ghana, the majority of families live from agricultural crops, and its seems cassava is the most favoured one for planting. By the way, yams and cassava have an important position in Ghana's economy, because they contribute around 46% of the country Gross Domestic Product(GDP). Also, between 1988 and 1990 production increased by 12.5% and since then, Nigeria became the largest cassava producer in the world. The reason why this african countries end up being dependent from root and tuber crops, is because in this case, *manihot esculenta* contains good amount of carbohydrates and a 30% of a daily calorie intake. Today, cassava roots are the main dietary source for more than 500 million people, and according to the United Nations Food and Agriculture Organization (FAO, n.d.), cassava ranks fourth as a food crop in developing countries, even after wheat and rice. Although, in several seasons in which weather normally affects plantation, with cassava the situation is different, because the crop can be reserved in the ground, and it works as a reserved food when other crops fail their production. On the other hand, *manihot esculenta* it is also important and used for industrial processes in manufacturing different products, and it is also used for animal feed.

1.2. Physical characteristics

Manihot esculenta is a perennial plant, therefore the plant grows best under fertile and well drained soils. The crop can grow up to 3-5 meters in height. Their leaves contain 3-7 lobes, which are attached to a slender stem by long petioles(FAO, n.d.). When the plant completes 8-10 months of plantation, some long roots would start to grow in a downward pattern, and they end up reaching a depth of 2-4 feet into the soil. Male and female flowers are produced on the same plant, each tuber weighs from one to several pounds depending on their type and texture. In their interior there is a kind of flesh with sweet-flavored meat, that can only be eaten after

cooking. However, the number of tuber roots differ depending on the different varieties of cassava, but they might reach a size of 30-120 cm long, 4-15 cm in diameter, and weight 1-8 kg or even more. The peel is made from an outer and an inner part, which compromises a layer of cork cells and the phellogen. The cork layer differs between 0.5 - 2% of the weight of the whole root, in which the inner part of the peel is the 8-15% of it. It's commonly that in ripe roots this is about 2-3 mm thick. Though, the cork layer needs to be removed, and the method that is commonly used by factories, is to brush water into it. The inner part of the peel has the phelloderm and the phloem, and that is what separates the peel from the body of the root.

1.3. Health benefits

Cassava has almost twice the calories than potatoes. Though, by comparing it with other tropical starch tubers and roots, it is one of the highest calorie value, because 100 g of root provides 160 calories. Their calorie value comes from sucrose, which accounts for more than 69% of the root total sugars. By the way, the roots also contain around 16-17% of amylose , which is another major carbohydrate source. Besides, it has more protein than other tropical food sources including potato, yam, and plantains. Also, one of the benefits of yuca is that it is a gluten-free starch, so it works perfectly for celiac disease patients food preparations. Perhaps, its leaves contain a good source of dietary proteins and vitamin K, and some beneficial B-complex group of vitamins like: folates, thiamin, pyridoxine (vitamin B-6), riboflavin, and pantothenic acid, and also a fair amount of potassium(271 mg per 100g or 6% of RDA)(Agricultural Research Council, n.d.).

Chapter 2: Distribution

2.1. Affinities and origin

The image that cassava represent in mythology is one of a savior which protects against starvation. There's a story from a women of a tribe in Brazil, which was devastated watching her child starve to death, while she can't do nothing. Suddenly, the child die, so she buried the body under the floor of her hut. During that night she was visited by a spirit, that named himself as "Mani", and he changed the child's cadaver into a root of a plant. That root would be later named as 'mani oca' , which means 'wood spirit root'. Native inhabitants throughout many tropical regions of the world, used for generations this plant as their base staple food. (Plotkin, 1993)
It seems that cassava was originated in Paraguay and Brazil, however, it was spread throughout South and Central America tropical regions way before Christopher Columbus arrival. Since then, *manihot esculenta*, is consider to be one of the most significant food crops for tropical countries. Today, it ranks as the 6th most important food crop worldwide(Morgenstern, n.d).

Rank
Kingdom: Plantae
Subkingdom: Viridiplantae
Super division: Embryophyta
Division: Tracheophyta
Class: Magnoliopsida
Order: Malpighiales
Family: Euphorbiaceae
Genus: *Manihot*
Species: Manioc, bitter cassava, tapioca, cassava
(ITIS, n.d.)

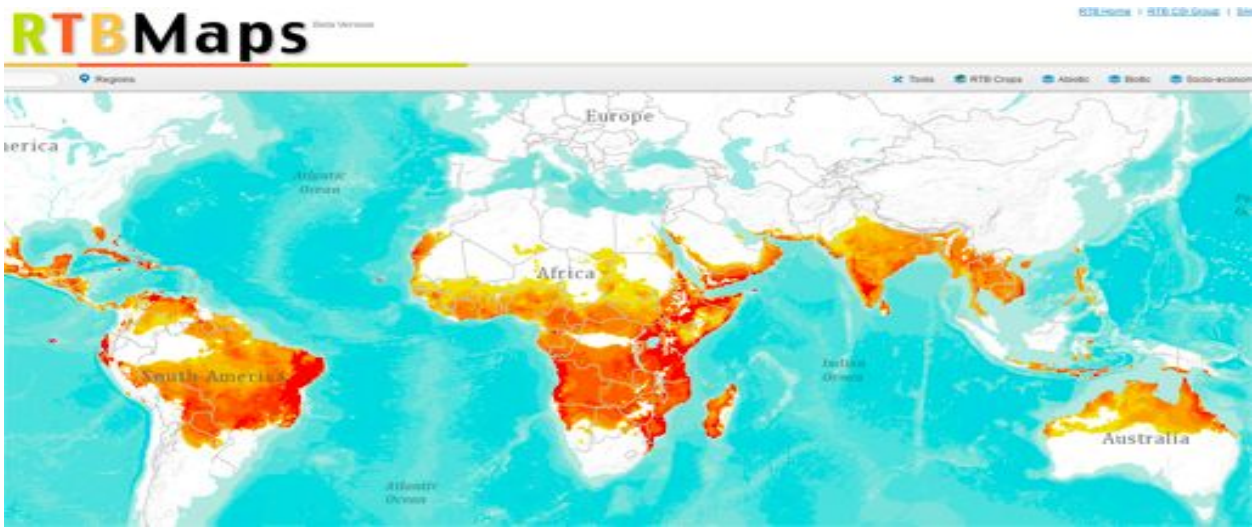

Figure 2.1. : World Map of cassava distribution

2.2. Fossil record

In fact, *manihot esculenta* was originated by its wild progenitor *Manihot esculenta ssp(Flabellifolia)*. It is mostly found in tropical lowlands located at the southern edge of the Amazon. The Amazon is the perfect place for yuca to growth, because sunlight and rainfall are abundant, and also it has some drought interval periods. Domestication was first adapted approximately 7,000 to 12,000 years ago, by some south american indigenous tribes(Duke, 1983). In order to found their maturity, diverse archaeological studies of a DNA analysis of a single locus, determine their ancient existence along with fossil records. Yet, modern cassava cultivars have similar characteristics like high content of biomass and starch yield, and also they show tolerance to barren soil and droughtiness periods.

2.3. Distribution

Mainly cultivated in tropics and subtropics of the Old and New world. The reason why there is abundance of this crop in these regions, is because its starch content is a primary source of food for natives. Many countries are creating extensive programs for raising the production of this crop, like: Jamaica, Colombia, Mexico, Brazil, Paraguay, Ghana, Madagascar, Federated

Malay States, Indonesia, India, Thailand, Philippine Islands, Sri Lanka, and Fiji. For instance, the development of this programs in India made *manihot esculenta* the second most important root crop of the country. By the way, yuca isn't found in a wild state, but there exist two centers of speciation, one in northeastern Brazil and the other one from southern Mexico to Guatemala. Besides, sweet cassavas are more extensively dispersed than bitter varieties, this is because ancient civilizations cultivated the crop 4,000 years ago in Peru and 2,000 years ago in Mexico(Duke, 1983).

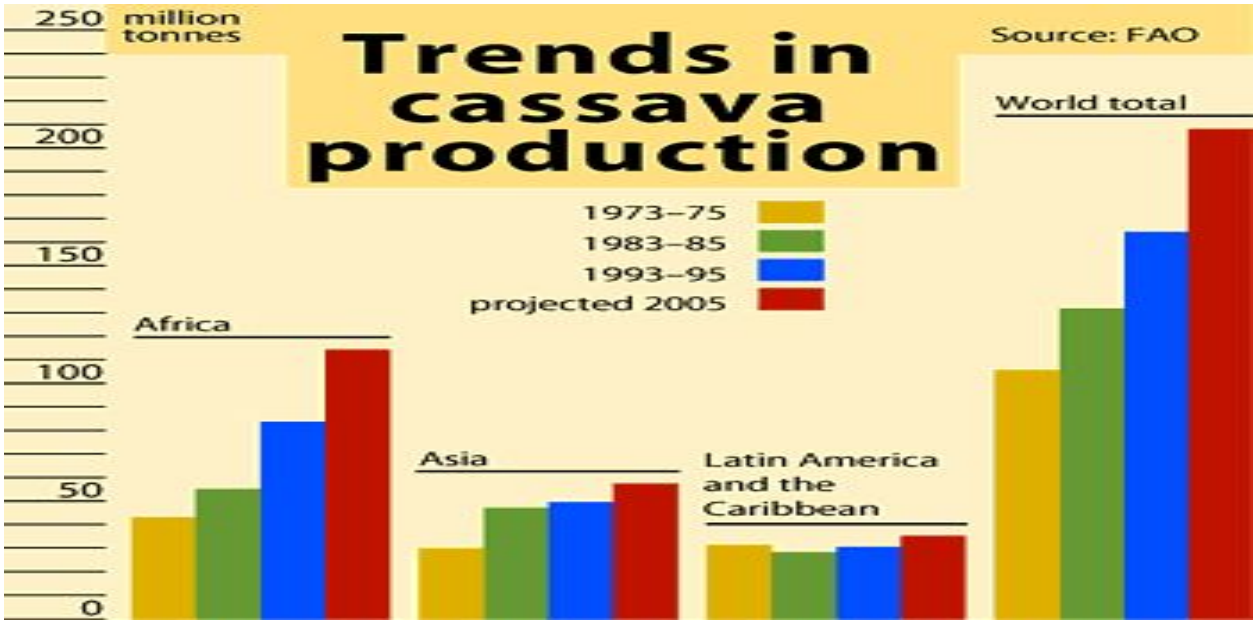

Figure 2.2. : Tends in cassava production(FAO)

2.4. Present distribution

The tubers of *manihot esculenta*, are betterly known in South America because of the starch proportion they offer, it has 10 times more starch than corn and potatoes, that's why 'yuca' is the richest source of it. Large tubers weight average is 5kg, and they supply 30% of their dry weight as starch(Wang, et al., 2014). By the way, it's very dangerous to consume the crop raw, due to its linamarin content, that ends up providing a precursor of cyanide glycosides, making the entire plant poisonous if it's raw. One of the reasons why cassava distribution is really important, is because it feeds over 700 million people in Africa (51%), Asia (29%) , and South America (20%), according to FAOSTAT(Wang, et al., 2014). Also, the distribution is so abundant, because the tubers are highly tolerant to drought periods and their storage roots can be conserved in soil for years.

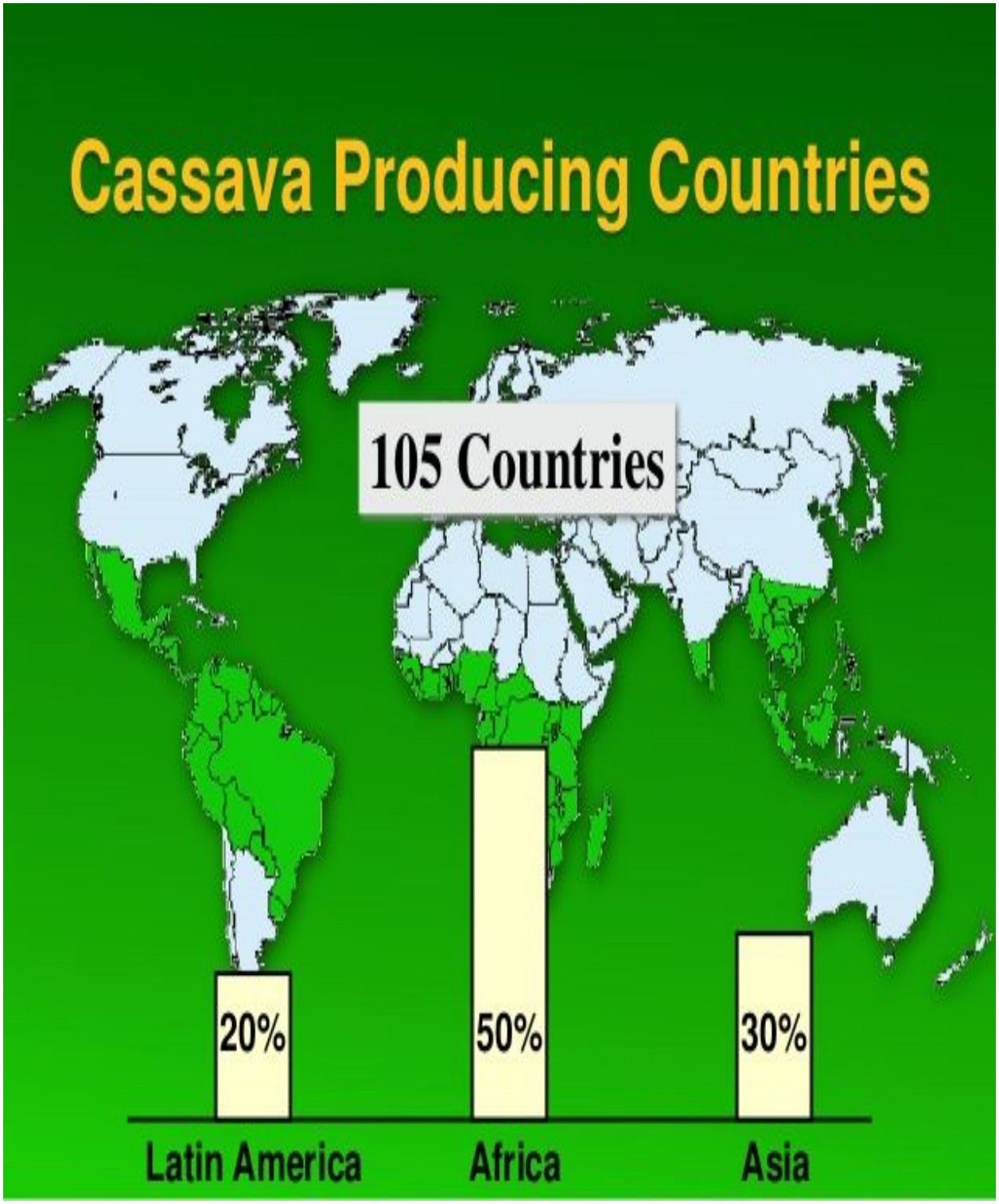

Figure 2.3. : World Map of cassava producing countries

Chapter 3: Environmental factors

3.1. Elevation

The crop is basically produced between 30º north and south latitudes, but also near the equator up to an altitude of 1800 masl. For instance, cassava is highly tolerant to droughtiness and hot temperatures, these allows the plant to have fertility in marginal areas with poor soils. *Manihot esculenta* grows best in areas with a temperature range between 25-29ºC, with a soil temperature of 30ºC. In this case, the plant would stop growing if it's exposed to a 10ºC area. However, the crop grows best in areas where the rainfall is distributed up to 1000-1500 mm, so it can be tolerant to grow under semi-arid conditions with a rainfall of 500 mm(FAO, n.d.). Therefore, cassava can adapt to diverse soils, but is best accommodated deep soils that are light-textured and well drained, except for saline and poorly drained soils. For example in Asia, most of cassava is grown on inclinations of 0-10%, but in Vietnam and southern China, the slope can be found of 15-50%. By the way, in Latin America about 417,000 hectares are found in tropical highlands, mostly in the Andean zone of Colombia, Peru, Ecuador, and Central America. In subtropical highlands, cassava is mainly found in northern Argentina, southeast Brazil, and eastern Paraguay(FAO, n.d.). One of the methods growers use to cultivate yuca in highlands, is to create terraces on slopes up to 40% or settling them on steeper slopes. Though, in southern South America the method is different. Growers often grow cassava on slopes up to 10%, but they face more probability to have a serious erosion in the soil.

3.2. Climate

Manihot esculenta is characterized for being a typical tropical plant. It best grows between boundaries from 30ºN to 30ºS latitudes. Although, most of cassava that is grown is approximately located between 20ºN and 20ºS areas. Yet, the crop requires to be in a warm and humid climate, that’s why it would stop to grow at 10ºC. This is one of the reasons why growers plant cassava in regions that are frost free the year round. Typically the crop highest tuber production can be expected in areas where the temperature average is around 25-27ºC, mostly below in a 150m altitude making tropical lowlands the perfect place for growing it(FAO, n.d.).

Even so, some varieties grow at altitudes up to 1,500m. When rainfall is constant, is when the plant produces with more abundance. In terms of rainfall, cassava can be grown where annually rainfall is as high as 5,000mm or as low as 500mm, that's why yuca is so tolerant for drought periods and so valuable for regions where seasonal distribution is irregular and rainfall is very low. However, drought periods would cease the growth, but a rainfall would immediately let resume the plant continue with its growth. Experiments had concluded that cassava needs 12 hours of light everyday, so by this the crop development wouldn't be affected.

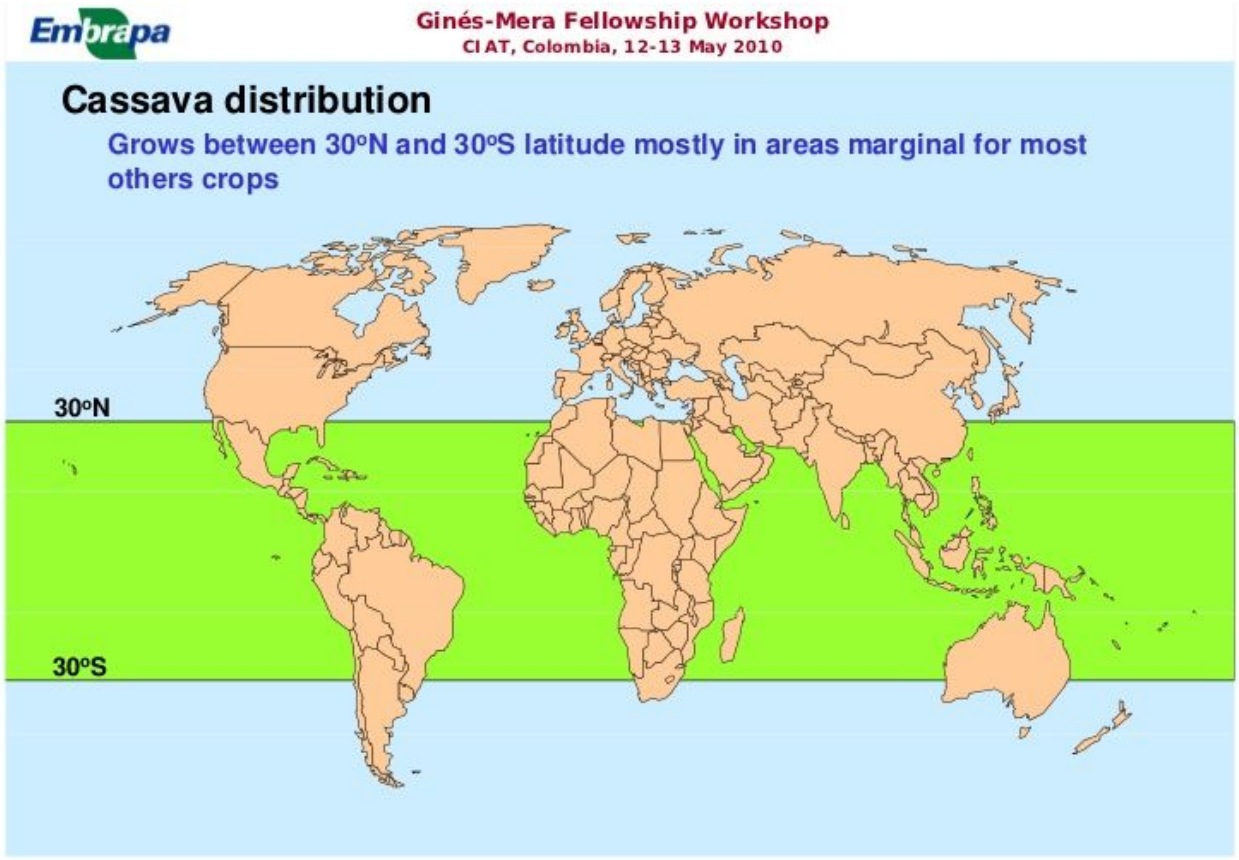

Figure 3.1. : Cassava latitude distribution(CIAT)

3.3. Rainfall

Even though cassava can resist long periods of drought, during the first three months after plantation, it is very sensible to water deficit in soil. During that early period, any water stress would affect significantly the growth of the roots, and subsequently the root storage. Once the plantation is established, yuca is able to grow in areas that annually received only 400 mm of rainfall. Different research studies in Thailand, state that maximum root yields are achieved when it correlates with a rainfall of 1,700 mm between the fourth to eleventh month after planting. In regions where there's only one rainy season per year, growers commonly plant as soon the rain starts(FAO, n.d.) . If planting season is delayed, it would lead to significant yield reductions. Although, in areas with two short rainy seasons the yuca is planted during the early or middle part of it. Then, after 10 to 14 months is harvested, farmers prefer harvesting during the dry season. In order to produce the highest yields, cassava must be planted early in the rainy season, because the plants have the appropriate soil humidity during the most severe part of their growth. Though, research show that yields may vary according to the soil, rainfall intensity, variety used, and the age of the plant while harvesting. However, planting towards the end of the rainy season ends up having less yield, but some advantages of it is that there's less competition and it could be sell for higher prices in the market.

3.4. Temp regime

Yuca is a tolerant and adaptable plant. It best grows under humid tropical conditions, and also it can resist draughts. Also, it doesn't require a lot of care, because the plant can protect itself with a poisonous latex that can be found around its leaves. Almost 30% of cassava cultivated in Latin America, is grown under subtropical conditions, while in Asia around 15% and 10% in Africa. Usually in Latin America and Africa, the crop is cultivated in highlands with fresh temperatures all year-round (22ºC), while in Asia farmers don't grow it on highlands. The dry-season length period is very similar in Africa and Latin America, with 40-45% of cassava grown in dry and humid seasonal zones, and 10-15% in semi-arid zones. Africa's semi-arid zone cultivation of cassava gathers around 20-30%, while in Asia is only 26% (FAO, n.d).

3.5. Geology and soils

When the cultivator has enough land, fertilization is not required, because cassava can be produced again on freshly cleared lands. Anyway, *manihot esculenta* such as every rapidly growing plant that produces carbohydrates, has special requirements that exhausts the soil very rapidly. When the yuca is cultivated for a long period of time in the same land, in this cases fertilization would be fundamental, because the soil would reduce its nutrients and therefore fertilizing is needed. Diverse experiments in Africa, Brazil, and India demonstrate significant increases in their roots and yields, due to the application of fertilizers. Though, starch content also boost up its content and with potassium salts they favour their growth. Yet, if the soil contains a serious amount of assimilated nitrogen, the result wouldn't be positive because root production is going to be affected, and this will only increase the vegetative growth. In general, Africa and South America adapted fertilization only for commercial plantations. On the other side, farmers in Thailand are not used to apply this technique because they found this practice too expensive for a small farmer, only a few of them consider it . In fact, most cultivators also use different types of organic matures when it comes to fertilizing process, and the most common ones are from duck and cattle.

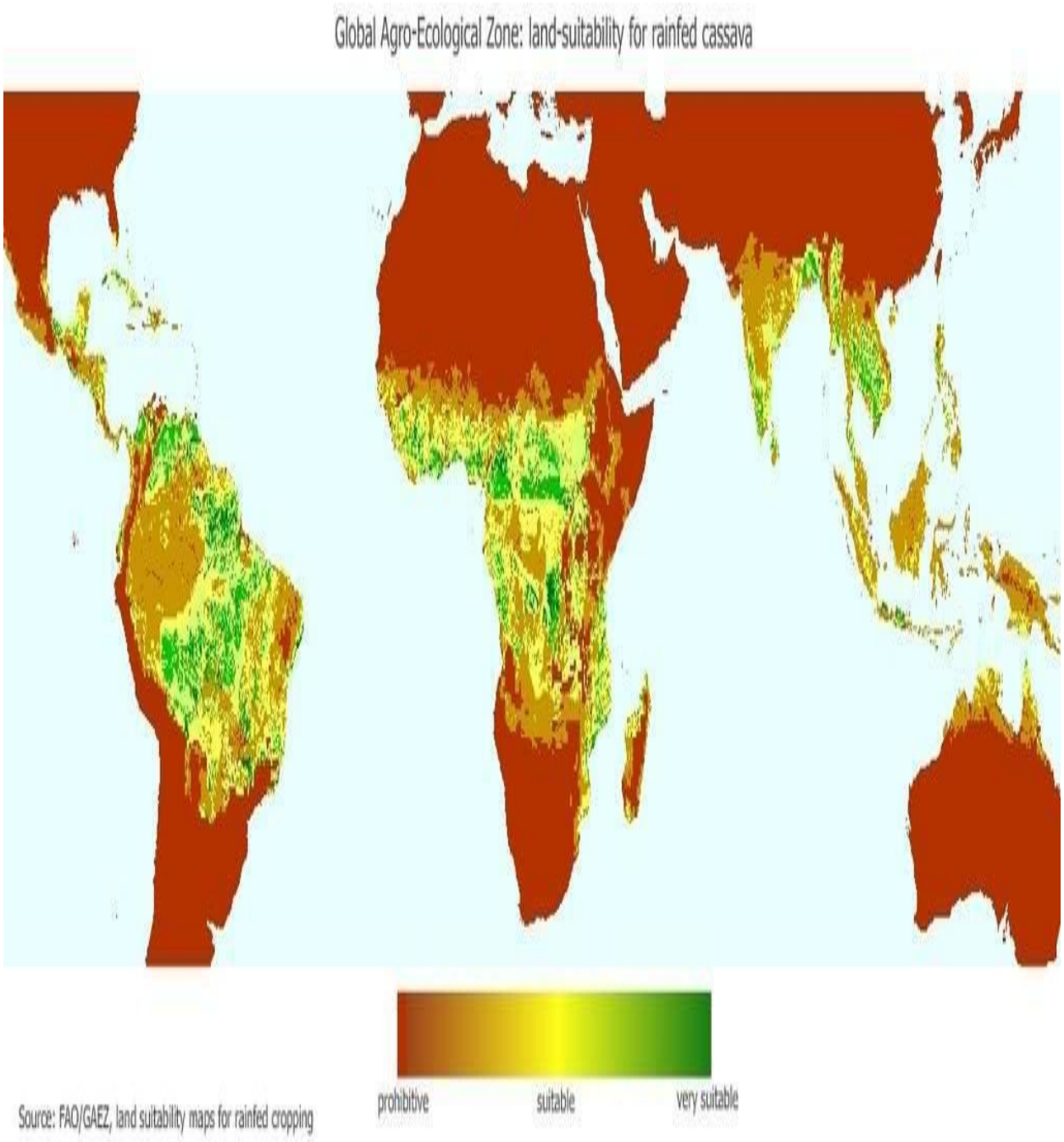

Figure 3.2. : Global Agro-Ecological Zone(land suitability for rainfed cassava) (FAO)

Chapter 4: Vegetation components

4.1. Associate species

Although yuca is a commercial crop in tropical countries, it has hundreds of varieties in existence, but just a few is known from the identification and nomenclature of them. Varieties can be distinguished by their morphological characteristics, like the color of their stems, petioles, leaves, and tubers. Usually, varieties are classified in two main categories: *Manihot palmata*(bitter) and *Manihot aipi*(sweet). Basically, the groups are created for economic convenience, due to the difficulty distinguishing them by botanical characteristics. Though, another way for differentiate them is by their hydrocyanic acid content, the one that causes toxicity in the roots.In dry conditions and poor soils, hydrocyanic acid tends to be higher. Today, all cassava varieties are considered to be varieties of *Manihot utilissima* , because in some circumstances a bitter variety may become sweet, or contrarily. Each root contain less than 50 milligrams of hydrocyanic acid per kilogram of matter. Long ago, it was thought that the toxicity of the root was associated with variety and species, until it was found that the hydrocyanic acid vary with the growing conditions of the plant. The acid content change drastically with the growing conditions of the soil, humidity, temperature, and plant age. Some varieties in Africa were found to be harmless if it's grown in Dahomey, and the opposite when it's grown in certain forest soils in Nigeria. When the bitter type crop from Jamaica was cultivated in Costa Rica the toxicity failed to produce.

4.2. Interactions and effects on soil

Yuca best grows on fertile and deep loamy sands, but it still can grow well on soils with low fertility. However, the crop is cultivated on a wide range of soils, if the soil texture is crumbly it would work. Besides, temperature is one of the most important factors, but if the soil receives a good amount of sunlight it wouldn’t have any issues. For a grower cultivating cassava ends up not being expensive, because the crop can be cultivated again on a depleted soil that was recently used. If the plant is located on rich soils, the tuber would produce stem and leaves in their roots(Wang, et al., 2014).

4.3. Relationship with animals and insects

Generally, in many regions cassava is not affected by diseases or pests. Although, in others it may be harmed by the following:

(a) Virus diseases: These viruses focus on attacking leaves, stems, and branches. Many parts of Africa promote these diseases and they are still trying to figure out a resistant variety in order to fight them.

(b) Bacterial disease: Bacteria such as *Phytomonas manihotis* (in Brazil), Bacterium cassava (in Africa) and Bacterium solanacearum (in Indonesia) would probably attack roots, stems, and leaves of the plant.

(c) Mycoses: There are different kinds. They differ from the area of the plant they attack, which in this case would be roots and stems, and they provoke diseases.

(d) Insects: Insects like: locusts, beetles and ants, affect the plant directly; while others affect the plant indirectly by the transferring a virus (aphids).

(e) Animals: Rats, goats and wild pigs are the ones that affect the plant because they feed from the roots.

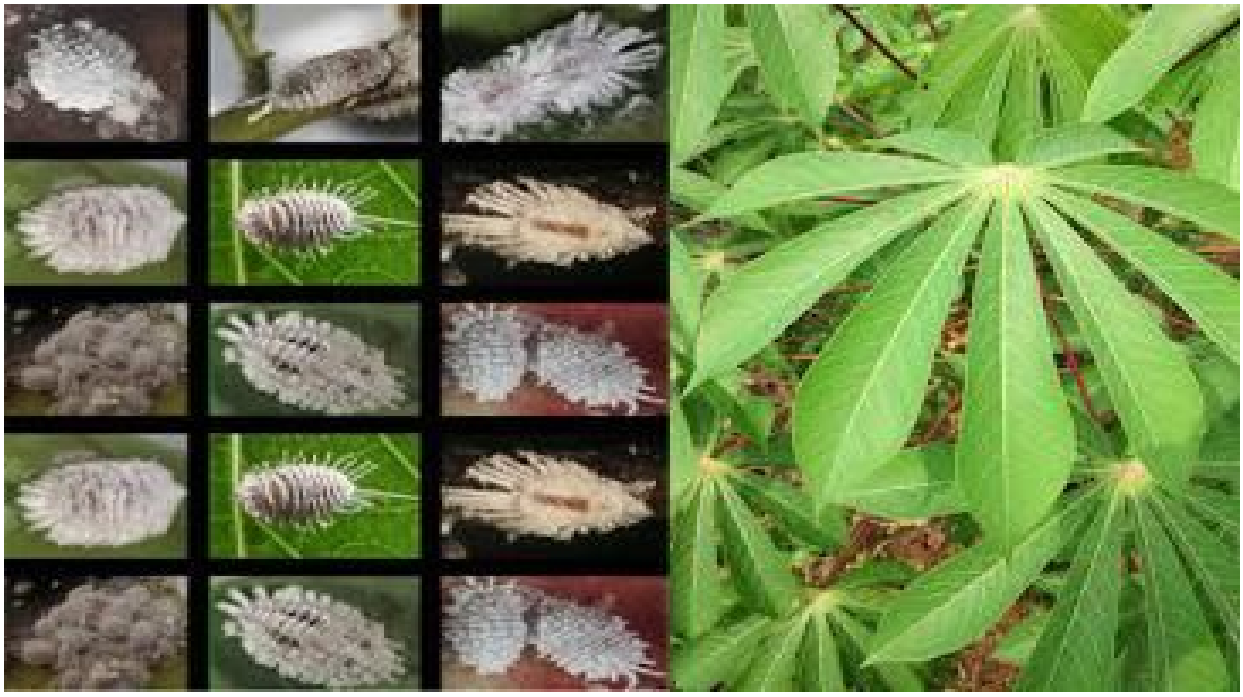

Figure 4.1. : Cassava pests

Chapter 5: Biology

5.1. Chromosome complement

All *manihot* species that have been analyzed, have 2n= 36 with very little and similar chromosomes(Jennings,1963). By comparing chromosome numbers of diverse genes of Euphorbiaceae, cassava can be consider an allotetraploid derived from the basic number of the familiy x=9(Magoon,1969). Although, there was reported an apparition of chromosomes of pachytene in different cultivars around the world, and this supports yuca's tetraploid and also suggesting that its diploid ancestors were karyotypically similar. Different species have been characterized by a great number of cytogenetic techniques, which helps detecting structural and numeric chromosomal alterations, and reconstructing the history on genetic maps(Gill, 1994). It has been possible to detect cytogenetic differences between species even with small and stable chromosomes, such as *Citrus* and *Phaseolus* (Guerra,1993). An specific study tried to "characterize the karyotype of *Manihot esculenta* and to evaluate the existence of chromosome variations among cultivars", with "thirty-nine cultivars of *M. esculenta* and eight wild species of *manihot* were analyzed with conventional staining techniques, looking at numerical or morphological chromosomal variations. In some of them, other cytological markers were investigated, namely C-band pattern, CMA/DAPI (chromomycin A and 4′,6-diamidino-2-phenyl-indole) fluorochrome bands, prophase chromosome condensation pattern, rDNA sites and the maximum number of nucleoli."

Table II - Chromosome number in wild *Manihot* species.

Species	Growth habitat	N	2n
M. handroana	Shrub	–	36
M. jolyana	Shrub	–	36
M. tripartita	Shrub	–	36
M. tripartita	Shrub	18	–
M. tweedieana	Shrub	–	36
M. humilis	Subshrub	–	36
M. pedicellaris	Shrub	–	36
M. gracilis	Subshrub	–	36
M. gracilis	Subshrub	18	–
M. dichotoma	Tree	–	36
M. glaziovii	Tree	18	–
M. glaziovii	Tree	–	36
M. anomala	Shrub	18	–
M. zehntneria	Shrub	18	–
M. oligbania	Subshrub	18	–
M. nana	Subshrub	18	–
M. tomentosa	Subshrub	18	–

Figure 5.1. : Chromosome number in wild cassava species

5.2 Life cycle and phenology

5.2.1.Selection of Cassava Plant Starts

Yuca is grown from stem cuttings. For these, the only stems used are the healthiest and pest-free. Stakes can be arranged from less than three inches, to almost a foot long. Longer stakes have more possibilities to succeed, however, the shorter length permits more stakes to be produced from the same stems. growers must have at least two leaf nodes present on each stake.

5.2.2. Planting Cassava Stakes

The cuttings are planted, usually by hand in humid soil. The orientation of the stem must be cleared, with the top of the cutting placed upward. If the soil is too flat, the stake must be laid flat and covered with an inch of soil.

5.2.3 Cultivating Cassava

In a few days, the stakes produce roots and new branches start to grow from the stem's leaf nodes. Therefore, weeding must be done for the first two to three months. Cassava is known for its hardiness in nutrient-poor, arid soils, but it's more productive in fertile ground with not much irrigation. Fertilizers need to be low in nitrogen, in order to prevent abundant leaf

growth in smaller roots.

5.2.4 Harvesting Cassava

Cassava don't have a mature stage. In this case is more consideration of the grower to harvested when the roots reach the size they wanted. Subsequently, roots are left in the ground for up to three years and they will continue to enlarge. Leaves can be harvested, as long as sufficient foliage is left in place to feed the roots. (Bryant, n.d.)

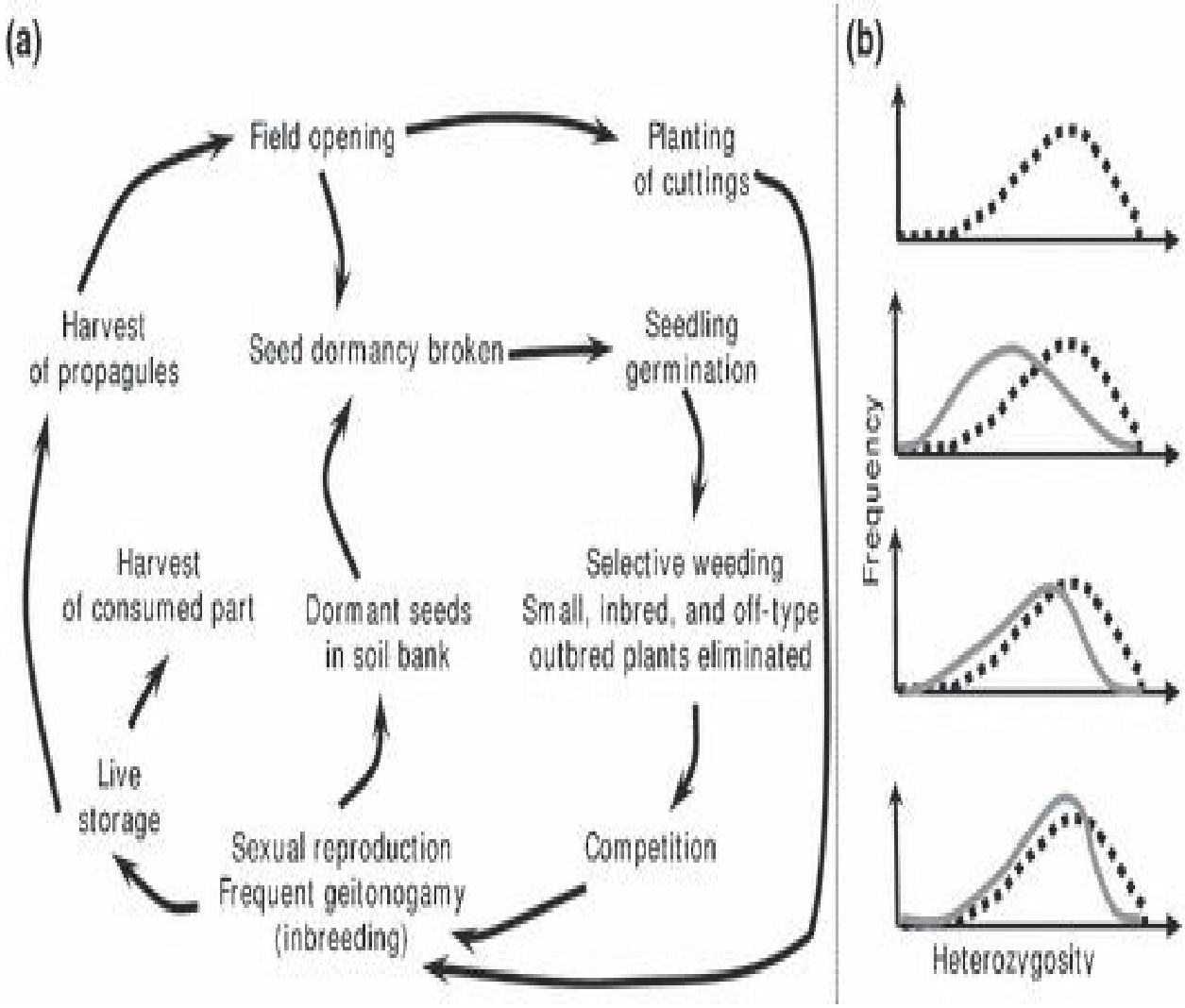

Figure 5.2. : Yuca's life cycle and frequency

5.2.5. Phenology

In Brazil, cassava is cultivated in all their states, and therefore gardeners had gathered specific information. For this study, nine cassava cultivars for industry "*(IAC 12, IAC 13, IAC 14, IAC 15, Roxinha, Fibra, Fécula Branca, Branca de Santa Catarina,* and *Espeto*) were evaluated, concerning growth and phenological attributes, as well as roots yield." The design of the experiment consist of randomized blocks with four applications. For instance, the highest cultivar was IAC 14, while IAC 15, Fécula, and Espeto were the smaller ones. Espeto and Fécula only present one stem per plant. The first one to bloom was Branca de Santa and Catarina, and by the way branching was present in all cultivars except for Fibra. IAC 14 demonstrate higher roots yield than *Branca de Santa Catarina, IAC 12, Fécula Branca, Espeto, IAC 13, and IAC 15*. " Roots dry matter for *IAC 12* was higher than for *Roxinha* and *Branca de Santa Catarina*."(Rós, Hirata, Araújo, & Narita, n.d.). The root number, individual mass, length, and diameter did not change. Results showed that those cultivars presented different type of growth, phenological features, and different root yields.

Yuca is the fourth largest source of calories in the human diet, as well as being suitable for animal feed and biofuel extraction. This experiment evaluates the performance of a thermal time (TT) model, in order to determine the phenological phases (FF) of two cassava cultivars settle in a growth cycle of 280 days, grown under field conditions in Corrientes, Argentina. During the years 2007-2009, phenological observations were done. TT calculation was based on the residual method; with a base temperature of 16°C. "Differences between cultivars were observed in the degree-days (GD) accumulated to comply the expansion of the first (00-01) and ninth leaf (00-02 H9) FF, and in the thickening of roots (00-04 ERR), the latter related to the leaf area index (IAF)." In order to complete the growth cycle of Palomita and Amarilla cultivars, it was required about 2027 to 2096 GD(Rós, Hirata, Araújo, & Narita, n.d.). The growth pattern and phenological development and growth pattern of the cultivars based on the accumulated GD, which can be used for characterizing the progress of the crop in their environment.

FENOFASE	Días cronológicos (DC)						Tiempo Térmico (TT16)					
	Cv Amarilla			Cv Palomita			Cv Amarilla			Cv Palomita		
	I	P	F	I	P	F	I	P	F	I	P	F
Plantación-00 (*)	8	9	10	10	12	13	12,15	17,1	22,4	22,4	37,5	41,7
00-01	25	26	29	14	30	39	149,6	162,6	187,5	76,5	203,2	247,3
00-02 (Hoja 2)	26	28	30	15	29	39	162,6	178,2	197,0	90,0	193,5	268,7
00-02 (Hoja 3)	27	30	32	18	30	43	171,2	197,0	211,6	113,2	203,2	314,5
00-02 (Hoja 5)	28	32	33	22	31	44	178,2	211,6	221,6	131,1	210,6	323,6
00-02 (Hoja 7)	30	34	35	24	32	47	197,0	229,1	236,5	152,7	217,0	347,7
00-02 (Hoja 9)	32	38	40	29	41	55	211,65	249,6	266,9	193,2	290,4	396,2
00-03 (Tallo1 cm)	21	28	30	15	30	39	131,7	178,2	215,3	90,0	203,2	268,7
00-03 (Tallo 2 cm)	28	33	35	18	32	36	178,2	221,6	236,5	113,2	217,0	237,7
00-04 (Diferenciación)	70	75	84	62	76	80	535,6	581,6	677	482,2	606,0	650,1
00-04 (Engrosamiento)	70	148	218	62	175	235	535,6	1333,5	1968,9	482,2	1623,4	2035,95
00-07 (Madurez)		...	±244		±240			2096,7	...	...	2027,3	...

(*) En días postplantación. (*) Days after plantation.

Figure 5.3. : Cassava phenology during the experiment

5.2.6. Flowering and fruiting

Manihot esculenta is a monoecious specie, their female flowers open 10-14 days before the male flowers on the same branch. Self-pollination may occur due to the same genotypes male and female flowers have on their branches(Jennings and Iglesias,2002). Therefore, flowering commonly depends on the environmental conditions along with the genotype. Branching happens when an inflorescence is formed. This is because "erect, non-branching types, are frequently preferred by farmers, the crossing of elite clones in certain regions may become more difficult because of the scarcity of their flowers." Yet, an issue in cassava breeding is the synchronization of flowering. "Some clones flower relatively early at 4 or 5 Months After

Planting (MAP), whereas others flower only at 8-10 MAP." The seed requires to be mature, and this process takes more than a year for obtaining seeds. Regularly, seeds have a dormancy period of a few months after reaching maturity and they need to be under high temperatures (30-35ºC) for a proper germination(Elias,2001).

Figure 5.4. : Cassava flowering

5.2.7. Year-to-year variation in flowering and fruiting

In order to discover some conditions of flowering different varieties of cassava, an experiment was made using diverse types, such as: " *TMS 30395, TMS 30001, TMS 30572, TMS 50395 and Isunikankiyan."* (Otoo,1983) Although, another factor that counts is the manipulation of day length and temperature on plants. Two photo-periodic classes were distinguished, and classified as short-day plants(SDP) and the long-day plants(LDP). Varieties that with an early flowering process belong to the SDP group, and the late ones to the LDP group. It seems that during a period of 16 hours, for SDP it tended to inhibit peduncle, flower, along with fruit and root storage development. Yet, in LDP varieties the plant height and number of branches increase drastically, therefore leaves, petioles, stem, and roots grow too. During a natural day length, peduncles are produced in SDP and LDP groups, and the female flowers, fruits, and

seeds, provide root and yield storage development which caused accumulation of starch in all of the cuttings of both groups. The ideal temperatures for promoting the initiation of flower development, is 27.29ºC during the day and 22-23º in the night. (Otoo)

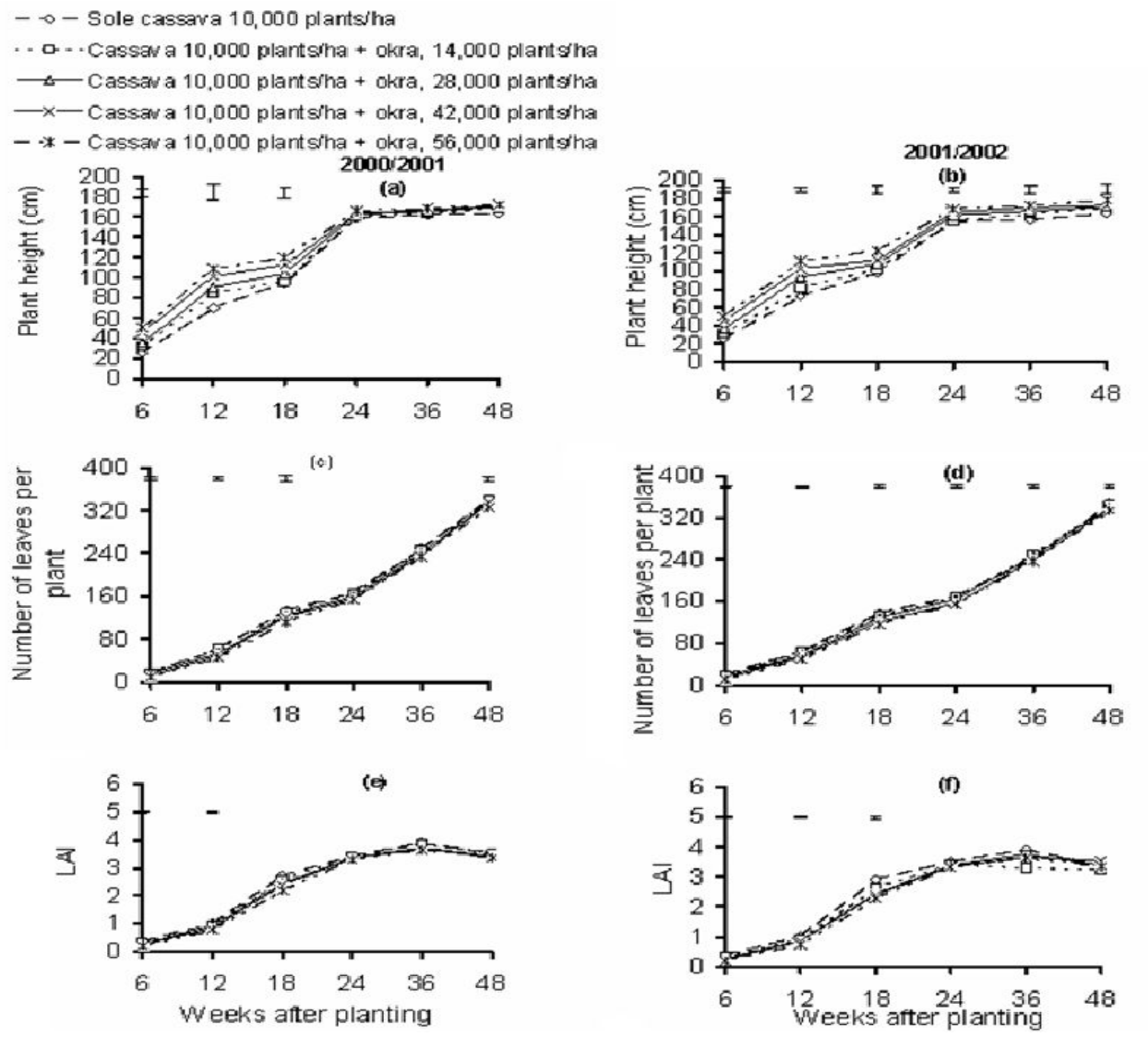

Figure 5.5. : Yuca's flowering growth

5.3. Reproductive biology

5.3.1. Pollen

Germination in vitro and in vivo, are processes that investigate cassava pollen grain growth. Some parts of vitro were able to produce germination percentages between a range of 0.4% to 5.7%, with an average of 1.2%. “The best germination of 5.7% occurred in a medium made of 150 ppm boric acid, 450 ppm calcium phosphate, 25% sucrose and 0.6% bacto-agar.””Pollen from the IITA improved clones TMS 4(2)1425, TMS 42025, TMS 58308, TMS 30555, and a wild species, *Manihot glaziovii*, were also tested in vivo. Thus, with hand crossing up to 34.5% fruit set, with an average of 2.6 seeds/fruit.”(Mbahe,1994) By comparing vitro pollen with seeds from artificial crosses by using the same pollen sample, it's reasonable to indicate that vitro germination above 1% would be acceptable for programs of growing different varieties of cassava.

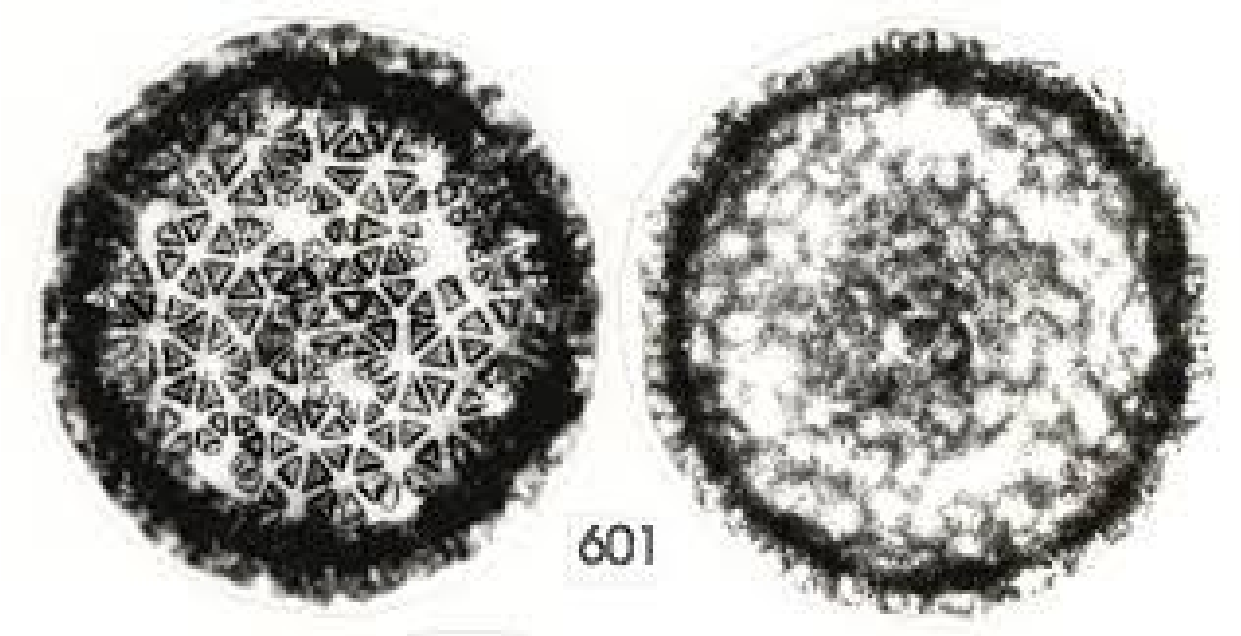

Figure 5.6. : Cassava pollen sample

5.3.2. Sexuality

Manihot esculenta is monoecious, and this is because the female flowers open 10-14 days before the males on the same branch, Although, self-fertilization can occur because male and female flowers of the same genotype open simultaneously in different branches or on different plants. The cross-pollinated seeds proportion depends on the genotype, planting design, and the insects that are present. Branching commonly occurs when the flowers bloom, but it also depends of the influence of the plant habit.

5.3.3. Anthesis

Before anthesis was present only in beans grown in monoculture, beans associated with cassava, maize, and sweet potato, showed traces of rust infection. Though, the rust was not detected in crops that involve the three components. As a result, beans grown with cassava and sweet potatoes during the anthesis, were more affected than beans grown in monoculture.

5.3.4. Pollination and potential pollinators

It is very easy to hand-pollinate cassava flowers, because large male and female flowers are separate and do not open at the same time. Even though the procedure is simple, the cost for producing large quantities of hybrid seeds is expensive. A successful pollination yields a maximum of three seeds, but this happen very rarely, but in most situations is a good average to obtain one seed per pollinated flower (Byrne,1984). However, diverse types of insects are known to reduce cassava ability for producing seeds. For example, the larvae *Teleocoma crassipes* perforate into staminate buds, and strongly decrease the amount of pollen formation.

5.3.5. Fruit development and seed set

By being mainly cultivated by stem cuttings, it would allow the accumulation of viral and bacterial diseases. In order to improve the development of the crop, growers use seed propagation, but it is still difficult to make the desired crosses. The reason why is so difficult to achieve crosses, is because the lack of flowering synchronisation between genotypes, especially in female flowers. Though, is common to found weak seed sets because of male sterility, which also leads to poor pollen viability and cross incompatibility. By comprehending the reasons why it didn't worked an specific cross, this would guide the farmer to choose the correct methods for trying to increase the possibilities for a successful cross.

Figure 5.7. : Pollination in cassava

5.3.6. Ovule and Ovary wall development

Cassava tends to be ineffective if it's compared with other crops. Therefore, the importance of doubled haploid is fundamental. Doubled haploid or DH, are plants derived from zygotic haploid cell structures. When DH is present in cassava, this would create baseline for the development of populations that depend of the crop. Also, one of the main goals is to identify high-value recessive traits, production of genetic stocks, and the management of molecular tools in breeding. Progenitors will be more efficient in their maintenance, exchange, conservation and exploitation of germplasm, which would increase genetic and molecular transformation. The

most efficient method while using DH in breeding is through anthers or microspore culture. Some analyses of cassava being cultivated in vitro, demonstrate that unpollinated ovules grow in a way simulate natural postfertilization development.

5.4. Ecophysiology

Manihot esculenta is currently one of the major food crops worldwide, because it feeds more than 500 million people in tropical and subtropical Africa, Asia, and Latin America. The starchy roots are used as a human diet, it can be eaten either fresh and low in cyanogens, or in many processed products. Although, cassava also works as flour and for animal feed. Due to its tolerance to different kinds of environments in which other crops would normally fail, for this reason cassava is considered a food-security source against hunger. Though, it only require a minimal care, and when it is under optimal environmental conditions, the yield potential tends to be much better than other staple food crops because of its production of energy.

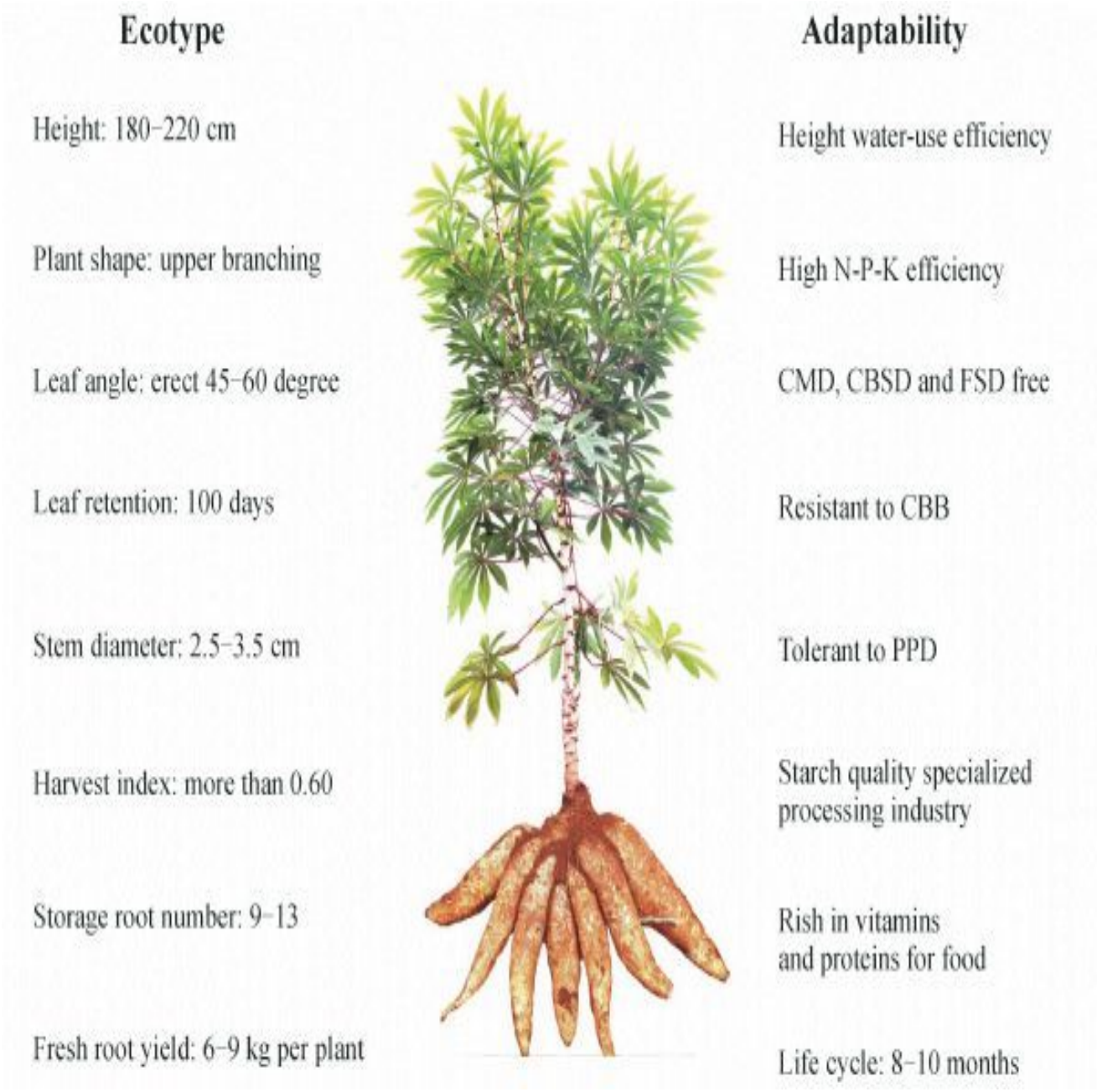

Figure 5.8. : Ecophysiology in cassava

Chapter 6: Propagation and management

6.1. Natural regeneration

6.1.1. When to regenerate?

Depending on the environmental conditions and the genotype, *manihot esculenta's* growing cycle is between 9 and 24 months. The ideal moment for the crop to regenerate is when their growth cycle is completed, this is around 18-24 months. By regenerating, the crop would avoid excessive growth and would be free of building up pest and diseases.

6.1.2. Method of regeneration

This method is based on: planting layout, density, and distance. The layout size and spacing would determine the purpose of the plantation. In order to do it correctly the following steps must be followed:

- Group germplasm: Establish three groups: high, intermediate, and low. Also, separate them by their height and branching habits.
- Distance: To avoid mixing up planting, separate the groups within a distance of 2.2m, 1.5m, and 1m.
- Space between plants: If the plantation consist for evaluating the plants, the space require between them would be from 1.0-1.5m. However, the space would be less if the plantation consist for germplasm maintenance, the space dividing them would be of "0.75–1.0 m within the row and 1.0 m between rows) to minimize weed growth and land requirements."
- Keep: Is important to keep 5-10 plants per accession that are in good conditions, this would help by supplying planting material to the ones that have weak genotypes. (Minyantorini, n.d.)

6.2. Nursery Propagation

6.2.1. Pre-preparation and implications for germinations

- Identified stakes from healthy plants earlier in the season, just before leaves start to drop off, because this is when pest and disease mostly appear. Checking the roots for pest and diseases symptoms is essential before consuming it.
- Preparation of stakes: First, select the portion of the stem that looks more mature, then, cut the top green stems and also the bottom section of the plant.
- Cut: Stakes must be at least 20 cm long and they need to have 4-5 nodes, the nodes would let the stakes to be cut at a right angle. By the way, it is not recommendable to cut the stems in a hard surface, because this can damage the nodes and it would provide entry points for pests.
- After cutting: Make sure to put in each package the number and day of harvest. Then, apply a mixture of insecticide and fungicide in the stakes. After that, add zinc sulphate in the soil, in the regions where zinc is not abundant. Make sure to avoid mixing the genotypes and handle the stems with care to prevent bruising. (Minyantorini, n.d.)

6.2.2. Sowing and the germination process

Two factors are really important when it comes to the growing cycle of the cassava, which is a tropical climate and at least 8 months of warm weather. Even though the crop grows best under well drained soils, it still can survive in wet soils with low rainfall. The roots grows appropriately under a full sun, in fact they don't tolerate freezing temperatures. Growing process from the beginning to harvest, normally is a period of 18 months. " The plants are started from propagules made from parts of mature stems. These are 2 to 3 inch cuttings with several bud nodes along the length."(Grant,2016) Cassava plants can produce big ornamental leaves. For example, in America, these leaves can be develop in the summer in most parts of the United States. In warmer temperature, it will promote the most rapid growth. For a good plant care, the use of fertilizer in spring needs to be done, and keep the plants moderately humid. When winter arrives, replant the plant into a pot and move it indoors before freezing temperatures affects the

growth, but transplanted once the sun heats back up.

6.2.3. Storage

Modern methods for cassava storage, are based on: chemical storage protection, refrigeration, and waxing of the roots. Reduced temperatures, let root storage ability to be extended. Experiments have demonstrated that the best temperature for fresh cassava to be stored is 3ºC. By keeping the root at this temperature, the total loss after 14 days ascend to 14% and 23% after 4 weeks(Knoth, n.d.). A bluish mould would appear on the surface of the root, if the roots are stored at high temperatures, which turns the flesh to be brownish, causing quality loss. Another method is to packed the roots into plastic bags and frozen them. The texture of the tissue would be soft, but the flavour would maintain the same. Also, the roots are only edible for 4 days after defrosting. This preservation method is commonly used in some Latin American countries. However, in India, for the first time they used the preserving method of coating the roots in wax, and this wax contains a special type of fungicide. They discover that with this method they could extend the storage duration for 10 days. Although, in Colombia they used a method that consist of dipped the roots into paraffin at a temperature of 90º-95ºC. Without fungicide, the storage could be extended to a period of 1-2 months.

6.2.4. Vegetative propagation

Manihot esculenta is propagated by cuttings and by planting pieces of stem. Roots are only used once, they are not used for making new plantations, this is why all the harvest is consumed or sold. For the cuttings, select stems 2 to 4 cm thick, and pick the ones that are the strongest and don't present disease symptoms. The stems that were selected must be tied up after the harvest. Also, is better to wait at least 10 days before planting them. Is important to keep the packages in a dry and cool place until planting time. And keep in my that the cuttings must be from stems that are ready to be planted. Each stem, needs to be cut into pieces of 20 to 30 cm long, which allows each stem to made 4 or 5 cuttings.

6.2.2.1. Grafting

Figure A: Step 1 in grafting of cassava. The bud is removed from the stem portion after 6-8 weeks old, a change in the tissue would appear.

Figure B: Step 2 in grafting of cassava. “Bud excised from non-lignified portion of virus infected plants with petiole attached is inserted into rootstock test plant.”

Figure C: Step 3 in grafting of cassava. With parafilm, the bud graft is secured.

Figure D:Step 4 in grafting of cassava. After one week of graft initiation, the buds must look healthy and “attached to rootstock with visible callus formation.”

Figure E: Step 5 in grafting of cassava. Results of a whole plant after successfully completing bud grafting. (Wagaba,2013)

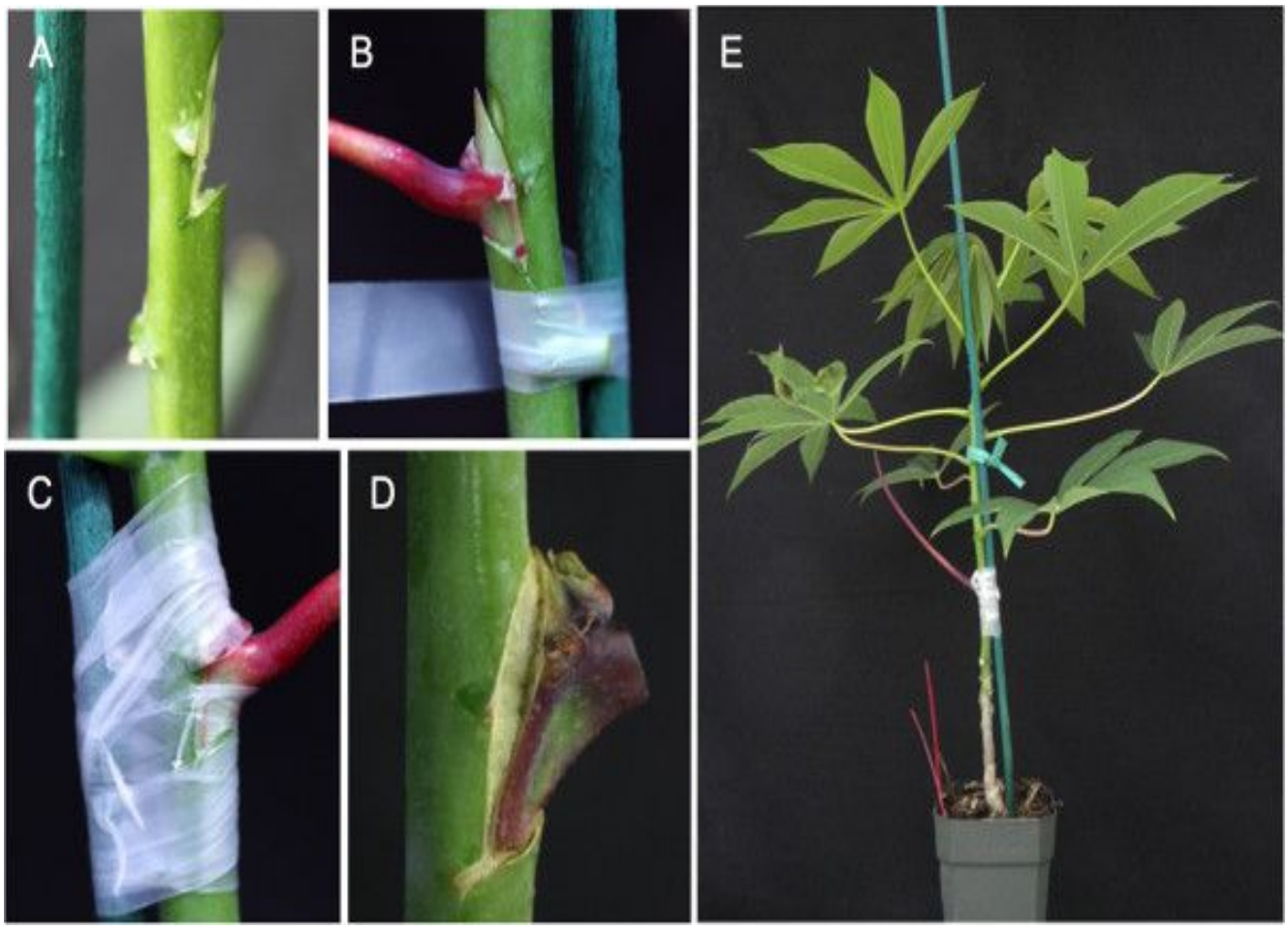

Figure 6.1. : Cassava grafting process

6.2.2.2. Cuttings

Manihot esculenta is a perennial. And cassava cutting is: “150mm to 200mm (6 to 8 inches) with 2/3’s in the ground and 1/3 out.” For example, in the subtropics in 9 months the crop would grow over 2 meters. When branches start to grow, the water demand would be less, but still it would need a well drained soil.

Figure 6.2. : Root starting to grow

Figure 6.3. : Starchy roots spread in the soil and have low fertility demand

Figure 6.4. : Crop planted in the subtropic. 8 months and produced “5.3 kilos (11lb 7oz) of root food”

Figure 6.5. : Cassava has an outer cortex, which is the outer layer of the root, and it can be easily peeled. Though, what needs to be cooked is the inner part of the root. (Lawton, 2014)

6.3. Planting

6.3.1. Planting method

First, put the stakes in a way they are half or two-thirds inside the soil. However, it depends of the slope to put the stakes vertically or horizontally. If is horizontal, the stakes must be bury about 5cm below the soil. Then, tag each plant that is on the left hand row of the field, and then draw a map of the planting that would let identify where the accession is. In addition, one month after planting is recommendable to replant missing plants(Lawton, 2014).

6.3.2. Field selection & preparation

Terraces must be light textured and the soil needs to be well drained and free from noxious weeds. It is important to avoid saturated, clay, and stony soils. Cassava functions in

different types of soils, however, it is important to make sure that in sandy soils by adding a short amount of tillage would help to conserve organic matter, soil, and moisture, also, this would reduce soil erosion. In hard soils, for a better establishment of the plant, the best method is to increase the volume of the soil per plant. If the soil is poorly drained, making ridges would help to reduce waterlogging. Every six months, is important to allow an overlapping period, because this would let the plants that did not germinate to be replanted. Though, plants that are replanted still provide material, but this material is used more for scientific research than consuming. Finally, secured the field from animals that can damage the planting(Lawton, 2014).

6.4. Management

6.4.1. Tending

For decades, farmers in Eastern and Southern Africa have dedicated to live and economically depend from cassava. Although,they have to deal with the outbreaks caused by the brown streak disease, and also with the cassava mosaic virus which is spread by the white flies, and these losses affect the regions that lack from food. Due to the lack of food in the region, agriculturalists and governments use cassava as an answer to fight hunger. In order to fight hunger, a multi million project is created. The initiative took four years, and it was funded by the Common Fund for Commodities(CFC), carry out by the International Institute of Tropical Agriculture(IITA), with the purpose to raise the crop as a "profitable and sustainable source of income for resource-poor farmers in the region." Furthermore, the Sh350 million($4.5 million) project was develop for promoting the production, use, and marketing of High Quality Cassava Flour(HQCF) that is achieved from fresh cassava roots. Though, the project was officially launched on February 2, in Lusaka, Zambia. It covers the regions of Zambia, Madagascar, and Tanzania. Also, the project will be under the supervision of the United Nations Food and Agriculture Organisation(FAO). According to Dr. Abass Adebayo, the project's regional coordinator and IITA specialist in cassava value chain, said that the project will work with 9,000 farmers and processors, that would produce and sell HQCG in the three countries. There's going to be a two-step processing of the crop. First, processors will buy fresh cassava roots from farmers, and they need to extract water in order to form semi-dry seeds. Then, other processors will make the next step which consist of drying and grinding for creating the HQCF. However, an issue with cassava is that the crop rots very fast, so in this case the dry seeds reduce weight by half, and allow the crop to have a longer life. One of the main goals of the project, is to set up in

the three countries a supply of cassava chain. Each chain will incorporate 3,000 farmers, four processors of dry seeds, and one final stage processor of HQCF. They hope that by showing profitability with cassava processing, other people establish more supply chains. By having 3,000 farmers working in groups, each year they are expected to supply at least 3,000 tones of fresh cassava. A farmer is in charge for working a hectare, so this led to an average yield of 10 tonnes per hectare. By the way, the three countries level of production were below Africa's and the world's average. Therefore, the project double the production by training better the farmers with agricultural practices. Dr. Adebayo said that "if the technology to produce HQCF was available then and it substituted only 10 per cent of the wheat exports, $23 million would have been saved in foreign exchange, this would have been redistributed to the smallholder farmers, processors and other players in the supply chain. And, it would have made a significant contributing to poverty reduction in the rural areas." In Kenya, products that are based on maize, only produce an estimate over 12,000 metric tonnes per year, that's why cassava can be a solution by making stronger the country's economy and fighting hunger. When the project was launch, the Director of Zambia Agricultural Research Institute(ZARI), Dr. Watson Mwale "said the four-year project was a build up of a successfully concluded Phase I which, demonstrated that of all the products derived from HQCF held great potential to generate income and create wealth." Since then, the CFC project manager, Nicolaus Cromme, claim in their interest of attracting the private sector with the project, and once the private sector is in, they are in charge for the commercial production of HQCF and make the product sustainable, competitive, and beneficial for the farmers in need. Some companies that have invested for HQCF, were satisfied because their costs reduce and the quality of their products maintain the same. The manager of Biscuiterie JB, Ralaivoa Solange, a biscuit factory in Madagascar said that they used HQCF to make wafers and biscuits, and the result was convenient because consumers like it and the company was saving money. In fact, the HQCF supplied was by using the sun-drying method.(Công ty TNHH Giải Pháp Tin Học NON Việt Nam)

6.4.2. Pest and disease control

Diversity of pests in America is greatest than in Africa and Asia. In Africa, the natural predators of the pests are scarce, so the lack of these predators let pests invade the plantings. In areas with low rainfall, the damage would be done in the dry season by the green mite(*Mononychellus tanajoa*) and the mealybug(*Phenococcus manihoti and P. Herreni*). In America, the major problem is "whiteflies (*Aleurotrachelus socialis and A. aepim*), hornworm (*Erinnyis ello*), stemborers (*Chilomina clarkei*), burrower bugs (*Sternocoelus manihoti and Tropidozineus fulveolus*), thrips (*Frankliniella williamsi*) and lacebugs (*Vatiga manihoti, V. illudens and Amblydtira machalana*)." However, America also deals with "while scales (*Aonidomytilus albus*), termites and grasshoppers", but these pest are more easy to handle.

Diseases that are mainly found in cassava in Africa, are caused by the african cassava virus(ACMV) and the cassava brown streak virus(CBSV). In South America, diseases are caused by “the cassava common mosaic virus (CsCMV) and by the cassava frogskin virus (CFSV).”(Minyantorini, n.d.) Other diseases that can be found are the cassava bacterial blight(CBB) and the cassava anthracnose.

- Planting material must be healthy
- Avoid taking cuttings from plants that contain “leaf chlorosis, shoot tip die-back, cankers, fungus patches or streaks on the stems.”
- Before planting and during certain periods of growth, apply to the cutting pesticides and fungicides.
- During the growth season, take out diseased plants.
- When the harvesting period is over, destroy stems and roots that seem to have disease and pest contamination symptoms.
- Natural predators work better and healthier against the pests, pesticide only need to be added when necessary.

Chapter 7: EMERGING PRODUCTS, POTENTIAL MARKETS

7.1. The overall picture

7.2. Flavour

Manihot esculenta contain cyanogenic glucosides. For example, in Thailand, farmers usually classify cultivars in two groups, but because is dangerous to eat the crop raw, they associated it with bitterness after it's processed. Though, growers that produce roots with bitter taste are called vyakubaba, and the ones who cultivate non-bitter roots are called vyakuzizra. In fact, in scientific literature they are classified as ‘bitter’ or ‘sweet’. The roots from ‘bitter’ are mainly processed prior to consumption. Cassava has a creamy taste, and its texture allows to have a similar flavour such as potato and sweet potato. Also, it might be bland, so that’s why it's recommended to add some sauce on it. However, the cyanogenic glucoside content level would determine if the plant is sweeter or bitter among the roots(Lixandru, 2015). Furthermore, climatic

conditions also can affect the taste of the crop, but normally it would has like the consistency of potatoes.(Team,2016).

7.3. Food items based on pulp, skin, and juice

In Africa, cassava is a versatile root crop for consuming, and is one of the most consumed crops in the continent. That's why yuca has become very important for the food industry, because they are currently using it as a material to produce biofuels and starch, which benefits paper and pharmaceutical industries. Although, cassava most popular processes are the following:

- Cassava bread: For indigenous tribes, cassava bread is a complement of their daily diet. They consume it because they said it would keep way 'new world' diseases, such as: high blood pressure, diabetes, heart diseases, and obesity. Also, when its dried in the proper manner, the bread can last for months. However, its shape swells because of the digestive juices it contains. Though, the flavour is better if it's properly dried as a biscuit and also consumed a day after baking.

- Cassava flour: The best quality of cassava flour is made within a day of harvesting. In effect, it's very white, and it has low fat content, but it's not as sour as cassava fermented flour. By the way, it does not provoke bad smells in any food product, and it also can be used for making bread and cakes by mixturing with wheat flour. However, this type of flour would be very useful for people that are looking for flour that is gluten free. In fact, bread that it's made from cassava flour, is a great beverage for people with celiac diseases. Likewise, yuca's bread is also recommended for people who suffer from obesity and diabetes.

- Cassava Fufu: In Nigeria, cassava fufu is considered to be the traditional meal of the region. For example in Igboland, the fufu is eaten along with traditional nigerian soups like bitterleaf and ora soups. (Wonderiyke, 2016)

7.3.1. Fresh fruit

In order to keep it fresh, the best method would be waxing coating. For keeping it fresh and prevent weight loss, wax would cover the outer layer of the cassava. This method allows the yuca yo remain fresh during a long period of time, and it helps by not letting lose it's humidity, which would be the consequence for decreasing weight. Yet, the method also reduce the

possibility of putrefaction during transportation and storing , and it makes the fruit color and texture to be more original.

7.3.2. Confectionary

The use of dextrose and glucose syrup as sweetening components in confectioneries is destined to produce certain types of candy such as jellybeans, hard and soft gums, hard candy, and boiled sweets. Now, is very popular for industries to use starch components for producing candy and also is use to prevent the mixture of sweets for sticking together. It seems that this industry's purpose is to replace sucrose for dextrose or glucose syrup, because it conserves the solid taste without giving it an excessive sweetness. (FAO, n.d.)

7.3.3. Juice, nectar, puree and flavoured products

Cassava is basically made into fermented and unfermented products. In the group of fermented products it would be: cassava bread, fermented cassava flour, fermented starch, fufu, lafun, akyeke, agbelima, and gari, and in the unfermented products it will be: tapioca, cassava chips and pellets, unfermented cassava flour and starch. Modern uses of the cassava would be the new gluten free and flour products. For example, the pearl milk tea or bubble tea, has became really popular in the last years. The reason why the tea is a tendency, is because it has chewy “pearls” at the bottom of the cup. These pearls has the shape of a marble, and are made out from tapioca, which is a starch extracted from the cassava root. Industrial operations along with modern scientific knowledge, have adapted the different methods cassava needs to pass through before consumption, because consumers demand quality and healthy product, that’s why yuca has root yield, spoilage, cyanide content, nutrient content processes(Fern,2017).

Figure 7.1. : Bubble tea

7.3.4. Alcoholic beverages

For the production of alcohol, cassava is one of the richest substances for its development. The fresh roots contain approximately 30% of starch, 5% of sugars, and a 80% of fermentable substances, which makes it a source of alcohol. When it comes to ethyl alcohol, for example in Malaysia, many factories use cassava as a subproduct of the sugar industry(FAO, n.d.) . Yeast fermentation is allowed to three to four days, when the pH value is adjusted by using sodium carbonate, within a properly temperature for the production of alcohol. Then, alcohol is separated by distillation. Raw cassava alcohol would be classified as average quality, because it smells very bad. However, the smell can be improved by distillation process. Although, it is mainly used for industrial purposes, like in pharmaceutical products, cosmetics, and solvents. But when is for human consumption, the roots should first pass through a process in order to eliminate hydrocyanic acid.

7.4. Items based on kernels

7.4.1. Oil

Despite the diverse uses of cassava, very little is known from the properties and potential of their seeds, which can be used as oil. One of the common methods is the mechanical expeller method, that is a press method with solvent extraction, and it allows oil to be extracted from dried seeds. Though, “Cassava seed oil is pale yellow in colour, odourless, tasteless, liquid at room.” (Lu, Zhai, Liu, & Wu, 1970)

Chapter 8: MEDICINAL AND TRADITIONAL NON-WOOD USES

8.1. Medicinal uses

Cassava contains a great amount of vitamin B and C, calcium, carbohydrates, and minerals. Also, is loaded with vitamins like thiamin, folates, riboflavin, vitamin B6, and pantothenic acid. The following are some medical properties found in cassava:

1. Promotes skin health

Vitamin C would help to lower skin dryness, appearance of wrinkles, and also it would assist to slow down the aging process. By the way, vitamin C is fundamental for the formation of tendons, blood vessels, ligaments, and skin. Some studies evidence that special skin creams with vitamin C reduces wrinkles, redness, and scars in the skin.

2. Assist treatment of cancer

If the drugs that are used in chemotherapy to fight cancer are developed with vitamin C, the effect would be more efficient and stronger. This is because vitamin C only target cells that require nutrients, while these drugs target also normal cells, and this cells can be damaged due to the medicine effect. For researchers, vitamin C is the most effective treatment against lung and ovarian cancer.

3. Repairs damage

Vitamin C has the capacity of preventing damage that is caused by pollutants, free radicals, and toxic chemicals. If free radicals accumulate, this would lead up to health ailments such as heart disease, arthritis, and cancer. Free radicals are build up during the breakdown of food process, or by being exposed to tobacco, smoke, and radiation.

4. Prevent osteoporosis

For older women that are likely to have weak bones and bone fractures, the combination of calcium, manganese, copper, and zinc, helps them to prevent that kind of injuries. The lack of manganese leads to bone ailments, because the manganese improves the bone metabolism by supporting the formation of enzymes and hormones. Researchers discovered that a good treatment to prevent osteoporosis is the intake of manganese with zinc, calcium, vitamin D, boron, magnesium, and copper, because this combination creates bone mass.

5. Assist respiratory health

Manganese has the ability to reduce inflammation and oxidative stress. If manganese if combine with minerals such as selenium and zinc, this would be beneficial for treating chronic pulmonary diseases that are caused by smoking.

6. Lower symptoms of PMS

The consumption of manganese with calcium helps to recover from symptoms such as anxiety, muscle pain, insomnia, tenderness, and mood changes. Also, for women that report low level of manganese in the blood, is normal for them to experience mood swings and more pain during pre-menstruation.

7. Brain health

Copper is very effective for brain pathways like galactose and dopamine. Pathways such as galactose and dopamine are in charge of maintaining the focus and mood. The lack of copper would be demonstrated through fatigue, bad mood, metabolic activity, and concentration problems. Yet, copper use antioxidants to prevent brain damage by free radicals. Another thing copper is very useful for, is by slowing down the aging process, which is normally responsible for cancer and neuro-degenerative disease. The antioxidants that helps copper are superoxide, vitamin C, ascorbate oxidase, dismutase, and tyrosinase.

8. Reduce arthritis

Copper strengthens the muscles by containing anti-inflammatory properties, which helps to relief pain related to arthritis, and repair connective tissue.

9. Enhance immunity

Vitamin B1, is fundamental in the process of hydrochloric acid secretion which is needed

for digestion and nutrient absorption of food. It also helps to keep the muscle tone on the digestive tract walls. A healthy digestive tract would be very effective because it completely absorbs all the nutrients of the food and prevent the body from diseases.

10. Vision health

Glaucoma and cataracts could be treated with vitamin B1, and this is because this vitamin has the ability to influence the signals between the muscles and nerves, which are crucial for transmitting information to the brain from the eyes. (Sylvia, 2016)

Nutritional value of Cassava

Serving Size: 100 g

Calories 160 Kcal. **Calories from Fat** 2.52 Kcal.

Proximity	Amount	% DV
Water	59.68 g	N/D
Energy	160 Kcal	N/D
Energy	667 kJ	N/D
Protein	1.36 g	2.72%
Total Fat (lipid)	0.28 g	0.80%
Ash	0.62 g	N/D
Carbohydrate	38.06 g	29.28%
Total dietary Fiber	1.8 g	4.74%
Total Sugars	1.7 g	N/D

Minerals	Amount	% DV
Calcium, Ca	16 mg	1.60%
Iron, Fe	0.27 mg	3.38%
Magnesium, Mg	21 mg	5.00%
Phosphorus, P	27 mg	3.86%
Potassium, K	271 mg	5.77%
Sodium, Na	14 mg	0.93%
Zinc, Zn	0.34 mg	3.09%
Copper, Cu	0.1 mg	11.11%
Manganese, Mn	0.384 mg	16.70%
Selenium, Se	0.7 µg	1.27%

Figure 8.1. : Nutritional value of Cassava

Vitamins	Amount	% DV
Vitamin C (Ascorbic acid)	20.6 mg	22.89%
Vitamin B1 (Thiamin)	0.087 mg	7.25%
Vitamin B2 (Riboflavin)	0.048 mg	3.69%
Vitamin B3 (Niacin)	0.854 mg	5.34%
Vitamin B5 (Pantothenic acid)	0.107 mg	2.14%
Vitamin B6 (Pyridoxine)	0.088 mg	6.77%
Vitamin B9 (Folate, Folic acid)	27 µg	6.75%
Choline	23.7 mg	4.31%
Vitamin A	1 µg	0.14%
Vitamin A, IU	13 IU	N/D
Betaine	0.4 mg	N/D
Vitamin E (alpha-tocopherol)	0.19 mg	1.27%
Vitamin K (phylloquinone)	1.9 µg	1.58%

Lipids	Amount	% DV
Fatty acids, total saturated	0.074 g	0.11%
Lauric acid (dodecanoic acid) 12:00	0.001 g	N/D
Palmitic acid 16:00 (Hexadecanoic acid)	0.069 g	N/D
Stearic acid 18:00 (Octadecanoic acid)	0.005 g	N/D
Fatty acids, total monounsaturated		
Oleic acid 18:1 (octadecenoic acid)	0.075 g	N/D
Fatty acids, total polyunsaturated	0.048 g	0.28%
Linoleic acid 18:2 (octadecadienoic acid)	0.032 g	N/D
Linolenic acid 18:3 (Octadecatrienoic acid)	0.017 g	N/D

Figure 8.2. : Nutritional value of Cassava

Amino Acids	Amount	% DV
Tryptophan	0.019 g	4.32%
Threonine	0.028 g	1.59%
Isoleucine	0.027 g	1.61%
Leucine	0.039 g	1.06%
Lysine	0.044 g	1.32%
Methionine	0.011 g	N/D
Cystine	0.028 g	N/D
Phenylalanine	0.026 g	N/D
Tyrosine	0.017 g	N/D
Valine	0.035 g	1.66%
Arginine	0.137 g	N/D
Histidine	0.02 g	1.62%
Alanine	0.038 g	N/D
Aspartic acid	0.079 g	N/D
Glutamic acid	0.206 g	N/D
Glycine	0.028 g	N/D
Proline	0.033 g	N/D
Serine	0.033 g	N/D

Figure 8.3. : Nutritional value of Cassava

8.1.1. Bark

Is thought that the bark of the plant along with cordyline terminalis could prolong life. (Fern, 2017)

8.1.2. Leaves

For rural communities cassava leaves are really important. These tribes use the leaves for dietary and medical purposes. However, over the last decades *manihot esculenta* leaves become very popular throughout the world, and especially in medical and cuisine areas. In fact, the leaves nutritional content is composed of: vitamin A, vitamin B1, fiber, carbohydrates, protein, and amino acids, this is why they are now very valuable for health. One of the benefits the leaves afford is the way how the help the body's metabolism, and this is because its contain of vitamin B1, which helps the body by producing body cells that will form enzymes later. Another outstanding fact about the leaves is their energy resources, because it contains a diverse proteins and essential amino acids, these factors make an exceptional contribution to build up energy in

the body. Likewise, amino acids in cassava to the correct process of changing carbohydrates into energy, in other words, what the body needs for energy. By the way, the leaves are also a source of antioxidants and they provide health benefits for preventing free radicals in the body. Free radicals are known to be one of the principal causes of diseases such as cancer and premature aging. Also, the leaves are another important source of cell regenerations, they work with the amino acids by creating proteins that would be useful for the growth of cells that had been damaged, so this would help to keep body cells updated and keep the organism functioning well. In addition, the leaves are used as a daily foot diet, because of the good amount of fiber and protein they have. Besides, one of the best benefits of the leaves, is the way how they interact with the digestive system, until the point the colon is heal by its contents. In the area of medicine, cassava leaves are also fundamental to treat some diseases. For example, to treat diarrhea, the seven pieces of *manihot esculenta* leaves are taken and washed, then, they are boiled with 800cc of water. After its ready, drink it twice a day. Though, the leaves are also very useful for treating rheumatism. So, people who often experience fatigue and arthritis symptoms could use the leaves for health benefits. The treatment is simple, first, five pieces of cassava leaves needs to be prepared and mixed with betel lives and a few amount of water. Then, rub them until they destroyed, and use this three times per day. (Syakira, 2017)

8.1.3. Roots

In order to treat diarrhoea, scabies, and dysentery, the roots of bitter varieties can be used. Also, for treating constipation and indigestion, drinking the juice of the tubers would be helpful. The flour made out of the roots can be used as a powder for the skin once it's mixed with carapa oil and rum, and this would be very effective as a treatment for abscesses, skin eruptions, and fungal dermatitis. (Fern, 2017)

8.1.4. Stems/twigs

A treatment for people suffering from glaucoma, is to take the stem, then folded and rubbed it across the patient eye. (Fern, 2017)

8.2. Non-wood usage

Starch is considered to be a good natural adhesive. There are two types, which are modified starches and dextrins, which can be presented as roll-dried adhesives and liquid adhesives. It seems that for the adhesive industry, cassava is designed to be the most important factor of it. While manufacturing the glue, the starch is coagulated in hot water or with the help of chemicals. Though, for conversion into dextrin, the process is subjected separately or simultaneously into the disintegrative action of chemicals between heat and enzymes. The three main types of dextrins are: british gums, white dextrins, and yellow dextrins. Industries also have applied the use of dextrins in non food products. For example, the cardboard manufacture is one of the largest users of dextrins, they use the starch glue for reinforcing the layers of each board. Besides, these adhesives are also very important for the remoistening gums industry, because they create postage stamps and envelope flaps with them. However, now is common to find in the market starch-based products that are used as adhesives for domestic uses and wallpapers. Even though, starch is being used in foundry as an adhesive for covering the sand grains, and this is a step in the manufacture of casting for metals. The paper industry uses the starch during three parts of the process while creating paper. Therefore, for magazines worked too, and its cheap price makes it better, so the new application of starch started in the machine-coating of magazine paper. By the way, starch is being used in well drilling. Starches mixed with clay are used to achieve the correct water-holding capacity in the machinery that is use for exploratory drilling of oil or water wells. These new starch-based products are replacing other common materials that were regularly used for well drilling. (FAO, n.d)

8.3. Magic ritual

8.3.1. Significance

Important food crops like cassava, tend to have powerful symbols in cultures, but mostly in South America. For example, the native tribe of Tukanoan, see yuca as their most important and highly valued food, and they consumed it in meals and snacks. Natives from Tukanoan believe that cassava was the first food that was planted. They believe it was planted by the first woman to make bread to the first man. For them, the extracted starch is the purest and nourishing food they can get.

Glossary

1. Lobes: a curved or rounded projection or division.
2. Slender stem: plant that usually grows upward above the ground and supports other parts, such as branches and leaves.
3. Petioles: a slender stem that supports the blade of a foliage leaf.
4. Cork cells: non-living, water-resistant, protective tissue.
5. Phellogen: a secondary meristem that initiates phellem and phelloderm in the periderm of a stem or root.
6. Ripe: fully grown and developed.
7. Phelloderm: a layer of parenchyma produced inwardly by a phellogen.
8. Phloem: a complex tissue in the vascular system of higher plants that consists mainly of sieve tubes and elongated parenchyma cells usually with fibers and that functions in translocation and in support and storage.
9. Starch tubers: an odourless, tasteless white substance occurring widely in plant tissue.
10. Sucrose: a sweet crystalline dextrorotatory disaccharide sugar C12H22O11 that occurs naturally in most plants and is obtained commercially especially from sugarcane or sugar beets.
11. Amylose: a component of starch characterized by its straight chains of glucose units.
12. Progenitor: a biologically ancestral form.
13. Locus: the position in a chromosome of a particular gene or allele.
14. Biomass: **:** plant materials and animal waste used especially as a source of fuel.
15. Starch yield: A naturally abundant nutrient carbohydrate, $(C_6H_{10}O_5)_n$, found chiefly in the seeds, fruits, tubers, roots, and plants.
16. Barren: producing little or no vegetation.
17. Linamarin: a bitter crystalline toxic cyanogenic glucoside C10H17NO6 occurring especially in flax and the lima bean.
18. Cyanide glycosides: any of a group of organic compounds, occurring abundantly in plants, that yield a sugar and one or more nonsugarsubstances on hydrolysis.
19. MASL: meters above sea level.
20. Harvesting: the quantity of a natural product gathered in a single season.
21. Loamy: a soil consisting of a friable mixture of varying proportions of clay, silt, and sand.
22. Crumbly: disintegrate.
23. Depleted: to lessen markedly in quantity, content, power, or value.

24. Euphorbiaceae: a widely distributed family of herbs, shrubs, or trees (order Geraniales) with usually milky often poisonous juice, unisexual flowers, and a superior usually trilocular ovary and including several medicinal plants (such as those yielding castor oil and croton oil), several trees yielding caoutchouc, and the cassava.
25. Allotetraploid:possessing four times the chromosomes in a haploid organism.
26. Pachytene: the stage of meiotic prophase that immediately follows the zygotene and that is characterized by paired chromosomes thickened and visibly divided into chromatids and by the occurrence of crossing-over.
27. Tetraploid: having or being a chromosome number four times the monoploid number.
28. Diploid: having two haploid sets of homologous chromosomes.
29. Karyotypically: the chromosomal characteristics of a cell.
30. Vyakuzizra: non-bitter roots.
31. Cytogenetic:a branch of biology that deals with the study of heredity and variation by the methods of both cytology and genetics.
32. Morphological: a branch of biology that deals with the form and structure of animals and plants.
33. Monoecious:having male and female sex organs in the same individual.
34. Inflorescence: the mode of development and arrangement of flowers on an axis.
35. Dormancy: the quality or state of being dormant.
36. Photo-periodic: a recurring cycle of light and dark periods of constant length.
37. Vitro: refers to the technique of performing a given procedure in a controlled environment outside of a living organism. Many experiments in cellular biology are conducted outside of organisms or cells.
38. Vivo: biological processes or experiments occurring or carried out in the living organism.
39. Cross-pollinated: the transfer of pollen from one flower to the stigma of another.
40. Germplasm: germ cells and their precursors serving as the bearers of heredity and being fundamentally independent of other cells.
41. Paraffin: a waxy crystalline flammable substance obtained especially from distillates of wood, coal, petroleum, or shale oil that is a complex mixture of hydrocarbons and is used chiefly in coating and sealing, in candles, in rubber compounding, and in pharmaceuticals and cosmetics.
42. Perennial: persisting for several years usually with new herbaceous growth.
43. Noxious: physically harmful or destructive to living beings.
44. Tillage: land for growing crops.
45. Moisture: liquid diffused or condensed in relatively small quantity.
46. Ridges: an elongate crest or a linear series of crests.
47. Vyakubaba: roots with bitter taste.
48. Dextrose: dextroglucose, commercially obtainable from starch by acidhydrolysis.
49. Glucose syrup: A syrup prepared from cornstarch, used in industry and in numerous food

products as a sweetener.

50. Lafun: fermented product of cassava.
51. Akyeke: fermented product of cassava.
52. Agbelima: fermented product of cassava.
53. Gari: fermented product of cassava.
54. Rheumatism: any of various conditions characterized by inflammation or pain in muscles, joints, or fibrous tissue.
55. Nourishing: to provide with food or other substances necessary for life and growth.

References

- F. (n.d.). Post-harvest loss due to pests in dried cassava chips and comparative methods for its assessment. - A case study on small-scale farm households in Ghana. Retrieved November 10, 2016, from http://www.fao.org/wairdocs/x5426e/x5426e02.htm
- Agricultural Research Council. Cassava nutrition facts and health benefits. (n.d.). Retrieved November 10, 2016, from http://www.nutrition-and-you.com/cassava.html
- Morgenstern, K. (n.d.). Plant profile. Retrieved November 10, 2016, from http://www.sacredearth.com/ethnobotany/plantprofiles/cassava.php
- ITIS. (n.d.). Manihot esculenta crantz. Retrieved November 10, 2016, from https://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=503688#null
- Duke, J. A. (1983). Manihot esculenta Crantz. Retrieved November 10, 2016, from https://www.hort.purdue.edu/newcrop/duke_energy/Manihot_esculenta.html
- Wang, W., Feng, B., Xiao, J., Xia, Z., Zhou, X., Li, P., . . . Peng, M. (2014, October 10). Cassava genome from a wild ancestor to cultivated varieties. Retrieved November 11, 2016, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4214410/
- Biopact. (2007, April 8). First comprehensive energy balance study reveals cassava is a highly efficient biofuel feedstock. Retrieved November 11, 2016, from http://global.mongabay.com/news/bioenergy/2007/04/first-full-energy-balance-study-reveals.html
- CARVALHO, R. D., & GUERRA, M. (2002, November 01). Cytogenetics of Manihot esculenta Crantz (cassava) and eight related species. Retrieved December 7, 2016, from http://onlinelibrary.wiley.com/doi/10.1034/j.1601-5223.2002.1360212.x/full
- Bryant, P. (n.d.). Life Cycle of a Cassava Plant. Retrieved December 10, 2016, from http://www.gardenguides.com/92104-life-cycle-cassava-plant.html
- **Rós, A. B., Hirata, A. C., Araújo, H. S., & Narita, N. (n.d.). Crescimento, fenologia e produtividade de cultivares de mandioca. Retrieved December 10, 2016, from http://www.scielo.br/scielo.php?pid=S1983-40632011000400014&script=sci_abstract**
- Tewodros Mulualem and Zelalem Bekeko, 2015. Assessment of Conventional Breeding on Cassava and its Physiological Adaptive Mechanisms: Implication for Moisture Stress. *Asian Journal of Agricultural Research, 9: 38-54.*
- *Otoo, J. (1983, January 01). The effects of day length of the flowering fruiting, seed-setting and other characters of cassava (Manihot esculenta, Crantz). Retrieved December 10, 2016, from*

http://agris.fao.org/agris-search/search.do?recordID=GH8800027

- *Mbahe, R. (1994). GERMINATION OF CASSAVA (MANIHOT ESCULENTA CRANTZ) POLLEN. Retrieved December 10, 2016, from http://www.actahort.org/380/380_25.htm*
- *Minantyorini, G. -. (n.d.). Guest - Dra. Minantyorini. Retrieved December 10, 2016, from http://cropgenebank.sgrp.cgiar.org/index.php/crops-mainmenu-367/cassava-mainmenu-232/regeneration-mainmenu-415*
- *Grant, B. L. (2016, March 19). Cassava Roots: Tips For Growing Cassava Yuca Plants. Retrieved December 10, 2016, from https://www.gardeningknowhow.com/edible/vegetables/cassava/growing-cassava-yuca.htm*
- *Wagaba, Henry(December, 2013)* Efficient transmission of Cassava brown streak disease viral pathogens by chip bud grafting. Retrieved December 10,2016, from https://www.researchgate.net/publication/259244777_Efficient_transmission_of_Cassava_brown_streak_disease_viral_pathogens_by_chip_bud_grafting
- Lawton, G. (2014, June 17). Growing Cassava. Retrieved February 24, 2017, from https://permaculturenews.org/2014/06/17/growing-cassava-perennial-main-crop-zaytuna-farm/
- *Công ty TNHH Giải Pháp Tin Học NON Việt Nam. (n.d.). Can cassava become Africa's next cash crop? Retrieved February 24, 2017, from http://tapiocavietnam.com/news/can-cassava-become-africas-next-cash-crop/86.html*
    - Team, T. T. (2016, December 16). What Does Cassava (Yuca) Taste Like? Retrieved March 11, 2017, from https://howthingstaste.com/what-does-cassava-yams-taste-like/
    - Lixandru, M. (2015, March 22). Tag Archives: Cassava toxicity. Retrieved March 15, 2017, from https://www.natureword.com/tag/cassava-toxicity/
    - Wonderiyke. (2016, January 10). ₦airaland Forum. Retrieved March 15, 2017, from http://www.nairaland.com/2854076/cassava-production-processed-products-made
- FAO. Cassava starchs and its uses. (n.d.). Retrieved April 8, 2017, from http://www.fao.org/docrep/x5032e/x5032E06.htm
- *Fern, K. (2017, February 26). Manihot esculenta . Retrieved April 8, 2017, from http://tropical.theferns.info/viewtropical.php?id=Manihot%2Besculenta*
- *Lu, Y., Zhai, Y., Liu, M., & Wu, Q. (1970, January 01). Biodiesel production from algal oil using cassava (Manihot esculenta Crantz) as feedstock. Retrieved April 8, 2017, from http://agris.fao.org/agris-search/search.do?recordID=US201301887745*
- *S. (2016, July 19). Cassava – Manihot esculenta. Retrieved April 8, 2017, from https://www.healthbenefitstimes.com/cassava/*
- *Syakira, S. (2017, January 30). The Health Benefits of Cassava Leaves. Retrieved April 8, 2017, from https://www.thealthbenefitsof.com/the-health-benefits-of-cassava-leaves/*

- *"Cassava." Encyclopedia of Food and Culture. . Retrieved May 09, 2017 from Encyclopedia.com: http://www.encyclopedia.com/food/encyclopedias-almanacs-transcripts-and-maps/cassava*

Glossary:

All words were defined by two dictionaries, The Merriam-Webster and The Free Dictionary.

Dictionary: Search the Merriam-Webster dictionary first. Here's why... (n.d.). Retrieved May 08, 2017, from https://www.merriam-webster.com/dictionary

Dictionary, Encyclopedia and Thesaurus. (n.d.). Retrieved May 08, 2017, from http://www.thefreedictionary.com/