Monograph - Agriculture

Musa × paradisiaca (Banana)

Javier Covarrubias

Agricultural Science

Colegio Bolivar

2018-2019

Dr Wojciech Waliszewski

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1: Importance

Musa × paradisiaca represents globally one of the most important fruit crops. With 50 million tons of produce annually worldwide. Also, banana has other uses, there have been experiments going on to do biotechnological production of protein, with the waste of bananas. It was also recently discovered that *"anthocyanin pigments in banana bracts were evaluated for their potential application as natural food colorants and were found to be a good source of anthocyanins" (Arvanitoyannis & Varzakas, 2008)*

Chapter 2 Ecology of Musa x Paradisiaca

2. Ecology

2.1: Affinity

Kingdom: Plantae
División: Magnoliophyta
Class: Liliopsida
Order: Zingiberales
Family: Musaceae
Genus: *Musa*

Singh (2017) found that there are 12 (twelve) species of Musa, which are shown in Table 1 below:

Table 1: Twelve species of *Musa* sp. (adapted from Singh, 2017). / *(Singh, 2017)*

Type of Musa	**Description**
Musa acuminata	Desert Banana, evergreen stoloniferous, native in southern Asia
Musa balbisiana	Perennial Herbaceous plant, native to eastern India
Musa cheesmani	Large, robust and fast-growing. Has big seeds
Musa itinerans	Know as Yunnan Banana. Seen across

	southeast Asian continental part of Northern India
Musa mannii	Known as Indian Pink Dwarf Banana, native to China
Musa nagensium	Native to Eastern Himalayas,
Musa ornata	Native to Southern India and Koraput region, has food and medicinal value
Musa sapientum	Cross from: Musa Acuminnata x Musa Balbisiana.
Musa sikkimensis	Known as Darjeeling banana, native to Sikkim
Musa superba	Jungly Kela
Musa thomsonii	Native to the Himalayas and Northern India
Musa velutina	Known as Hairy of Pink banana 

2.2: Fossil Record

The first fossil samples of Musaceae came from the Upper Carboniferous from about 330 million years ago and were found in Bohemia, Czechoslovakia, by Sternberg in 1825, categorized as *Scitaminites musaeformis* (Jain, 1964). More samples were collected in the Tertiary, in Java by Goeppert in 1854 (ibid). These were categorized as *Musa truncatum* species and came from banana-like leaves. Samples similar to *Musa truncatum* were later found through places in Europe and America. Also in places such as Colombia, Venezuela, and Cuba. In 1925, Berry described some carbonized fossil seeds discovered in coal beds of Cerros de Guadalupe and Monserrat. These were classified as *Musa enseteformis.* A petrified fruit was found in the locality of Deccan Intertrappean Series, India. This fossil sample was found by Jain in 1963 and was classified as *Musa cardiosperma.* From *Ensete enseteformis,* various breeds such as *Musa paradisiaca* were developed (Jain, 1965)

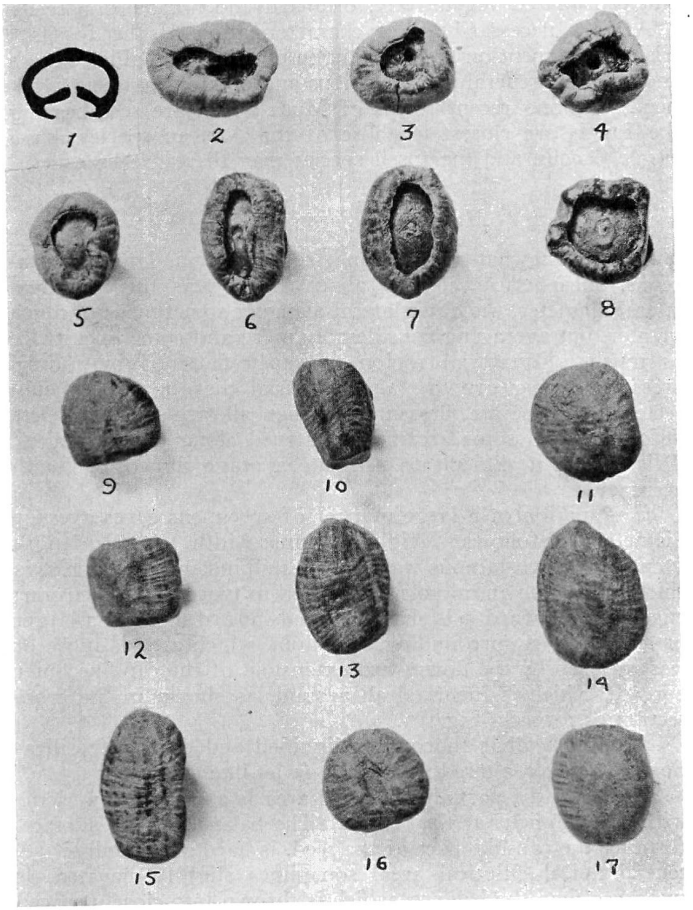


Fig. 1.—*Musa enseteformis* Berry, n. sp. Seeds from the Tertiary of Colombia.

Figure 1. *Musa enseteformis* Berry, n sp. Seeds from the Tertiary epoch of Colombia *(Jain, 1964)*

2.3 Origins

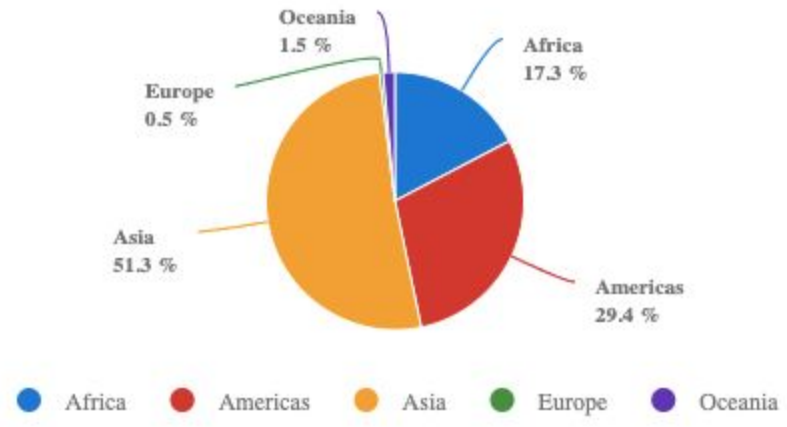
Bananas have been interwoven in history for a very long time, in several cultures and civilizations of southern India. Banana forms part of history particularly in countries that have been influenced previously by Hindu and Buddhist cultures, according to Reynolds (1951). The generic name of banana, which is *Musa,* comes from the Sanskrit word *Moca*, derived from the Arabic *Mouz* or *Mauwz* (Rumphis, 1627) India's literary reference for banana comes in two names; *Ramayana* and *Mahabharata*. There is strong evidence of banana agriculture obtained

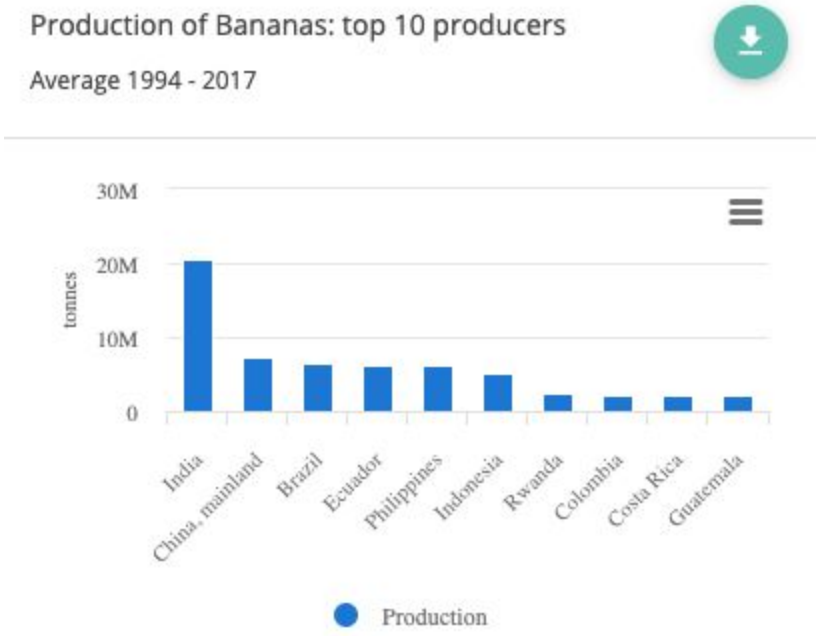
from the Kuk Swamp in the Wahgi Valley (Golson 1977). These samples found rose independently in New Guinea by at least 6950 to 6440 BP as shown by Caro, colocasia, and banana cultivation.

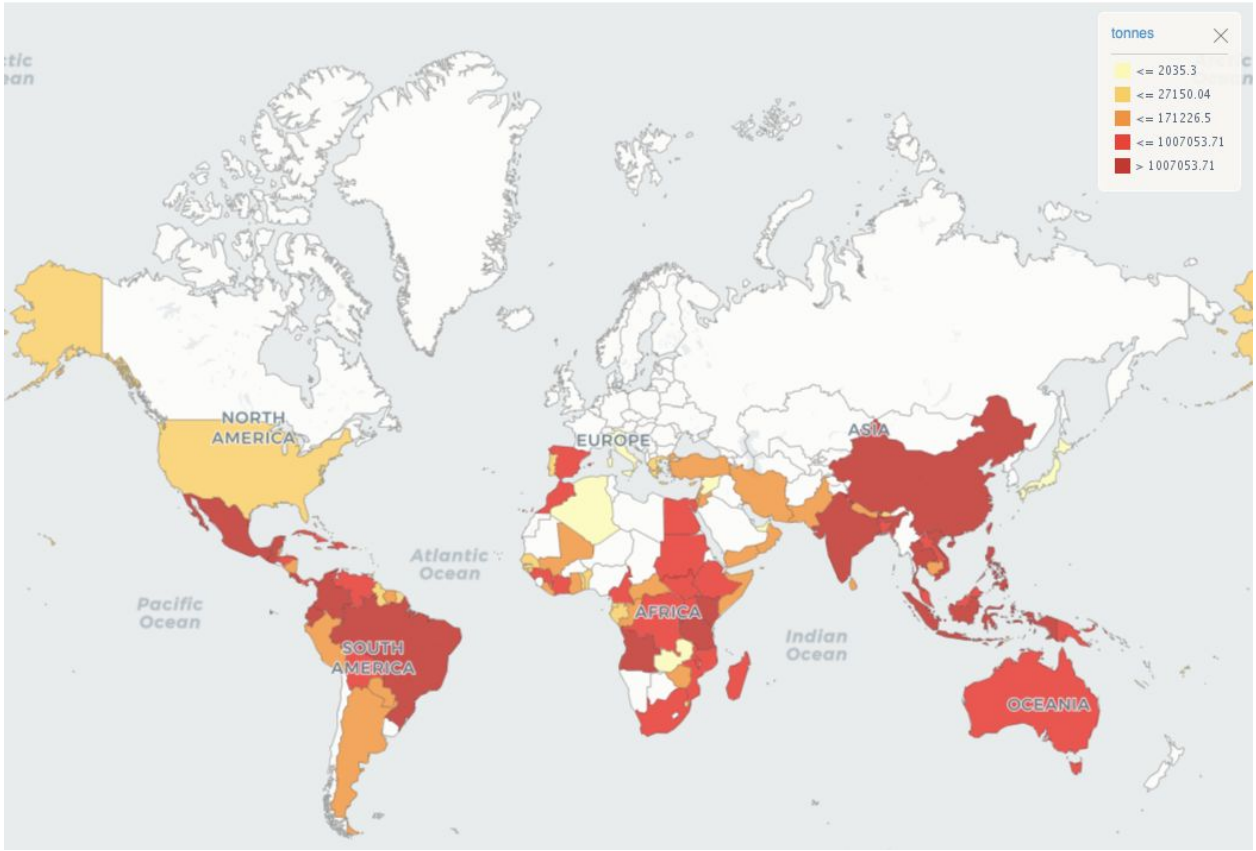
2.4 Present Distribution

Musa is widely distributed geographically in the tropics (from 175º E to 150º W) longitude and from (30º N to 23º S) latitude. it is distributed in thousands of islands of the south and southeast Asia, west tropical Pacific Ocean, Sri Lanka, through peninsular east India and also India's northeast region. Bangladesh, south and southeast China, Myanmar, Laos, Vietnam, Cambodia, Thailand, Malaysia, Indonesia, Philippines, and New Guinea. All Wild bananas are warm-region plants.

Images retrieved from (FAOstat, 2017)




Production of Bananas: top 10 producers
Average 1994 - 2017
30M
20M
10M
0
tonnes
India
China, mainland
Brazil
Ecuador
Philippines
Indonesia
Rwanda
Colombia
Costa Rica
Guatemala
Production


tonnes
<= 2035.3
<= 27150.04
<= 171226.5
<= 1007053.71
> 1007053.71
NORTH AMERICA
EUROPE
ASIA
AFRICA
SOUTH AMERICA
OCEANIA
Atlantic Ocean
Pacific Ocean
Indian Ocean

2.5 Elevation & Climate

Bananas are specifically restricted to tropical and near tropical regions, no other. Areas with latitudes in between 30ºN and 30ºS. This regions usually have varied but dry climates. A climate suitable for banana plantations would be a mean temperature of 26.7ºC and a mean rainfall of 10 m per month ("Genus Musa," n.d.). Cold weather would retard the growth in banana plantations. In countries such as Australia, bananas are planted in sunny hillsides with elevations of 60 to 300 meters. There avoid the cold air currents that settle in lowers levels, which can kill the plant. There are exceptions for certain types of bananas. *Dwarf Cavendish,* for example, is successful in an altitude of 1,200 m. *Vella vazha* for example is cultivated in altitudes between 975 to 1,600 meters. Winds have negative effects on banana plantations because they can break the leaves of the plant of distortion the form of the plants crown.

Irrigation Management is also very important to keep the plants alive. Banana plants need between 900-1200 mm of water during their whole life cycle, this water can be supplied by natural precipitation (rainfall) or can be supplemented. Providing an optimum drainage system is also very important to drain out excess water from the root zone. For warm climate zones, it is recommended to irrigate the plants every 3-4 days, for cooler climate zones, banana plants should be irrigated every 7-8 days. There are different methods to keep the plants watered; Furrow irrigation, Trench irrigation, Drip Irrigation, and Fertigation are some of them. Furrow irrigation is the most common method, it consists on creating small parallel channels along the length of the field, then with a slight level of slope the water will flow in between the crops, down the slope.

2.6: Soil & Geology

The banana plant is able to grow and fruit under very poor conditions but it needs better quality soil for it to be able to be economically productive; well-drained soil - loam, rocky sand, marl, red laterite, volcanic ash, sandy clay, even heavy clay - but not fine sand which holds water. Overhead irrigation is said to improve the filth of heavy clay and has made possible the use of clay soils that would never have been considered for banana culture in the past. Alluvial soils of river valleys are ideal for banana growing. Bananas grow better in acidic soil but if the pH is below 5.0 lime should be applied the second year. Low pH makes bananas more exposed to Panama disease. Where waterlogging is likely, bananas and plantains are grown on raised beds. Low, perennially wet soils require draining and dry soils require irrigation. (Heslop-Harrison & Schwarzacher, 2007)

Javier Covarrubias; Musa × paradisiaca (Banana)

Image retrieved from (Wikipedia, 2008)

Chapter 3 Biology of Musa x Paradisiaca

3. Ecology

3.1 Chromosome Complement

3.1.1 Chromosome number & data

Cultivated bananas, as well as plantains, are both sterile and parthenocarpic, which means that the fruit develops without seed. Cultivated species and hybrids are usually triploid (2n = 3x = 33; a few are diploid or tetraploid) (Heslop-Harrison & Schwarzacher, 2007). There are thousands of domestic *Musa* cultivars and their genetic diversity is very high, which means there are multiple different origins of wild hybrids between two principal ancestral species. However, due to difficulties in the genetics and sterility of the crop, the development of new varieties through mutation, hybridization or transformation wasn't very successful in the 20th century (Heslop-Harrison & Schwarzacher, 2007).

3.2 Life Cycles & Phenology

Banana is a neutral fruit crop, it has a long flowering/fruiting cycle which is notoriously affected by weather, depending on the place it is being cultivated. Banana trees are considered as trees but they do not have a woody structure, they do not deteriorate and die like a typical tree. Banana trees sprout from underground roots, these grow horizontally from a mature banana tree. It takes 10 -15 months for the tree to sprout and form a stalk, then the leaves grow and can go up to 9 feet long and 2 feet wide, also up to 25 feet tall. When a banana tree produces its fruit it dies (Chaurasia et al., 2017; Hoyt, 2017)

Image 1: *Banana life cycle process (Pinterest, 2017)*

3.2.1 Flower Production

Banana is often confused with a tree or a plant, it is actually a herb. A herb is a seed-bearing plant, it does not have a woody structure and dies to the ground after flowering. Bananas are perennial plants that replace themselves, these do not grow from seeds but from rhizomes and bulbs. The growth takes between nine to 12 months, from a banana bulb turning into a harvestable fruit. Banana flowers appear between six and 7 months. Bananas do not have specific seasons to grow, these can grow all year long.

3.2.2 Fruit Development

The fruit develops after a nine-month period, while they still are green. They are taken to the packhouse for an inspection process before being sent to export. Many clients (the UK for example) set very high standards for the fruits. Because of this, the bananas have to be unbruised. Bananas are transported at a temperature of 13. C and in careful conditions to maintain their quality.

3.3 Productivity and Biology

3.3.1 Pollination

Usually, for any plant to be self-fruiting, it sets pollen from its own fruit, rather than being pollinated by a separate plant. Edible bananas *(Musa spp)* are a different case, these produce fruit

without the need of outside pollination, and the flowers do not need any pollination as well. These fruits develop with no pollination at all, from female flowers, therefore, there are no seeds. this is known as parthenocarpy. It's important to note, that there may be certain banana species exempted from this. For example, *Musa acuminata* is pollinated while living near to other wild species and can develop some seeds. (Chaney, n.d.)

3.3.2 Sexuality and Reproduction

Cultivated bananas are produced as a result of asexual reproduction since there are no seeds on the fruit. When a banana herb dies after producing the fruit, another one will grow, from the same already existing roots. Sometimes this process can continue for years. (Koeppel, 2005)

Chapter 4 Propagation & Management

4.2 Propagation

4.2.1 Rhizome Propagation

Large rhizomes develop in the root mat of the banana plant, these serve as a point of banana pseudostems to grow. These rhizomes can be divided into smaller pieces which are known as bits, the purpose of this is to divide the individual growth point and provide new points for more banana trees to grow. As long as the new bits have at least one meristem, a plant will be developed in the course of two years. (Slaven & Shrubb, n.d.)

Pseudostem*: A pseudostem, looks like the stem of the banana tree but it actually is not; It is an enlarged version of the stem with a fleshy structure and holds plenty of water.*

Rhizomes: *Rhizomes are characterized by their underground horizontal growth, their production of multiple nodes and production of clonal plants*

Meristem: *Meristem clusters are a type of banana tissue which has been successfully cryopreserved*

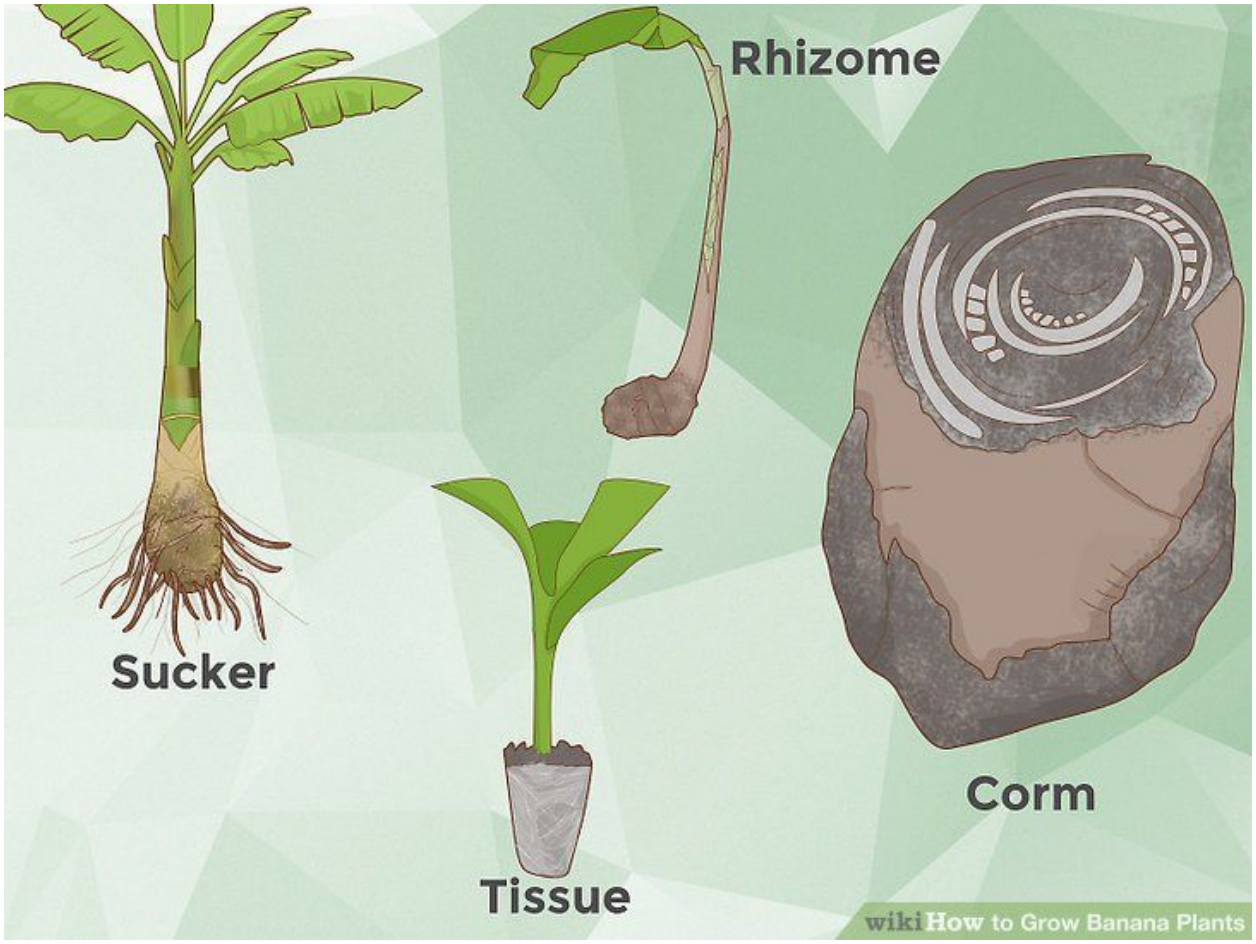


Image 1: *Shows the different types of banana stems, image retrieved from (WikiHow, 2017)*

4.2.2 Sucker Propagation

If suckers are harvested when they are small these can be planted and develop a new banana plant in the course of 1 year (Suckers grow from rhizomes). There are two types of suckers that develop from banana plants; “Swords suckers” and “Water suckers”. Water suckers will not produce a good banana plant, they have a small rhizome and can be identified because of their broad leaves. Sword suckers grow straight with a thin leave structure, they will produce a big banana plant due to the fact that they have a big rhizome.

Image 2: *Shows two different types of banana suckers; "Water Sucker" and "Sword Sucker", image retrieved from (SlideShare, 2016)*

4.3 Planting

The planting process for every plant starts with the preparation of its soil. For a banana sucker to develop its roots properly it has to be planted in damp soil, a lot of water would prevent the roots from growing. The ditches have to be made in the direction of the slope, the recommended distance between every ditch is 15 meters, depends on the method being used for planting. The holes have to be made two months before planting, need to be 60 centimeters deep and have to be filled up with compost. For planting the suckers they have to be in between 50 cms and one

meter tall, they should also have a broad base. Before planting these they have to dry in the shade during 3-4 days. Just before planting them, trim the points at 50 centimeters from the base of the plant and dip them in water in which potassium permanganate is mixed. For the suckers to grow properly they should be planted at the end of the dry season, if these are planted during the rainy season the suckers will rot. During the two months since the hole was made to the moment of planting, the hole is left filled up with compost. Before planting the sucker, most of the compost is removed and the hole is less deep than it was before. Put the sucker in with the soil from above, then finally cover it with dirt from bellow mixed with compost. (As shown in the picture below) ("Bananas," 1984)

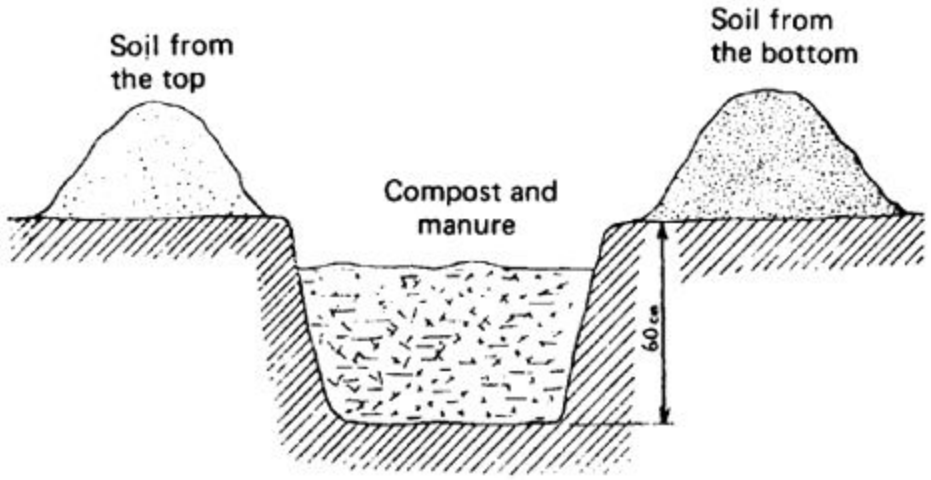


Image 3: *Shows banana suckers planting process, image retrieved from (FAO, 1992)*

4.4 Management

In order to keep a banana plant properly managed, it needs some requirements to be accomplished: The soil has to be kept clean, needs fertilizers applied, prune the plant, prevent it from falling, look after the plant, and protect it from diseases and insects. **Soil Management:** When banana plants are small, usually grass grows around them, but when the plant gets taller, it will cover the grass and prevent it from getting sunlight, which will eventually kill the grass. If the grass doesn't die, it can be kept alive longer with a chemical named Gramoxone (0.4 liters, Gramoxone, mixed with 400 liters of water (to treat one whole hectare)) In certain places, water

will not get to the soil, causing it to dry and dehydrate the plants. To prevent this from happening, there should be ditches opened in between the plants so water can fall into them and keep the dirt moist. These ditches should also be irrigated in case there is no rainfall or a nearby water source. **Applying fertilizers:** Even though the plants get compost from their dead leaves and other compost materials, these still need mineral salts. The following minerals should be provided to the banana plants every year. *Nitrogen*: 750 grams of ammonium sulphate or 300 grams of urea. *Phosphorus*: 300 grams of dicalcium phosphate or 500 grams of Thomas slag (Bessemer basic slag). *Potassium*: 600 grams of potassium chloride. (FAO Economic and Social Development Series, 1984) Phosphorus and Nitrogen should be applied to the plant 4 to 5 times a year. If the plant is properly irrigated, the minerals will not be washed away by the rain. **Supporting the plant**: The fruit of banana plants is very heavy, the weight may bend the plant causing it to fall, therefore it needs support to prevent it from falling, it should be supported with bamboo, or another type of resistant support, bamboo is recommended. (Example is shown in the picture below) ("Bananas," 1984)

Image 4: *Shows banana tree supporting system, image retrieved from (FAO, 1992)*

4.4.3 Pest Disease and Control

Bananas are attacked by a lot of insects, Banana Weevil for example; these insects make holes in the bananas, plant their eggs and eat the heart of the banana, but they're very difficult to spot. It can be noticed if banana fruits do not grow properly or in a weird shape. To control the weevils use BHC. (25 to 30 grams around each plant). There are other insects that attack the banana plant such as eelworm or nematodes. There are also various common diseases that attack banana plants. **Panama disease:** is caused by a fungus in the soil, causing the leaves to break and give the trunk a brownish red color. Some others are; Mosaic disease, "Cigar-end" rot, Leaf spot disease, etc… these can be managed with the use of fertilizers and chemicals. ("Bananas," 1984)

Chapter 5 Markets and Uses

5.1 Markets

Table 1: The top 5 producers of banana around the world are India (29135000 tonnes), China (11197559 tonnes), Mainland China (10940000 tonnes), Indonesia (7007125 tonnes) and Brazil (6735260 tonnes). The following chart includes the top 20 banana producing countries worldwide.

Chart adapted from FAOSTAT (http://www.fao.org/faostat/en/#data/QC)

Area	Unit	Value	Flag Description
India	tonnes	29135000	Official data
China	tonnes	11197559	Aggregate, may include official, semi-official, estimated or calculated data
China, mainland	tonnes	10940000	Official data
Indonesia	tonnes	7007125	Official data
Brazil	tonnes	6735260	Official data
Ecuador	tonnes	6529676	Official data
Philippines	tonnes	5829142	Official data
Angola	tonnes	3820873	FAO data based on imputation methodology
Guatemala	tonnes	3775150	Official data
Colombia	tonnes	3691163	Official data
Republic of Tanzania	tonnes	3563596	FAO data based on imputation methodology
Rwanda	tonnes	3037962	Official data
Costa Rica	tonnes	2417876	Official data
Mexico	tonnes	2384778	Official data
Viet Nam	tonnes	1941935	Official data

Kenya	tonnes	1288588	Official data
Papua New Guinea	tonnes	1219075	FAO data based on imputation methodology
Egypt	tonnes	1214077	Official data
Cameroon	tonnes	1187547	Official data
Dominican Republic	tonnes	1140182	Official data

Some of the biggest banana supplier companies in the world are: ChiquitaFyffes (Ireland), Dole Food Company (United States), Fresh Del Monte Produce (United States), Grupo Noboa S.A. (Ecuador)

5.2 Uses

5.2.1 Edible Uses

Bananas are yellow curved fruits, with a slightly high concentration of sugar which gives them a sweet taste. Bananas can be used for making various foods, smoothies for example. The fruit alone can be eaten peeled or raw, it can also be cooked with or without the skin. Bananas are perfect food for babies; These are simple to mash and are adequate for a baby's consumption. Bananas contain: Potassium, Fiber, Calcium, Magnesium, Phosphorus, Selenium, Iron, Vitamins A, B2, B6, C, E, Niacin, Folate, and Pantothenic Acid. Bananas rarely cause allergic reactions and are very easy to digest. (Kumar, 2012)

Table 2: *Chemical composition of Banana fruit (Sidhu & Zafar, 2018)*

Constituent	Amount µg, mg, g, or percent daily value
Energy	371 kJ (89 kcal)
Water	74.91 g
Carbohydrates	22.84 g
Sugars	12.23 g
Dietary fibre	2.6 g
Vitamins	
Pantothenic acid (B5)	0.334 mg, (7%)
Pyridoxine (B6)	0.4 mg, (31%)
Choline	9.8 mg, (2%)
Vitamin C	8.7 mg, (10%)
Minerals	
Magnesium	27 mg, (8%)
Phosphorus	22 mg, (3%)
Potassium	358 mg, (8%)
Sodium	1 mg, (0%)
Zinc	0.15 mg, (2%)

Adopted from: Wikipedia, Internet, USDA databases.

5.2.2 Medicinal Uses

Bananas contain a good amount of a mineral called potassium. This mineral helps regulate the movement of nutrients and waste out of the cells, also helps maintain fluid levels in the body stable. Bananas have a lot of medicinal properties, beyond their nutritive value. Such as;

- **Reduce the risk of a stroke:** People with low amounts of potassium in their systems are much more likely to have a stroke.

- **Restore a normal Bowel activity:** Bananas are rich in non-digestible fibers, such as cellulose, hemicellulose and alpha glucans which can help restore bowel activity in the body. It also helps with diarrhea and constipation.

- **Have cholesterol-lowering effects:** Dietary fiber component in the banana pulp have a cholesterol-lowering effect in the human body.

- **Improve kidney health:** The high potassium levels banana fruits contain improve kidney health: The ingestion of potassium suppresses calcium excretion in urine which reduces the risk of having kidney stones.

- **Reduce the risk of high blood pressure:** The amount of potassium bananas have are excellent to make the heart function properly and maintain normal blood pressure.

Banana flowers are also used to treat dysentery, ulcers, and bronchitis. Also, cooked banana flowers are considered to be good food for people who suffer from diabetes. Banana saps are used to treat a large variety of ailments such as; leprosy, hysteria, fever among others. Roots in banana herbs can be used to treat digestive disorders. (Kumar, 2012)

5.2.3 Use in textiles

The fashion industry uses various textiles such as cotton, petroleum-based fibers, polyester, spandex, and nylon to make products. But the use of these textiles causes irreversible damage on the planet. The use of Banana fiber is a great option nowadays, due to the fact that this fiber is a sustainable alternative. Banana fiber is also known as *Musa Fibre* and it's one of the strongest

natural fibers. This fiber is made from the stem of banana trees, it is extremely durable and also biodegradable which means it is friendly to the environment. Banana fiber consists of a thick-wall celled tissue, mainly composed by cellulose hemicelluloses and lignin, bonded together by natural bonds. Bamboo fiber shares some similar characteristics to banana fiber. This can be used to produce various varieties of textiles, this depends on what part of the plant was the fiber extracted from. Outer shells of the banana herb are used to extract thicker fibers, the inner part of the plant has softer fibers than the ones on the outside. Banana has been used since the early 13th century, it was used by Japanese people, but it's being innovated and used again nowadays. Several products can be made from this fiber, for example; mats, handmade paper, ropes… a company named *Green Banana Paper* located on the island of Kosrae is using banana fiber to make vegan wallets, papers, purses, among other products. The company was founded by Matt Simpson, it uses recycled banana stems, collected from around the island, it also buys leftovers of banana stems to local farmers, helping the economy as well. (Hendriksz, 2017)

Image retrieved from *FashionUnited*

These two images come from *Green Banana Paper* company *(FashionUnited, 2019)*

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