THE BIOLOGY OF BANANAS AND PLANTAINS

Photo: INIBAP

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Banana as a Crop

Bananas and plantains constitute the fourth most important global food commodity (after rice, wheat and maize) grown in more than 100 countries over a harvested area of approximately 10 million hectares, with an annual production of 88 million tonnes (Frison and Sharrock, 1999). The all year round fruiting habit of bananas puts the crop in a superior position in bridging the 'hunger gap' between crop harvests. It therefore contributes significantly to food and income security of people engaged in its production and trade, particularly in developing countries. In Africa they provide more than 25% of the carbohydrate requirements for over 70 million people (IITA, 1998). Eastern and Southern Africa produces over 20 million tonnes of bananas which accounts for 25.58% of total world output (Karamura et.al., 1999). The Great Lakes region covering parts of Uganda, Rwanda, Burundi, Tanzania, Kenya and DRC is the largest producer and consumer of bananas in Africa (Smale, 2006) where *per capita* consumption has been estimated at more than 250kg; the highest in the world (FAO, 1985).

Uganda ranks second after India in the world banana production with an annual output of 9.84 million tonnes accounting for 11.18% of the world's total production (INIBAP, 1999). The area under banana production is 1.3 million hectares and this constitutes 75% of arable land (NARO, 2000). However, outbreak of banana bacterial wilt disease is seriously affecting the production of all genotypes (Tushemereirwe *et al.,* 2003).

A healthy diet consists of eating a variety of foods from 5 food groups but in the correct proportions. These include; foods containing starch, fruit and vegetables, milk and diary food, foods containing protein, and that containing fats and sugars. Bananas fall in the fruit and vegetable group as well as the food group which mostly contain starch. Sweet dessert bananas are generally eaten raw (fruit), while cooking bananas and plantains are boiled, steamed, fried or roasted (food). A person should eat at least 5 portions of fruit and vegetables every day where one whole banana fruit is equivalent to one portion just as two tomatoes and or half cucumber**.** Bananas provide a good source of nutrients for both human and animal consumption and the nutritional values per 100 grams of edible portion are indicated in table 1 where the same amount of grams yield up to 120 kcal of energy (EDinformatics, 2006). Compared with many snack foods, the banana provides energy primarily in the form of carbohydrate with minimal contribution to energy from fat. Any food containing carbohydrates should be the main part of our daily meals. More additional nutrients are provided in table 2 and 3 after the banana nutrition group UK and Dickinson, 2000. The nutritional values indicated in the tables below vary between different cultivars, degree of ripeness and the growing conditions. In unripe bananas the carbohydrates are mostly starches. In the process of ripening the starches are converted to sugars; a fully ripe banana has only 1-2% starch (Forsyth, 1980).

Table 1: The nutritional values of bananas per 100g of edible fresh portion (ED informatics, 2006).

	Nutrients	Amount	Daily recommended values
1.	Water	74%	240ml
2.	Carbohydrates	23 %	300 grams
3.	Protein	1%	50 grams
4.	Fats	0.5%	65 grams
5.	Fibre	2.5%	25 grams

Table 2: Vitamin content of the banana (nutrients per 100g ripe, edible banana). *The banana nutrition group (UK); Dickinson, 2000*

	Vitamins	Amount	Daily recommended intake per normal adult
1	Carotene	21 micrograms	800 micrograms
2.	Vitamin E	0.27mg	15mg
3.	Thiamin (B1)	0.04mg	1.5mg
4.	Riboflavin (B2)	0.06mg	1.7mg
5	Niacin	0.7mg	20mg
6.	Pyridoxine (B6)	0.29mg	1.3-1.7mg depending on age
7.	Folic Acid	14 micrograms	400micrograms
8.	Pantothenate	0.36mg	10mg
9.	Biotin	2.6 micrograms	300micrograms
10.	Vitamine C	11mg	75mg women, 90mg for men

Table 3: Mineral content of the banana (nutrients per 100g ripe, edible banana). *The banana group (UK); Dickinson, 2000*

	Minerals	Amount	Daily recommended in take per normal adult
1.	Sodium	1mg	2400mg
2.	Potassium	400mg	3500mg
3.	Calcium	6mg	1000mg
4.	Magnesium	34mg	400mg
5.	Phosphorus	28mg	1000mg
6.	Iron	0.3mg	18mgs
7.	Copper	0.1g	2.0mgs
8.	Zinc	0.2mg	15mg
9.	Chloride	79mg	3400mg
10.	Manganese	0.4mg	2.0mg
11	Iodine	8 micrograms	150 micrograms

It is considered important to know about the minerals and vitamins because a significant drop in their volume leads to dreadful disease and pathological symptoms. Vitamins are organic compounds that function as metabolic regulators of the body. The body requires a small amount of vitamins for the various metabolic functions of the body, but any deficiency can lead to metabolic and physical disorders. Most vitamins are not produced in the body, but a diet rich in fruits, vegetables, grains and cereals can provide the essential vitamins needed by the body, in small doses, and in a balanced way. Minerals can be broken down into two basic groups based on their requirement, macro and micro minerals. The macro minerals, such as Calcium, Magnesium, sodium (salt) potassium and phosphorus are needed in fairly substantial amounts for proper health, where as, the micro minerals are needed in far smaller quantities and include substances such as Zinc, Iron, Copper Manganese Chromium, Selenium and Iodine. Though minerals and vitamins are required in trace quantity these trace minerals function in a wide and varied form to regulate and balance the body from certain disease and improper functions. The need of the vitamins and minerals is reflected at the time of physiological symptoms of the disease and their required value. The tables above (2 & 3) show the lists of minerals and vitamins found in the ripe bananas and their required levels in the body to function properly.

Other uses and/or products include: hand crafts from the leaves and fibre, ropes, peels for animal feeds and leaves for wrapping foodstuff (Frison and Sharrock, 1999).

Banana Allergenicity[1]

Banana allergy can take two different forms: one associated with allergy to tree pollen, such as birch, and another type associated with latex allergy. People with birch-pollen allergy can develop symptoms either immediately or up to one (1) hour after eating fresh banana or a banana-containing food. Symptoms comprise local reactions in the mouth and throat with itching and inflammation (called oral allergy syndrome, OAS).

Others develop banana allergy because of the similarity between the allergens in banana and natural rubber latex (e.g. gloves, condoms, balloons) a condition known as the latex-fruit syndrome. Symptoms developed by these individuals comprise generalized urticaria, abdominal pain, vomiting and sometimes life-threatening symptoms. These individuals often develop adverse reactions to chestnut, avocado, mango and kiwi. The class I chitinase in these fruits, which belong to a family of pathogenesis-related proteins (PR-3), has been reported to be an important cross-reactive allergen for latex-sensitized people (Diaz-Perales A, *et al.,* 2003). Allergenicity to bananas increases with ripeness.

Taxonomy and Genetics of Banana

The term banana is used throughout the text to refer to all types of bananas including cooking bananas and plantains. Bananas with all its species, varieties or hybrids belong to the genus *Musa,* order Zingiberales, family Musaceae*.* The genus *Musa* contains 30-40 species, with all wild species being diploids (2n=2x= 14, 18, 20, 22) and native to South East Asia (Stover and Simmonds, 1987). Based on the basic chromosome numbers, orientation and arrangement of flowers in the inflorescence, *Musa* is grouped into 5 sections. Two of the sections contain species with a basic chromosome number of 10 (2n=20) *(Callimusa* and *Australimusa*), two other sections have species with a basic chromosome number of 11 (2n=22) (*Eumusa* and *Rhodochlamys.*). The last section is *Incertae sedis* created for *Musa ingens* Simmonds a highland species of Papua New Guinea, and now with *Musa boman and Musa lasiocarpa* (Daniells*, et.al*., 2001) the three having different basic chromosome numbers although further research is needed to consolidate and confirm their grouping. The species in the sections *Callimusa* and *Rhodochlamys* are of ornamental interest only and do not produce fruits. The section

[1] http://foodallergens.ifr.ac.uk/food.lasso?selected_food=5#summary

Australimusa contains *M. textilis* Nees (Abaca) from which Manila hemp is produced and it is within this section that the seedless edible Fe'i bananas of the Pacific belong as well. The section *Eumusa* sometimes called *Musa* (true bananas) with a pendent or semi-pendent inflorescence is the largest of the five sections with 13-15 species. It is the most diversified, most ancient and widely distributed section (Karamura, 1998). The edible bananas (chromosome numbers 22, 33, 44; the basic number being n = x = 11) are derived from at least two wild species; *Musa acuminata* Colla (A genome) and *Musa balbisiana* Colla (B genome), both of which belong to section *Eumusa.*

Although some diploid bananas are still grown today, the most widespread and economically most important bananas are the triploids, while tetraploids are very rare naturally or they are artificially bred. In Uganda banana production is largely based on a distinct group of triploid cultivars known as the East African Highland bananas (*Musa* AAA-EA), constituting 85% of bananas grown in the country (Karamura *et al*., 1996). This type of bananas is a dominant feature in the Great Lakes region of Eastern Africa and is used mainly for cooking (Matooke) and beer (Mbidde) production. Based on morphometrics the East African Highland bananas are categorised into 5 clone sets namely, Musakala, Nakabululu, Nakitembe, Nfuuka and Mbide (Karamura 1998). Other groups of bananas introduced some time back and grown in the country are Pisang awak (ABB) and Kisubi (AB) used for juice/beer, plantains (AAB) and Bluggoe (ABB) used for roasting and cooking, Gros Michel, Red/Green Red (AAA) and Sukali-ndiizi (AAB) used for dessert. Most popular genomic groups and their respective purposes are summarized in table 4.

Table 4: Most popular genomic groups in Uganda and their respective Purposes

Genome	Purpose	Examples
AAA	Dessert/ Cooking/ juice	Gros-Michel/Cavendish/Matooke/ Mbidde
AAB	Roasting/cooking/dessert	Plantains /Sukali Ndizi
ABB	Cooking/ Juice/Beer	Bluggoe /Pisang awak (Kayinja)
AA	Dessert/juice	Pisang Lillin
AB	Juice	Kisubi
AAAA*	Dessert	Kabana 1 & 3

*****synthetic tetraploids

Pollen Viability

Pollen viability differs between genome groups and within genome groups. Different species and cultivars of *Musa* possess different levels of competency in the production of microspores, which correlated positively with levels of pollen fertility. A study carried out in Australia by Fortescue and Turner (2004), where pollen viability was examined using the Alexander's pollen stain procedure, showed that diploid species *M. acuminate and* M*. balbisiana* had 3 times more viable pollen than the edible tetraploids (AAAB), and the tetraploids contained 3 times more viable pollen than the edible triploids AAA, AAB and ABB. The genome A or B did not affect pollen viability within the triploid cultivars examined. Pollen viability rates reported for *M. acuminata* and *M. balbisiana* were 71% and 98%, respectively while among the triploid Gros Michel had the highest percentage of viable pollen at 13% (Fortescue and Turner, 2004). Most cultivated bananas are triploid and are characterized by high male and female sterility (Nyine and Pillay, 2007).

Centre of Origin of bananas

Bananas originated from South East Asia, a region considered as the primary centre of diversification of the crop and where the earliest domestication has occurred (Simmonds, 1962). This is an area bordered on the west by India and on the east by Samoa, Fiji and other South Pacific islands (Simmonds, 1966). *Musa acuminata* is said to have originated from Malaysia, while the hardy *Musa balbsiana* originated from Indochina. The low land areas of West Africa contain the world's largest range of genetic diversity in plantains (*Musa* AAB) (Ortiz and Vuylsteke, 1994). Conversely in East Africa, bananas are highly evolved into an important zone of secondary genetic diversity for the East African highland bananas (*Musa* AAA) (Smale, 2006).

Morphology and Reproduction of Banana

Bananas are large perennial herbs with an underground stem called a corm, which is the true stem of the banana plant. The corm produces aerial shoots which arise from the lateral buds which develop into eyes and later suckers. The continuous vegetative growth of suckers perpetuates the corm's life and hence the perennial status of bananas.

The aerial shoot is called a pseudostem and grows to height of 2 to 8 m depending on the variety and the conditions. The pseudostem consists of large overlapping leaf bases which are tightly rolled round each other forming a cylindrical structure almost 48 cm in diameter. The roots are initiated from the corm and they range from 50 to 100 cm in length; occasionally sub-horizontal roots reach 3 m (Blomme and Ortiz, 2000). The corm also consists of the apical meristem from which the leaves and ultimately the flowers are initiated. On average, each plant produces 35 to 50 leaves in its growth cycle. When the banana plant has formed an average of 40 leaves (within 8 to 18 months), the terminal bud of the corm develops directly into the inflorescence which is carried up on a long smooth unbranched stem through the centre of the pseudostem emerging at the top in the centre of the leaf cluster. The inflorescence is a compound spike of female and male flowers arranged in groups. Each group consists of 2 rows of flowers, one above the other, closely appressed to each other, and the whole collection is covered by a large subtending bract. The bracts and their axillary groups of flowers are arranged spirally round the axis and the bracts become closely overlapping each other forming a tight conical inflorescence at the tip. The lower bracts of the axis enclose female flowers; the middle few bracts enclose neuter flowers (absent in some cultivars) whilst at the tip of the inflorescence male flowers occur (Purseglove, 1972). In a few cases, (*M. schizocarpa, M. acuminata* ssp. *banksii* and *M. acuminata* ssp. *errans*) hermaphrodite flowers are produced (Sharrock, et.al. 2001). The female inflorescences develop into fingers that constitute the bunch. Banana bunches possess 4 to 12 hands (clusters), each with at least 10 fingers. In wild bananas both male and female flowers produce abundant nectar and pollen whereas in cultivated bananas, many clones lack pollen. Banana pollen is tiny and sticky, being coated with waxes and proteins held in place by sculpture elements. The quantity of pollen is an important factor to enhance the germination potential of pollen grains (Dumpe and Ortiz 1996). The female flowers have ovaries that develop first by parthenocarpy (without fertilization) to form pulp which is the edible part of the crop. However, wild bananas exhibit cross pollination and ultimately fertilization to form seeds instead of pulp (non-parthenocarpic).

Banana Breeding and Seed Production

Banana production still depends on a limited number of landraces selected by farmers from the small natural germplasm in East Africa. This practice has maintained a small genetic pool and has ultimately put the banana germplasm at a risk of serious pest and disease outbreaks. In addition, the genetic improvement of bananas has been severely hampered by lack of useful genetic variability and low female fertility levels resulting from the triploidy nature of cultivated bananas leading to irregular meiosis. Consequently, most cultivars exhibit low seed set. Banana improvement is further constrained by the long generation cycle (at least 2 years are required to complete a seed-to-seed crop cycle) and the large space requirement of a minimum 6 square metres per plant in the field (Ortiz *et al*., 1995). In East Africa the International Institute of Tropical Agriculture (IITA) and the National Agricultural Research Organization in Uganda have been the major breeding programmes using conventional methods. The two programmes have been trying to overcome the obstacles of the banana crop mentioned above by screening germplasm for fertility, manipulating ploidy and intensive application of tissue culture techniques (Vuylsteke et.al., 1997). The main constraint associated with production of plantlets of improved varieties is the Banana Streak Virus (BSV) which evolves during tissue culturing. Certain hybrids (particularly plantain hybrids) have already been found positive for this virus, and are therefore not available for distribution.

A wide range of biotechnology tools have been developed to improve breeding efficiency in bananas. A comprehensive review of this is provided by Crouch *et.al*. (1998). In Uganda, work between the National Agricultural Research Organisation (NARO) and the International Institute of Tropical Agriculture (IITA) has identified 37 female fertile East African highland banana landraces, which produced scanty seeds on screening 84 of them using pollen from a highly male fertile diploid Calcutta 4 (*Musa acuminata* ssp. *burmannicoides*). Nakabululu and Nfuuka clone sets were found to be more female fertile yielding 5.06 and 5.52 seeds per bunch respectively than Mbide, Musakala and Nakitembe clone sets which yielded less than one seed per bunch (Ssebuliba, 2002). In addition, some of the introduced cultivars particularly genome groups AAB and ABB were also found to be female fertile. The low female fertility and seed germination capacity of bananas make its improvement process very expensive and time consuming because several crosses must be made in order to obtain adequate quantities of seeds and subsequently seedlings.

Weediness and Invasiveness of bananas

Cultivated bananas have been domesticated for quite a long time that they cannot survive for long in abandoned fields. However, being vegetatively propagated, their underground corms enable them to stand draught and weedy conditions for a limited period of time. Baker (1965) described the characteristics of weeds among which there is “discontinuous germination and long-lived seeds” which is exhibited only in wild bananas. Since, non-seeded edible bananas are not considered as weeds in agricultural production, weediness is not an important factor for bananas. In addition, bananas are not invasive since they survive under conditions of strict management. If bananas persist in fields in an invasive manner, they can be controlled by chemical methods, manual or mechanical removal from undesired fields.

Mode of Gene Escape in Banana

Cultivated bananas and plantains evolved from the intra and/or interspecific hybridisation of two wild species, *Musa acuminata* Colla that originates from Malaysia and *M. balbsiana* Colla originating from Indochina (Vuylsteke et al., 1997). As a result of natural hybridisation, a range of diploid cultivars designated as AA evolved. Triploids AAA were generated from AA by chromosome restitution while inter specific hybridizations between *Musa acuminata* (AA) and *M. balbsiana* (BB) gave rise to various groups like AB, AAB and ABB. Hybridization has been accomplished artificially by cross-pollination to produce genome groups like AABB, ABBB, and AAAB. In such cases no flow of transgenes is possible among the triploids since they are generally sterile while the developed hybrids (tetrploids) are clonally propagated. In bananas, it is clonal propagation and the system of disseminating plant material rather than gene flow that would cause risk of resistance evolution for transgenic bananas (Melinda et.al. 2006).

Wild Relatives of banana in Uganda

Although wild diploids are known to occur only in Asia, a few diploids were incidentally found in the coastal zones and on humid slopes of some hills and mountains in East Africa (De Langhe, et.al. 2001). One diploid ‘Paka’ was used in the ‘Gros Michel’ breeding programme in Jamaica (Simmonds, 1966). However, the diploids known to exist in Tanzania and Uganda are not wild plants but cultivated and edible types that have no female seeds and are sterile.

The other sexually compatible wild relatives of bananas available in Uganda are *Musa ornata* Roxb. and *Musa acuminata* ssp.*zebrina* nom.nud. used as ornamental plants in very few flower gardens and *Musa balbsiana* Colla and *Musa acuminata* ssp. *burmannicoides* (Calcutta 4) restricted to research stations for breeding purposes. However, the seeds of these banana relatives have a very low germination potential if planted directly in the soil. Therefore they are vegetatively propagated, thereby limiting the possibility of transferring transgenic traits into their subsequent generations.

Banana Pests and Diseases

It is now two decades since banana production in East Africa started declining. This decline in banana performance has been attributed to damage by pests, diseases and poor soil fertility (Gold *et al*., 1994; INIBAP Report, 2003). In Uganda for example, the average yields have dropped from 8.5 tonnes per hectare per annum in 1970 to the current level of about 5.7 tonnes per hectare per annum. Research work on various aspects of pest, disease, and soil complexes are already being carried out in different East African countries but effective and sustainable control of the given constraints can only be achieved by an integration of methods which can interrupt life cycles of pests and pathogens and also alter their population dynamics. Major pests and diseases affecting bananas include the following:

Banana weevil

The banana weevil *Cosmopolites sordidus* Germar (Coleoptera: Curculionidae) is a major insect in all the banana and plantain growing areas of the world (Waterhouse and Norris, 1987). It is associated with yield losses of up to 50% even to 100% in severe infestations which may lead to total crop failure (Mitchel, 1980; Sengooba, 1986). The larvae bore tunnels in the corm from where they inflict serious damages to the banana. Plants affected by weevils are characterized by: splitting of leaf sheaths, tunnelled corms and pseudostem snapping. Serious weevil attacks may lead to massive toppling of bananas. Other detrimental effects of weevil infestations include: premature plant death, stunted growth, delayed fruit maturation, production of small bunches, reduced number of suckers, reduced sucker vigour and development of water suckers (Abera *et al*., 2000). Weevils are more destructive in low land areas than highlands, and cease to be a problem beyond 1500 m above sea level due to the reduced temperatures.

Nematodes

These are microscopic worms exhibiting a parasitic effect on a number of plants including bananas. Parasitic nematodes can be of three broad categories; the root or aerial parasites, the ectoparasites or endoparasites and either migratory throughout the life cycle or sedentary for at least part of female development. All the important species that feed on bananas are root parasites. *Pratylenchus goodeyi* (Cobb) Sher and Allen*, Radopholus similes* (Cobb) Thorne *and Helicotylenchus milticinctus* (Cobb) Golden, are migratory endoparasites. Both *Meloidogyne* species and *Rotylenchulus* are sedentary endoparasites. These differences have implications for both the type of damage caused and appropriate biotechnology for their control (Caswell et al., 1990; Starr and Page, 2000) Nematodes attack roots, causing lesions thereby reducing water and nutrient uptake to the upper parts of the plant and also paving way to pathogenic micro organisms. Nematode infestation is characterized by poorly developed root system, production of small poorly formed bunches and plant toppling (complete uprooting of the plant including the corms). The most damaging species on bananas include: *Radopholus similis* (Cobb) Thorne (Kashaija *et al*., 1994)*, Pratylechus coffeae, P. goodeyi* (Namaganda *et al*., 2000) and *Helicotylechus multicinctus*.

Banana bacterial wilt (BBW) disease

BBW is caused by a bacterium called *Xanthomonas campestris* pv. *musacearum*. The disease affects all types of bananas including: East African highland bananas and the exotic (dessert/beer) bananas. The major characteristics of the disease are yellowing and complete wilting of the plant starting with the most peripheral leaves (Tushemereirwe *et al.,* 2003). The fruits exhibit discolouration of the pulp when sectioned. After wilting the leaves tend to droop and the plant eventually stops growing and dies. Secretion of bacterial ooze can be seen on leaves. The most common symptoms are wilting and premature ripening of the bunch in addition to male bud wilting and sometimes discoloration.

Fusarium wilt

Fusarium wilt (Panama disease), caused by a soil borne fungus *Fusarium oxysporum* Schlecht. f.sp *cubense* (E.F. Smith) Snyd. and Hans. is a typical vascular disease causing disruption of translocation and systemic foliage symptoms in bananas, which eventually lead to collapse of the crown and pseudostem (Jeger, et.al., 1995). Symptoms generally commence as premature yellowing of the oldest leaves which develops as a band along the margin and spreads towards the midrib. The leaves hang between the pseudostem and the middle of the lamina while still green. The leaves wilt, the petiole buckles and spreads towards the midrib. All the leaves eventually collapse where the petiole joins the pseudostem and die (Rawal, 1996). *Fusarium* f.sp. *cubense* is also capable of infecting and surviving on a wide range of alternative hosts, including coffee and maize, both of which may be intercropped with bananas. As a result, disease diagnosis and development of control strategies, involving the use of plant varietal resistance is hampered by difficulties encountered in identification of alternative hosts and relevant pathogenic forms present. *Fusarium* wilt affects only exotic banana cultivars Gros Michel (*Musa* AAA), Kisubi (*Musa* AB), Sukali Ndizi (*Musa* AAB) rather than the indigenous East African highland bananas (*Musa* AAA-EA).

Black Sigatoka

This is the most important foliar disease in bananas, caused by an air borne fungus called *Mycosphaerella fijiensis* Morelet and causes yield losses of 30-50%. The majority of exotic bananas together with all the East African highland bananas are susceptible to black Sigatoka. The symptoms are reddish-brown streaks which first appear on the under leaf surface ten to fourteen days after infection and later enlarge to black streaks visible on both leaf surfaces. Streaks later develop into fusiform patterns of dark brown to black lesions with water soaked borders surrounded by yellow leaf tissue. Finally centre of the lesion dries out to light grey, but a narrow dark brown or black border persists giving eye spot appearance. Necrotic lesions may coalesce to form large areas of dead tissue, causing leaves to wither and collapse (PQL, 1982). The plant affected by black Sigatoka has a scorched appearance while the unfolded heart leaf and the two youngest leaves do not show the symptoms (Rawal, 1996). Black Sigatoka causes great amount of damage to foliage which reduces substantiality the amount of fruit produced on affected plants. The symptoms of black Sigatoka are very similar to those of common or yellow Sigatoka caused by *Mycosphaerella musicola Leach.* This disease can only be distinguished from black Sigatoka in the very early stages of development on the basis of their conidia and conidiophores (Johanson and Tushemereirwe, 2000). Initial streaks of common Sigatoka appear yellowish-green and are visible more on the upper leaf surface. *M. fijiensis* is more virulent than *M. musicola* and has a shorter life cycle. Both the two diseases are economically important throughout the world, but where black Sigatoka exists; it eventually displaces yellow Sigatoka and can be more devastating (Fullerton and Stover, 1990).

Banana Streak Virus (BSV)

Banana Streak virus (BSV) is a member of the genus *Badnavirus*, a double stranded DNA virus with bacilliform particles. Banana streak disease is caused by BSV and occurs wherever bananas and plantains are grown (Lockhart et.al., 1995). Symptoms appear as yellow and necrotic leaf streaks, lethal stem necrosis, pseudostem splitting and choking in which fruit bunches may fail to emerge from pseudotems. Severely damaged plants may have reduced bunch size and misshapen fruits. The disease is disseminated in vegetatively propagated planting materials such as corms, suckers and tissue derived plants. In the field it is also transmitted in a semi persistent manner by the citrus meal bugs (*Planococcus citri* Russo) (Ndowora and Lockhart, 2000). BSV gained importance in Uganda when it broke out in Masaka and Rakai districts causing damage to almost 50% of the crop grown in those areas (Karugaba and Kimaru, 1999). The disease is difficult to control since it is much more associated with vegetatively propagated materials. It is recommended that clean planting materials on clean fields should be used while restriction is put on the transportation and spreading of planting materials from affected areas through quarantine. These recommendations can reduce the spread of the disease.

Banana propagation, growth requirements and agronomic practices

Edible bananas do not produce seeds and therefore are clonally propagated using a number of methods. The methods include; tissue culture derived plantlets, suckers and split corms sometimes called bits. For good establishment sources and selection of suckers are very important. A new and most promising planting material consists of in-vitro plants which are small suckers produced from meristem culture (Swennen, 1990). Planting materials can also be collected from an existing old field, and or a multiplication plot planted only for the production of suckers. Seed propagation is only possible in wild bananas which produce vast seeds from open pollinations.

Bananas are mostly cultivated between 30° N and S of the equator demanding a mean monthly temperature of 27ºC for optimal growth. They do shrive in both low and high altitudes for instance plantains grow well in lowlands while the East African highland bananas (matooke) survive at altitudes between 1000 and 1800 metres above sea level. Bananas require well distributed rainfall of an average of 2000 to 2500 mm through out the year and short dry seasons. Although bananas can be grown on a wide range of soils, deep well drained retentive loam soils, with high humus content are the best (Zake, et.al. 2000). Bananas require considerable amounts of mineral nutrients to maintain yields. Nitrogen, potash and phosphorus are the major nutrients required in bulk quantities and can either be supplied by fertile soils or by commercial fertilizers.

Furrowing and mulching are very necessary to control soil erosion and soil moisture conservation. Mulching can also improve soil fertility as well as controlling weeds at the same time. Sources of mulch can consist of elephant grass (*Pennistum purpureum* .L), dried weeds and kitchen refuse. Weed control is an important operation from planting time onwards. Once plants are as tall as 1.5 meters high, herbicides registered for use on bananas can be applied. These include ametryne, simazine, diuron, paraquat and glyphosate (Robinson, 1995). Weeds particularly perennial grasses such as couch grass should be controlled by spraying with systemic herbicides like glyphosate. However, Glyphosphate, diuron and gramuron are not recommended for plantains because they can be phytotoxic (Swennen, 1990).

Although bananas can have good yields as a mono crop, they are mainly intercropped with annual crops such as beans and groundnuts or perennial crops like coffee and cocoa. The usual spacing is 3 x 3 metres when planted as a mono crop but it is adjusted when intercropped. The average size of the hole required for planting bananas is 60 cm wide and 60 cm deep

Suggested Reproductive Isolation

Conventional breeding programmes for bananas have been extremely limited due to the inherent sterility of the crop (Vuylsteke et.al., 1997). Genetic engineering offers one of the few possibilities of introducing resistant genes into the local varieties. Since the majority of bananas are sterile or with very low levels of female fertility, the risk of gene transfer from genetically engineered bananas into the environment and or from one population to the other through cross pollination is very low. However, in order to exclude any possibility of this phenomenon, there is need to do bagging at shooting (emergence of the inflorescence) coupled with timely removal of the male bud from the plants to be tested (GMOs). The isolation distance between the field of genetically modified plants and any other banana population might not be of much importance to the reproductive nature of bananas, however to eliminate any risks associated with out crossing, bananas should only be planted at a distance not less than 200 m from the confined field trial. Furthermore, the trial needs to be separated from other fields by physical barriers such as chain links.

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