FNCA／MEXT
Technical Material

Achievement

Sub-Project on Disease Resistance in Banana

(2004 – 2010)

Mutation Breeding Project

Forum for Nuclear Cooperation in Asia (FNCA)

March, 2011

Preface

Banana (*Musa* spp.), as dessert fruit and plantains for cooking, is one of the most important crops in tropical and sub-tropical countries. In many Asian and African countries, bananas are important staples next to rice, wheat, and maize. According to FAOSTA, the total production of bananas in the world accounted to 95.6 million tons in 2009. Currently, banana is one of the major fruit crops in the international market. According to FAOSTAT the total world export of banana was 18.0 million tons in 2008. Japan imports about 1 million tons in 2008 making the fourth biggest importer of bananas next to USA, Belgium and Germany. At present, India is the number one producer of banana but the product is consumed domestically to meet the high demand for bananas. For countries such as the Philippines, the third biggest exporter of bananas after Ecuador and Costa Rica, banana generates income and sustains food security for small holder farmers and workers in plantations. Meanwhile, the various production systems, consumption and trading forms, and genetic diversity of cultivated bananas are not well established because the popular banana varieties and cultivars used in each countries and in the international markets are limited. Hence, the limited genetic diversity in bananas makes them prone to pests and diseases. Likewise, it is difficult to find genetic sources for breeding of disease resistant varieties. As most bananas are propagated vegetatively, conventional cross breeding is not possible due to its sterility. With this, mutation breeding is a promising tool to improve banana varieties.

Presently, there are four major diseases threatening the global banana production. These are Fusarium wilt or Panama disease caused by a fungi, *Fusarium oxysporum* f.sp. *cubense* (Foc), black leaf streak diseases or black Sigatoka caused by a fungi, *Mycosphaerella fijiensis,* bacterial wilt caused by *Ralstonia solanacearum* together with recently emerged *Xanthomonas campestris* pv. *musacearum*, and banana bunchy top disease caused by *Banana bunchy top virus* (BBTV). As diseases cause serious and expanding threat to banana, farmers and producers straggled to overcome this problem. The current practice to overcome the problem such as cultural control and chemical application however remain partial in controlling these diseases. We conducted mutation breeding to produce Foc and BBTV resistant lines.

The Mutation Breeding Project focused on the improvement of Fusarium wilt and BBTV resistance in banana as a sub-project developed through the Forum for Nuclear Cooperation in Asia (FNCA), organized by the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT), in 2003. The sub-project was established in collaboration with member countries including Malaysia, the Philippines, Vietnam and Bangladesh with partial collaboration of Indonesia. With the termination of the sub-project we are happy to publish a book entitled Achievement of Sub-Project on Disease Resistance in Banana. Primarily, the book aimed at maximizing the mutation breeding technology through gamma-ray irradiation.

We strongly hope that the outcome of this sub-project such as the developed promising lines, technologies and information which we shared and human network built during the project implementation will benefit the banana farmers and researchers in Asia. We also expect that this book will be useful not only for the breeders interested in gamma ray induced mutation breeding but also for the breeders of bananas.

Finally I would like to express my gratitude to the contributing authors for their achievements in this sub-project. Special thanks are due to individuals who cooperated generously in doing experiments inside and outside of the laboratories. We acknowledged Dr. H. Nakai, our Project Leader, Dr. H. Nakagawa, former Project Leader, for their academic support and the assistance given by the staff of FNCA, Japan.

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March, 2011

Content

1. General Background

1.1 Banana production

1.1.1 World

Musa spp., banana and plantain, constitute the fourth most important staple food commodity of the world, after rice, wheat and maize. In Asian and Pacific regions, banana has great socio-economic significance. The region is the major centre of diversity and most of the edible bananas are believed to have originated in South-east Asia and Western Pacific regions. Cheesman (1948) first suggested that cultivated bananas originated from intra and interspecific hybridization between the two wild diploid species *Musa acuminata* Colla. and *Musa balbisiana* Colla., each contributing the A and B genomes respectively. Through complex hybridization events between two species, *Musa acuminata* and *Musa balbisiana*, we have now banana cultivars with acuminata characteristics (AA, AAA, AAAA), balbisiana characteristics (BB, BBB, BBBB) and both acuminata and balbisiana characteristics (AB, AAB, ABB). Likewise, cultivated bananas are referred to by their genome groupings. The crop encompasses a range of diploids, triploids and tetraploids. The identification of *Musa* cultivars has traditionally been based upon various combinations of morphological, phenological and floral criteria. Simmonds and Shepherd (1955) devised a scoring technique based on 15 diagnostic morphological characters to differentiate *M. acuminata* clones from *M. balbisiana* cultivars and their hybrids into 6 genome groups. According to this system, cultivated dessert and East-African highland bananas are classified as AAA whilst plantains are AAB. Though in local consumption, diversified banana cultivars are maintained and used in banana trade, Cavendish subgroup (AAA) is an extremely important. There exist other genome combinations, for example ABB and ABBB. They occur naturally or are produced by artificial hybridization (Stover and Simmonds, 1987).

Banana is now distributed in most of tropical and sub-tropical countries. The world production of banana was about 95 million tons and most of the production was consumed locally (Ganapathi et al., 2002). Meanwhile, two decades ago the world banana and plantain productions are of 41 and 20 million tons respectively (FAO, 1984). This indicates that the world banana production trends increasing significantly as staples and export commodity. Recent FAOSAT (2008~) tells that total banana production in the world was 96 million tons in 49 million ha in 2009. In South-east Asian countries produce 19.0 million tons. Major banana exporting countries are Ecuador (5.2 million tons), Costa Rica (2.0 million tons), the Philippines (1.9 million tons) followed by Colombia and Guatemala. We also notice, however, that in many Asian and Pacific countries, bananas are mainly consumed domestically. India, for example, is not a banana exporting country but the largest banana producer in the world with 26 million tons followed by the Philippines (8.6 millions tons) and China (8.0 millions tons). As banana importing countries, many non-banana producing and developed countries are listed such as USA (4.0 million tons) and Japan (1.0 million tons).

Production and horticultural characteristics of bananas are well documented by Robinson and Sauco (2010). Status of Banana production in each participating country is as follows.

1.1.2 Bangladesh

Banana is one of the most important food and cash crop in Bangladesh and grown around the year in the country as a commercial purpose and homestead area for local consumption. In addition, banana stood first position among the fruits producing in the country and supplies 42% of the total fruit requirements in the country and also its financial return as a crop is higher compared to other fruits and field crops (Haque, 1988b). Banana is the first cultivated crop in South-east Asian region (Sauer, 1952). The first report in banana cultivation came to know from Indian subcontinent region (Reynolds, 1951). The first user of banana is known to South-east Asian countries (Simmonds, 1966). It is also a nutritious fruit crop in the world and grown in many tropical areas where they are used both as a staple food and dietary supplements (Assani *et al*., 2001).

In Bangladesh, total banana production in year the 1999-2001 was about 0.580 million tons but it increased to 0.654 million tons in the year 2003 (FAO, 2004). In the year 1975 - 1976, the total banana cultivated area was 37,200 ha and it was increased to 49,280 ha in the year 2003 - 2004 and total production was increased 0.5691 to 0.7065 million tons due to increasing cultivated area but yield was decreased during those days from 15.07 t/ha to 14.33 t/ha due to constrains of banana cultivation (BBS, 1980, 2003). The average yield of banana in the country is about 15 t/ha that is far below the average world yield 30.63 t/ha in India (FAO, 2006 - 2007). Through banana cultivation in the country the net income per hectare at about TK. 297,690/= ~USD 4,252.7 (Haque, 2008). The total per capita consumption is about 4.7 kg. This is very much lower than that consumed by Europe especially Belgium (26.7 kg), Sweden (16.7 kg) and Germany (14.5 kg) while USA consumed 13.1 kg and UK at 10.5 kg (Siti Hawa, 1998). Thus the potential for expansion of banana cultivation and increase per hectare yield is needed in the country. Although bananas are important export commodities of some developing countries in Africa, Latin America and the Asia, unfortunately Bangladesh is not exporting country but bananas are consumed by locally. Banana is a very versatile crop. The whole plant or fruit, leaves, stem and other plant parts play a major role in the daily activity or use by the local population where they have multiple uses. While some of the uses form part of the daily activity of the population such as food wrapper, whole plants at ceremonies, landscaping, pharmaceuticals, rope, paper and viable commercial industry.

There are 32 landraces including dessert and cooking banana cultivar in Bangladesh (Haque, 1985a). The popular dessert bananas in the country are Amritasagar (AAA), Sabri (AAB) and Champa (AB) but their yield is not satisfactory. Moreover, the second leading commercial cultivar Sabri (AAB) is highly susceptible to Panama disease (Fusarium wilt) and total crop failure due to this disease has been reported. A local seeded cultivar Bichikala (BB) derived from the wild species of *Musa balbisiana* (BB) is resistant to most of the diseases. But the main constrain of the fruit is that it contains huge number of seeds that makes them less popular to the local people. The cooking cultivar is locally called Anajy kala (ABB).

Sabri AAB

Sagar AAA

1.1.3 Malaysia

Bananas (*Musa* spp.) are amongst the most important food crops in the world. Global banana production has been estimated to be about 99 million tons annually, mostly produced by tropical countries (FAO, 2003). Banana is one of the important fruit crops cultivated in Malaysia. It is ranked second in terms of production area and fourth in export revenue based on the balance of trade figures. This crop will remain as an important industry, emphasis given to this crop in addition to the other fruit types listed under the National Agricultural Policy.

In Malaysia, banana is the second most widely cultivated fruit, covering about 26,000 ha with a total production of 530,000 metric tones with more than 15 % of the yearly production and a balance of trade of more than RM30 million (US$8 million). About 50 % of the banana growing land is cultivated with Pisang Berangan and the Cavendish type. However, banana production in Malaysia has decreased because of an increasing threat of diseases (particularly Fusarium wilt), high labor costs and marketing issues. However, it is still popular grown and contributes about 16 % of the total fruit production areas. Banana remains the second most important fruit crop (after durian) in Malaysia, amounting to about 15% of the total acreage under fruits. Traditionally, it is planted as a cash crop or temporarily intercropped with oil palm, rubber and other perennial crops. There are only a few large banana plantations in Malaysia. The popular dessert cultivars are Mas (AA), Pisang Lemak Manis (AA), Berangan (AAA), Rastali (AAB), Embun (AAA) and Cavendish (AAA); while the popular cooking cultivars are Nangka (AAB), Raja (AAB), Awak (ABB), Abu (ABB), Tanduk (ABB) and Relong (AAB). Most of the bananas produced were consumed locally and about 10% are exported, mainly to Singapore, Brunei, Hong Kong and the Middle East.

Banana cultivation is largely a smallholder enterprise where farms are small, unorganized and farmers often adopt inferior technology. Apparently, this production practice often results in low yield and inferior quality. Poor quality has been a major constraint to export of fresh fruits, including banana. It is therefore necessary to adopt good production practices and inefficient postharvest handling to ensure consistent supply of high quality banana for export. Efforts are being undertaken to more than double the production figures in the next 5 or more years. It is envisaged

that this can be achieved through increasing the production areas, increasing the yield per unit area and enhancing the production technology.

Popular Dessert Bananas

Pisang Mas (AA)

Pisang Lemak Manis (AA)

Pisang Berangan (AAA)

Pisang Rastali (AAB)

Pisang Embun (AAA)

Pisang Cavendish (AAA)

Popular Cooking Bananas (Plantain)

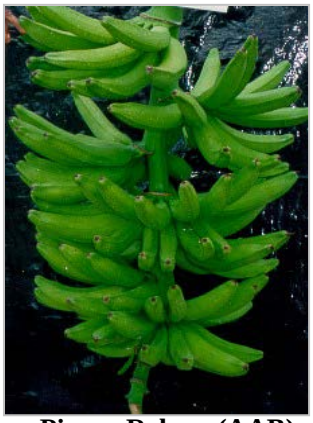
Pisang Nangka (AAB)

Pisang Awak (ABB)

Pisang Abu (ABB)

Pisang Raja (AAB)

Pisang Tanduk (AAB)



Pisang Relong (AAB)

1.1.4 Philippines

Banana is one of the most important fruit crops in the Philippines both for domestic and export markets. The total area for banana production amounts to 446,371 ha with a total production of 9.01 million metric tones valued at about 16 billion pesos (BAS, 2010). %. Banana is grown in all parts of the country with the export banana grown mostly in southern Philippines. More than 75% of the banana producers are small-scale farmers engaged in local or domestic production.

The three major banana cultivars are Saba (BBB) a cooking banana for domestic and export market (banana chips), followed by Cavendish banana (AAA) dessert banana mainly for export, and Lakatan (AA) dessert banana grown for domestic market and as novelty banana for the export market. Of the total banana production of the country, Saba cultivar contributes about 41.5%, Cavendish 17.4% and Lakatan 12.6%. Lakatan is the most popular dessert banana grown for domestic market with a total area of production of about 57,000 hectares and production volume of 0.92 million metric tones (BAS, 2010). The area planted to Lakatan has increased by more than 3,000 has in the last three years (BAS, 2010).

<u>Major banana cultivars grown in the Philippines</u>

Saba (cooking banana)

Cavendish (dessert banana)

Lakatan (dessert banana)

1.1.5 Vietnam

Banana has been grown for thousands of years in Vietnam. It is now one of the most important fruits growing in Vietnam. Its total cultivated area is estimated at 99 340 ha and production is about 1.2 million tons 20% of which are for exportation. The banana cultivation is based on small-scale garden, usually surrounding the household, and on hillside. The common size of banana gardens ranges from 0.2 - 1.0 ha. Bananas are intercropped with other crops like maize, soybean, sweet potatoes or fruit trees. Compared with sole banana gardens, the productivity is lower in mixed banana gardens. The average yield is about 10 - 15 t/ha, depending on the region and the farmer's cultivation level.

The popular banana cultivars in Vietnam are as follows;

Chuoi Tieu (AAA/Gia): This Cavendish group consists of the most popular banana cultivars in Vietnam, which can be divided according to three different plant height; tall (2.8 - 3.5 m), medium (2.0 - 2.5 m) and dwarf (1.5 - 2.0 m). They are grown alongside rivers and highly humid areas. They give high yields of 20 - 25 kg/bunch, with 8 - 14 hands/bunch. Its fruit size is 2.8 - 3.5 cm. Ripened fruits are sweet and aromatic and have yellow skin and flesh. In the North, during the winter, the ripened fruits have a better quality compared with those grown in the South. Its growth duration is 14-15 months. Chuoi Tieu is used for export and local market.

Chuoi Tay (ABB, Xiem): It is planted throughout the country, from the delta to hilly regions. Its pseudostem is 3 - 4 m long. It gives high yield with 18 - 20 kg/bunch, 8 - 12 hands/bunch. The fruit size is 9-11 cm long and 3.0 - 3.5 in diameter. The ripe fruits have dark yellow skin and yellow, sweet and aromatic flesh. Sometimes, there are few seeds in the fruits. Chuoi Tay is tolerant to drought and poor soil. Chuoi Tay is used only for domestic consumption. They also can be eaten as fresh or processed as candies, cake, boil, etc.

Chuoi Ngu (AA, Cau); It is one of the most preferred varieties because of its special characteristics. Pseudostem is 2.2 - 2.6 m long. Normally, its yields are 8 - 10 kg/bunch with 6 - 8 hands/bunch. The fruit size is 7 - 10 cm long and 2.5 - 3 cm in diameter. Ripened fruits have attractive bright yellow and pink, color and a sweet and aromatic flesh. The growth duration is 12 months.

Chuoi Ngu Tien (AA); In the olden days, this variety was used as precious donations to the kings which is why the variety was given the name Tien (donation- Dai Hoang). The fruit's characteristics and growth duration are similar to those of Chuoi Ngu but its fruits have a very attractive form and color and the flesh has better quality. Pseudostem is 1.5 - 2 m in height. These cultivars are grown nowadays in Nam Ha province.

Chuoi Bom (AAB); It has a high tolerance to drought and is grown 137 popularly in the central highlands. It has a short growth duration (10 - 12 months) and high multiplication rate (8 - 10 suckers/plant). Its yield is 6 - 10 kg/bunch with 6 - 8 hand/bunch. Fruit size is 10 - 15 cm and 2 - 2.5 cm in diameter. Ripened fruits have bright yellow thin skin and yellow pink flesh, and are suitable for processing to make dried banana. These popular banana cultivars are shown in Figure 2 (Nhi 1997). There are some other cultivars such as Chuoi Com (AA), Chuoi Bot (AAB), Chuoi

La (ABB), Chuoi Mat (AB), scattered over the different areas. These can be used as feed, cake draping etc.

1.2 Major constraints of banana production

1.2.1 World

Banana infected by Fusarium wilt disease

Among many constraints in banana production in the world as well as in Asia, two diseases are targeted in this Sub-Project. They are Fusarium wilt caused by *Fusarium oxysporum* f. sp. *cubense* (Foc) and Banana bunchy top disease caused by *Banana bunchy top virus* (BBTV).

Fusarium wilt often known as Panama disease is very famous and destructive disease. Since the disease was first reported in Australia in 1876, the symptoms such as wilt and collapse of leaves, as well as discoloration of vascular system, cause serious damage in many banana-producing countries in the world. At the first pandemic of this disease in the 1950s, the production of a susceptible variety, Gros Michel, was almost wiped out in Central America. Cavendish (or varieties in Cavendish subgroup), then introduced as a resistant variety, is now susceptible to a specific race of Foc. Among three races of Foc, which attack bananas, race 4 is most pathogenic and affects many susceptible banana cultivars including Cavendish. The pathogen, Foc, can be disseminated through suckers, soil, water, and by farming practices when farmers use contaminated tools. Chemical control, such as soil fumigation, is promising measure but give strong impact to the environment. As the pathogen persists in the contaminated soil by producing chlamydospores even in the absence of the host bananas or sometimes by infection of roots of some weeds. As a result, once the field is invaded by Foc, the field cannot be used for banana production up to 30 years. Resistant varieties and/or clones have been produced but not many of them are favorable and marketable in local and international markets.

Typical banana bunchy top disease symptom showing yellowing and erected leaves.

BBTV, a virus species in the genus Nanovirus, has been reported in many banana-producing countries in Asia, Africa, and Oceania but not in Central and South America. The virus is transmitted in a persistent manner by banana aphid (*Pentalonia nigronervosa*) and through vegetative propagation. Cultural control such as rogueing infected plants, control of aphids by pesticides, and replacement by virus-free seedlings if available, is only practical measure taken at present. Thus, once the virus invaded and established in the area, it is almost impossible to manage the disease.

Conventionally protection against banana diseases may account for more than 40% of the total production cost and the farmers without good access to chemicals have to cope with yield declines of 30% or more (Sagi et al., 1998). The difficulty in control of these two diseases, Fusarium wilt and banana bunchy top disease, requires the production of resistant varieties. To follow the preferences of farmers, traders, and consumers, mutation breeding is most promising because mutation breeding realizes the rapid production of new resistant varieties with the favorable traits in original ones. Jain and Swennen (2004) reviewed banana improvement technologies including gamma irradiation.

1.2.2 Bangladesh

There are several non-biological and biological constraints affecting banana production in the country and abroad. Out of them a few can cause serious economic losses. Banana is mainly tropical crop and 27°C temperature is optimum for normal growth and development. If temperature raised above 38°C the growth and development stopped and if temperature fall down to below 10°C then crop period extended and reduced the bunch weight (Haque, 2008). Draught, water logging condition and in adequate sun light also cause crop damage and yield loss. At present no non-biological resistant variety developed yet although in Bangladesh the cultivar Bichikala (BB) have some degree of tolerant to insect-pest-diseases and draught and also water logging condition. Biological constraints such as insect-pest-diseases are also cause serious damage and yield loss of banana. The most damaging of the fungal disease is panama disease or Fusarium wilt caused by *Fusarium oxysporum* f. sp. *cubense* (Foc). Infection by this fungus will result in yellowing and wilting of the leaves which eventually turn brown, the leaves will dry up and hang from the plant and eventually the plant dies. Longitudinal sections of the pseudo stem will show sign of vascular discolouration and this discolouration will be more distinct in the corm tissue. Most of our cultivars are more or less susceptible to this disease. Among the cultivars, Sabri (AAB) is highly susceptible to this disease. At present no resistant variety developed against this disease in the country and abroad and chemical control also is not available. Foliage of banana is susceptible to sigatoka leaf spots. *Mycosphaerella fijiensis* causes black sigatoka and *Mycosphaerella musicola* causes yellow sigatoka disease is considered as the most serious disease of banana resulting in yield loss. In Bangladesh, Amritasagar (AAA) is susceptible to this disease. *Ralstonia solanacearum* (*Pseudomonas solanacearum*) causes Moko disease is similar to Fusarium wilt also resulting yield loss, which not very often have seen this disease in the country. Many plant parasitic nematodes were associated with banana plants in the world. The most common nematodes are *Meloidogyne* spp., *Rotylenchulus reniforms*, *Helicotylenchus dihystera* and *Radoholus similes*. Those are reported to be the most damaging in banana producing countries (Stover and Simmonds, 1987). In Bangladesh *Radopholus similes* is very common and our most of the banana and plantain cultivars are affected by this nematode (Haque, 2008). There are a number of virus diseases of economic importance affecting banana production worldwide. *Banana bunchy top virus* (BBTV) is reported to be affected by some of our cultivar. The virus is transmitted by aphid. Banana leaf and fruit beetle

and also pseudo stem borer causing yield loss and reduced market value. In ensuring high quality banana for the consumers, post-harvest diseases must be controlled to prevent rotting and losses during handling and storage. Bananas after harvest can be infected by anthracnose, crown rot, fruit rot and neck rot (Nik Masdek *et al*. 1998). In Bangladesh more or less we are having those diseases in bananas. At present against those diseases has the precaution measure and chemical control. Low reproductive fertility and slow propagation rate is also one of the constraint of banana production.

1.2.3 Malaysia

In Malaysia, banana production by smallholders involving small farm sizes are not well organized and with low inputs and poor quality planting materials, thus resulting to lower yield and fruit quality. The large scale growers uses better quality planting materials (disease-free tissue cultured plantlets) and higher inputs; and adopt more modern technologies, good agricultural practices and better pest and disease management, thus, higher yield and better quality fruits. In Malaysia, the diseases caused by fungi and nematodes are the major limiting factor in successful quality production of this crop and almost all the commercial cultivars of banana are highly susceptible to certain deadly diseases.

The most serious constraint to the production of banana and plantains is considered to be Fusarium wilt or Panama disease caused by *Fusarium oxysporum* f. sp. *cubense*, a soil-borne disease which affects many important cultivars of banana and plantain. The disease has caused serious crop losses in Malaysia and it is a devastating disease of banana worldwide. Most of the cultivated clones originated as spontaneous variants are highly susceptible. Pisang Berangan is susceptible to *Fusarium oxysporum* f. sp. *cubense* Foc Race 1 and very susceptible to Foc Race 4. Infection occurs through roots and progresses to the pseudostem. Symptoms are internal stem necrosis (reddish or reddish-brown xylem), root and rhizome rot, yellow leaves, plant wilting, and plant death. Plants may die during flowering or during periods of moisture stress. The fungus may survive for a long period of time in the soil.

Field evaluation of disease-tolerant banana plants in soil infested with *Fusarium oxysporum* f. sp. *cubense* (Foc) is highly effective. However, it is slow because disease expression usually takes 4-5 months; and factors affecting disease expression such as inoculum concentration, edaphic conditions, temperature and other variables are difficult to control. An alternative method of pre-screening of seedlings at the nursery stage turned out to be effective and can greatly save cost, labour and time. Only those that showed no symptoms of infection from *Fusarium oxysporium* were further planted and screened in the field.

Black sigatoka or black leaf streak *caused by Pseudocercospora fijiensis* (syn. *Mycosphaerella fijiensis*) is another serious disease of banana in Malaysia. It is globally distributed and epidemic in many locations and is the most important disease of *Musa* worldwide. Common symptoms develop are reddish-brown streaks appear initially on the undersides of the third or fourth youngest leaf; streaks develop into elongated spots with gray or tan centers and dark brown to black margins; lesions may be surrounded by yellow halos; lesions may coalesce to form large, blighted areas of

leaves in parallel with leaf veins, or bands of dark streaks, causing leaves to turn brown and wither. Significant defoliation may occur whereby a banana plant may have only a few or no green (disease-free) leaves upon flowering. Chemicals can be used to control the pests but as the costs, both economically and environmentally, continue to rise, the need for resistant cultivars as the main component of an integrated system for pest management, becomes imperative.

Nematodes are also considered as major causes of diseases of banana in Malaysia. The root-knot nematodes (*Meloidogyne* spp.) and the burrowing nematode (*Radopholus similis*) can significantly weaken root systems, reduce yields, topple plants before harvest, make plants more prone to wind knockdowns, reduce fertilizer uptake and thereby reduce the banana-growing lifespan. Nematodes can be managed by using clean (nematode-free) planting material, heat treatment of planting material, pre-plant soil fumigation, crop rotation, mulching and composting, fallow, chemical nematicides, plant propping, fertilizer use, and varietal resistance.

1.2.4 Philippines

Banana bunchy top virus (BBTV) remains as the most destructive virus disease of banana (*Musa* spp) in the Philippines. It causes stunting and leaf malformation that leads to premature death of infected plant, thus causing yield losses of about 100%. The spread of the disease is greatly aided by an aphid vector, *Pentalonia nigronervosa*. Most dessert banana cultivars including Lakatan are very susceptible to BBTV.

While rapid propagation of disease-free planting materials is a viable disease management option for BBTV, its effectiveness is limited where residual or alternate inoculum sources are present. Regular replanting has to be done as the initially disease-free plants get infected within one or after a few growing seasons. Even in a well managed farm BBTV re-infection in the field ranged from 20-50%.

Another major problem of banana is the nematodes. Nematodes are present in most banana growing areas. The most common species associated with bananas are *Radopholus similis, Meloidogyne incognita*, *Pratylenchus* sp. and *Helicotylenchus multicinus*. Of the four species, *R. similis* is considered the most destructive as it causes root rotting leading to toppling down, reduction in bunch weight and death especially when younger banana plants are infected. In the field, when the number of *R. similis* reaches 4,000, a corresponding yield reduction of 60% is observed. On the other hand, *M. incognita* causes root galling, and reduction in bunch weight. Yield loss of 45% is obtained when the *M. incognita* reaches 10,000 larvae. In previous study, Lakatan is susceptible to both nematodes under screenhouse conditions.

1.2.5 Vietnam

In a survey conducted by D.V. Thanh in the north and by Nuong in the south Vietnam in 2000, a total of 19 pathogenic micro-organisms, 4 nematode species and several insects were observed on bananas grown in the field. The most important and popular banana cultivars in Vietnam belonging to genome group AAA/AA such as Chuoi Tieu, Chuoi Bom, Chuoi Ngu, Chuoi Cau and Chuoi

Com are affected by sigatoka and bunchy top diseases. The symptoms of *Banana streak virus* (BSV) are often recorded on Chuoi Cau Lun (AAB). Another important disease is Fusarium wilt caused by *Fusarium oxysporum* f.cp. *cubense* (Foc), which attacks on genome group ABB/BB. Presently, Foc also caused damage in Chuoi Cha Bot (AB/ABB). Major insect pests recorded to infect banana such as corm borer are considered to be very destructive. Banana aphids play an important role in spreading viral diseases. In 1997, Thanh *et al*. recorded that 28 nematode species are parasitic on banana with four important species: *Helicotylenchus* sp., *Pratylenchus coffeae*, *Meloidogyne incognita* and *Radopholus similis*.