Chapter 12
Abaca (*Musa textilis* Nee) Breeding in the Philippines

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Abstract Abaca (*Musa textilis* Nee.), a plant native to the Philippines, is the source of fiber known internationally as Manila hemp. It is indigenous to the Philippines whose favorable climatic condition and volcanic soils are suited to its cultivation. It is often used as raw material for cordage, clothing, and various handicrafts. Furthermore, the fibers can be manufactured into specialty papers such as currency notes, filter papers, stencil papers, and tea bags, among others. The abaca industry is a major dollar earner and an important export crop of the country. Due to the current concern for biodegradable products and forest conservation, it is expected that the abaca industry will continue to flourish in both domestic and international markets. With the advent of new uses of abaca, the crop will be extensively utilized for more industrial applications because it is a natural and superior material. The Philippine abaca industry continues to make a stronghold in both international and domestic markets generating US$80 M annually from 1996 to 2000. Being an export-oriented commodity, the country's abaca industry has maintained its status as the world's largest producer accounting for 97 % share of world imports. However, the abaca industry is still relying solely on traditional varieties, and due to limited attention devoted to sustained varietal improvement, the old abaca varieties had outlived their usefulness and now become easy prey for disease devastation.

Different plant breeding techniques are employed to develop abaca varieties possessing desirable traits like high fiber yield, good fiber quality, and high degree of resistance to major diseases of abaca. With conventional breeding method coupled with the recent advances in molecular biology and biotechnology, a more directed solution to the disease problem of the industry can now be identified. It is possible to isolate resistance genes from abaca varieties or in wild relatives. With basic knowledge on mechanisms of abaca-pathogen interactions, similar approaches can be applied to abaca breeding to produce durable resistance at a much faster pace. These improved abaca varieties can either be used directly for commercial planting or as genetic stocks to develop high-yielding varieties resistant to various diseases. The availability of these improved resistant high-yielding varieties backed by appropriate marketing strategies and employed with sound

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resistance management schemes brings forth a package of technology that promises to make abaca one of the top foreign exchange earners of the country.

Keywords *Musa textilis* Nee • Breeding • Abaca industry • Genetic conservation

Introduction

Abaca (*Musa textilis* Nee.), a plant native to the Philippines, is the source of fiber known internationally as Manila hemp. It is indigenous to the Philippines whose favorable climatic condition and volcanic soils are suited to its cultivation. It is often used as raw material for cordage, clothing, and various handicrafts. In addition, the fibers are manufactured into specialty papers such as currency notes, filter papers, stencil papers, and tea bags. The abaca industry is a major industry in the Philippines. Due to the current interest for biodegradable products and forest conservation, it is expected that the abaca industry will continue to flourish in both domestic and international markets. With the advent of new uses of abaca, the crop will be extensively utilized for more industrial applications because it is recognized as a natural and superior material.

The Philippine abaca industry continues to make a stronghold in both international and domestic markets generating US$80 M annually from 2001 to 2010 [1]. Being an export-oriented commodity, the abaca industry has maintained its status as the world's largest producer accounting for 85 % share of world imports. Domestic consumption is increasing with a 5.7 % growth rate. The economic and social impact of abaca is further indicated by the fact that the biggest sector of the industry consists of farmers with small landholdings, averaging close to only 2 ha. Of the country's total land area planted to abaca, it is the major crop in the Eastern Visayas and the Bicol Region of the country, accounting for 36 % and 30 %, respectively.

Philippine production of abaca fiber for the past decade has been relatively stable, averaging 65,701 metric tons (MT) per year. Three regions in the Philippines (Bicol Region, Eastern Visayas, and Davao Region) account for 79 % of the total national abaca production during the 10-year period. Among the provinces, Catanduanes continues to be the top producer of the crop with 18,971 MT of abaca produced in 2010, equivalent to 33 % of the total regional production (Fig. 12.1). The provinces of Leyte (12 %) and Northern Samar (7 %) rank second and third, respectively. The volume of abaca production in the Bicol Region has been fluctuating for the past 10 years due to the prevalence of typhoons that hit the region, particularly the province of Catanduanes where the bulk of production is found [1].

In general, the Philippine abaca industry still relies on traditional varieties. However, through the years and due to lack of germplasm diversity, the old and traditional varieties are becoming susceptible to various diseases resulting to genetic erosion. Extensive rehabilitation programs in abaca-growing regions are

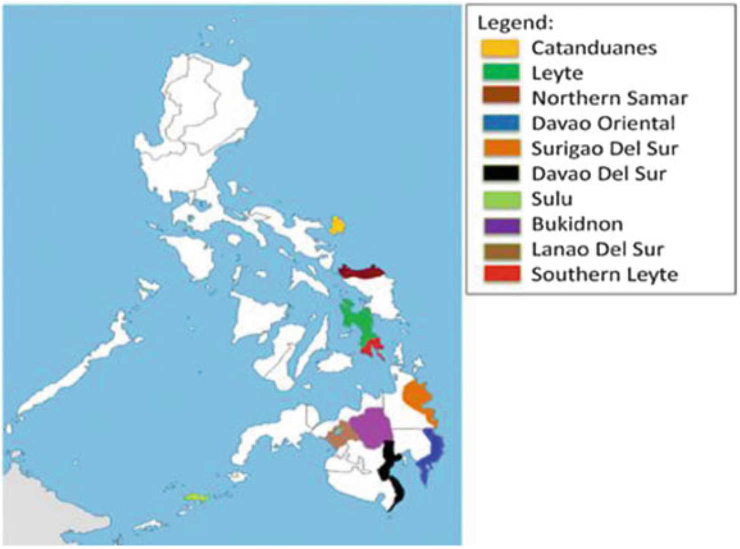

Fig. 12.1 Top ten abaca-producing provinces in the Philippines, 2010

currently being done as a concerted effort in addressing the primary problems of the industry. Breeding programs are being revitalized. In addition, a more flexible breeding methodology is being adapted to anticipate any shift in demand by the abaca industry for fibers.

Different plant breeding techniques are employed to develop abaca varieties possessing desirable traits like high fiber yield, good fiber quality, and high degree of resistance to major diseases of abaca. Conventional breeding methods are coupled with recent advances in molecular biology and biotechnology to come up with a more directed solution to address the disease problem of the industry. Biotechnologies make it possible to isolate resistance genes from abaca varieties or wild relatives. With basic knowledge on mechanisms of plant-pathogen interaction, progress in abaca breeding to produce durable resistances is expected to proceed at a much faster pace. Improved abaca varieties can either be directly used for commercial planting or as germplasm materials to develop other high-yielding varieties resistant to various diseases.

Importance of Abaca in the Philippine Economy

Abaca has been grown in the Philippines for centuries and was known to Filipinos before the Spanish occupation. The crop has been cultivated, processed, and traded, and abaca products have been used for tax payments. When the Spaniards arrived in the island of Cebu in 1521, they noted that the natives were wearing clothes made from the fiber of the abaca plant and the weaving of abaca fiber was already widespread in the island.

It was, however, only much later that the commercial or export importance of abaca was recognized. According to historical accounts, an American lieutenant of the US Navy brought abaca fiber to the United States in 1820, and 5 years later, the first exportation of the fiber was made. Since then, abaca became well known as one of the strongest materials for marine cordage due to its superior tensile strength and proven durability in saltwater applications. Attempts to introduce the crop in 1822 to India, Borneo, German East Africa, West Indies, and Florida were either unsuccessful or found not commercially viable [2]. During the twentieth century, abaca fiber became the premier export commodity of the country. The US government introduced the crop in many countries with a climate similar to the Philippines to ensure supply of marine cordage for the US Navy [3]. The US government introduced abaca in 1923 in several Latin American countries with tropical, humid, and warm climate similar to the Philippines. These include Panama, Ecuador, Costa Rica, Guatemala, Honduras, Dominican Republic, Brazil, British and French Guiana, Cuba, Jamaica, Puerto Rico, Martinique, Guadeloupe, Trinidad, Mexico, St. Vincent, Bolivia, Peru, Nicaragua, and El Salvador [4]. In 1925, Abaca seed pieces from the Philippines were also used to establish plantations in Sumatra, in British Borneo, and in Malaya. It was also introduced in New Caledonia and Queensland [5]. An abaca plant was noted growing in a garden in New Zealand. The crop was introduced in Vietnam in 1958 with seed pieces from Costa Rica. It was after World War II that a Japanese owner of the abaca plantation in the Philippine province of Davao started a formal field testing and a successful cultivation of abaca in Ecuador. The country now also produces abaca for export, and it supplies approximately 15 % of the world market.

A joint project by the Philippines and Ecuador was conducted from 1998 to 2004 for the improvement of fiber extraction and identification of high-yielding varieties. This was funded by the Common Fund for Commodities (CFC), United Nations Industrial Development Organization (UNIDO), FAO Intergovernmental Group on Hard Fibers (FIGHF), and Philippine Fiber Industry Development Authority (FIDA). The lead collaborating agency in Ecuador was the Ecuadorian Abaca Corporation (CADE). Fiber extraction machines and tools were developed, evaluated, and improved by both countries. New varieties were developed, but the planned varietal exchange activities between countries did not materialized. The variety being planted by the CADE was an introduced Philippine variety "Tangongon" [6].

Abaca is currently cultivated in almost all regions in the Philippines except the Ilocos Region, Cagayan Valley, provinces in Region 3, and Cavite and Batangas provinces in Region 4. Small-hectare experimental plantings have been established in Ilocos Norte, Rizal, Sultan Kudarat, and Tawi-Tawi. Abaca grows best in Philippine provinces characterized with the most amount of rainfall, no dry season, a humidity range of 78–88 %, and with average temperature of less than 27 °C.

Today, abaca – known commercially as Manila hemp – has been transformed from its traditional use as a raw material for rope and paper into a source of material for the fashion industry and composite fibers used in luxury automobile upholstery. Philippine fashion designers sell intricately embroidered "barong" shirts made of abaca "sinamay." The Japanese also know it as "makiwara" – the rope tied around posts used in martial arts practice. Its superior tensile and folding strength and high porosity also make it especially suitable for currency papers (the Philippine peso bills have 20 % content, while the Japanese yen has 70 % content), furnitures, home décors, textiles, cosmetics, cigarette papers, surgical masks, sausage casings, tea bags, coffee filters, and others.

In 2007, the Philippines produced 60,000 MT of abaca fiber, while Ecuador produced 10,000 MT. Exports from the Philippines, where 85 % of world supply comes from, are mostly pulp rather than raw fiber. The county generates about US $76.8 million a year from exports of raw fibers, pulp, cordage, and fiber crafts. Only the Philippines (where it is a small farmer's crop) and Ecuador (where it is grown on large estates) supply the world market. Indonesia is a small producer, but it is currently expanding its abaca hectarage.

In 2004, the price of abaca fiber reached an average of US$0.71 (about ₱40) per kilogram of which US$0.39 or 56 % went to farmers. Abaca farmers produce 78,000 MT a year valued at over US$0.10 billion. By 2020 – when farms expand an additional 32,600 ha – abaca fiber production should reach 152,000 MT. Fiber yield is expected to increase from 565 kg per hectare per year to 900 kg per hectare. This requires an investment of US$5.93 million during the first 5 years. The cost of establishing a low-level technology abaca farm is US$524.02 per ha. Abaca, which matures in 18–24 months, can be harvested three times a year. Abaca extraction is 80 % manual and only 1 % of the fiber is recovered. Simple technology innovations like a portable stripping machine that costs about US$806.02 can increase fiber extraction by 3 %.

Abaca fiber ranks ninth among the Philippine major agricultural exports – after coconut oil, banana, pineapple, tuna, shrimps, tobacco, and desiccated coconut. Besides fiber, abaca pulp and cordage are exported to the United Kingdom, Japan, and the United States. For pulp, Germany is the main market followed by Japan and the United Kingdom. Principal buyers of cordage are the United States, Singapore, and Canada. Foreign exchange earnings from the export of abaca had been declining at 2.8 % each year from 1995 to 2004. Except for abaca pulp which had been increasing at 2.6 % per year, the Philippine foreign exchange earnings from the rest – raw fiber, cordage and yarns, and fabrics and fiber crafts – have declined.

Abaca Market Flow

From the producer/farmer/fiber stripper, the abaca fiber was sold at an "all-in" basis and ungraded to the "barangay" (village) dealer. The fiber then goes to the town/city dealers. To some extent the farmers sell directly to exporters/grading and baling establishments (GBEs). In some cases, farmers' cooperatives/associations have a direct link to domestic processors.

1. *Local Consumption*
   Domestic processors utilize about 66 % of the country's total production of abaca fiber. A steady increase of 3.2 % per year in the consumption of abaca fiber by local processors resulted to more income through production of high value products and employment opportunities in the Philippines. The pulp sector is considered the highest growth area of the abaca industry due to the favorable developments in the world market increasing demand for its end products such as meat casings, tea bags, cigarette papers, and other specialty paper products. The pulp sector accounted for about 57 % of the total local consumption for the past 10 years. Consumption by this sector grew 6.9 % annually. The cordage sector, on the other hand, accounted for about 31 % of the total fiber usage by the domestic manufacturers. During the 10-year period, a decrease of 1.4 % per year in the sector was observed largely due to stiff competition posed by synthetic cordage.
2. *Export*
   Most of the processed products like pulp, cordage, and fiber crafts are exported by the Philippines to various countries and from which, with raw fiber exports included, an average of US$79 million a year are generated (Table 12.1). About 82 % of export earnings or an average of US$65 million came from abaca manufacturers. The rest (18 %) was contributed by raw fiber exports with annual average earnings of US$14 million. Among the abaca manufacturers, pulp contributed the highest export earnings at 39 % of the annual total followed by fiber crafts at 22 %. Exports of cordage and allied products contributed 14 % and yarns and fabrics 0.7 %. The United States remains as the biggest market for Philippine abaca cordage while Japan and Germany for abaca pulp exports during the past 10 years. Increasing quantities of pulp are also being marketed to the United States as well as the European and Asian countries like France, Taiwan, Korea, and China. The major markets for fiber crafts include the United States, Germany, Japan, and Australia. An average of 12,887 MT of raw fibers

Table 12.1 Average exports of abaca fibers and products 1997–2006

Exports	Volume (MT)	Value (in FOB US $)	Destination
Raw fibers	12,887	14,049,398	United Kingdom, Japan, Indonesia
Pulp	17,384	38,391,313	Germany, Japan, United Kingdom, France, United States
Cordage, ropes, and twines	7,725	11,370,481	United States, Singapore, Canada, Malaysia, United Kingdom, United Arab Emirates
Yarns and fabrics		396,910	
Fiber crafts		15,046,555	United States, Japan, Spain, Italy, United Kingdom, France, Australia
Average total earnings		79,254,657	

were exported every year during the past 10 years with 91 % of the total going to the United States, the United Kingdom, and Japan. For the past 10 years, raw fiber export has been declining at the rate of 2.3 %, but this is offset by an increasing trend in the domestic consumption and export of manufactured abaca in the forms of pulp, cordage, and fiber craft.

Sectors of the Abaca Industry

The abaca industry is made up of five major sectors: farming, fiber stripping, trading, fiber exporting, and processing (Table 12.2).

1. *Farming Sector*
   There are more than 77,500 Filipino farmers that grow abaca on about 127,258 ha. An abaca farmer has a small landholding that averages about 2 ha. The national average production is 850 kg/ha, which is relatively low compared to the potential of 2,000 kg/ha.
2. *Fiber Stripping Sector*
   Stripping abaca fibers is done either by hand or mechanical means. About 80 % of the abaca fibers in the country are hand stripped – practiced mainly in Bicol and some parts of Leyte and Samar provinces. The remaining 20 % of the fiber is produced through spindle stripping and is employed principally in Mindanao and the Leyte provinces. Included in the stripping work are harvesting of stalks and tuxying and drying of fibers. The fiber strippers are paid either in cash or by share. Under the sharing system, they receive 50 %, 60 %, or 70 % of the harvest depending on the prevailing practice agreed upon.
3. *Trading Sector*
   Trading is done at different levels depending on the location of the farmers and where the accumulation of fiber is done. Hence, there are traders in the barrio, town, province, city, and region. In each level, the pricing system includes markup attributable to the service provided by the trader. There are a total of 617 traders at various levels of trading.

Table 12.2 Summary of abaca industry sectors

Sectors		Number
Farmers		77,500
Traders (licensed)		617
Traders-exporters (licensed)		31
Fiber exporting	Grading and bailing (licensed)	20
Processing	Cordage firms (licensed)	6
	Pulp manufacturers (licensed)	6
	Fibercraft processors (licensed)	105

4. *Fiber Exporting Sector*
   The fiber exporters, also known as grading and bailing establishments (GBEs), operate in major abaca regions and usually maintain liaison offices in Metro Manila. The establishments employ classifiers who ensure that the fibers are in accordance with government standards. They likewise operate pressing machines for bailing of fibers intended for trading in both domestic and international markets. The standard bale of fiber is equivalent to 125 kg and measures 100 × 55 × 60 cm.
5. *Processing Sector*
   (a) *Pulp Mills*
   There are six abaca pulp companies operating in the Philippines, which have combined rated capacities of 16,180 MT per year. The companies have well-established market networks for their pulp which are principally destined for the international market.
   (b) *Cordage Manufacturers*
   There are six cordage firms operating in Metro Manila, Cebu, and Davao. They use abaca as the principal raw material for rope, cordage, and twine manufacture. Blending with other natural fibers like maguey is done depending on the specifications of the buyers. The combined rated capacities of these companies are approximately 21,350 MT per year.
   (c) *Fiber Craft Manufacturers*
   The fiber craft sector, including handmade papermaking and carpet manufacturing, is primarily characterized as "cottage based." Operating mostly in the countryside, especially in the central Philippines, the sector is a major source of livelihood especially to the women and out-of-school youth. Several of these manufacturers have successfully established their markets abroad, especially through their unique, functional, and creative designs.
   (d) *Textile/Fabrics*
   The textile/fabric sector produces handwoven abaca fabrics which are used as raw material for making novelty and household items, as décor and wrapping material, as well as for fashion wear and accessories. Some abaca weaves are blended with metallic thread or polyester, while others have striped and ethnic designs to suit the varying needs of the market. The industry is confined in Western Visayas, the Bicol Region, and Southern Mindanao where indigenous people are actively engaged in *tinalak* weaving. Production of new product lines for fashion wear and accessories and specialty/novelty items is based in Metro Manila.

Threats and Problems

Although abaca has been an established Philippine industry, it is still plagued with problems. Areas that continue to be addressed are (1) farm productivity and (2) fiber quality. Also among the serious challenges in the Philippine abaca industry includes:

1. Aggressive moves by Indonesia to massively produce abaca under the government's reforestation program, increasing market competition
2. Availability of similar materials from China and India and technological advances and breakthroughs which make possible production of cheaper substitutes, whether from natural (e.g., sisal, Ecuadorian abaca) or synthetic-based materials
3. Threat from destructive pests and diseases, natural calamities, use of a few genotypes, overexploitation due to over-harvesting of natural stands, and changing land use brought about by development and population pressure

As early as 1980, there was a rapid decline in abaca production not only due to the unavailability of improved varieties but also due to three major virus diseases – abaca bunchy top (ABT), abaca mosaic (AM), and abaca bract mosaic (BM) (Fig. 12.2). There were resistant lines identified from the abaca germplasm collection. However, these have often fibers of inferior quality. Control of these viruses is difficult even with different disease control strategies. Other diseases remain important as they affect production of abaca. Superior hybrids developed by conventional breeding could be adopted directly by abaca farmers if they possess resistance to diseases caused by viruses and other pathogens. Continuing effort on identifying sources of resistance to these diseases is being done to be able to sustain abaca production in the country.

Abaca bunchy top, abaca mosaic, and bract mosaic virus are economically the most devastating virus diseases in abaca. These often occur in the same growing area. The average incidence of abaca bunchy top and abaca mosaic diseases in Bicol in 1991 was 5.19 % with an estimated fiber yield loss of more than 800,000 kg valued at about ₱18 million [7]. The estimate for the same year in the Eastern Visayas was disease incidence of 8.16 % valued at about ₱8 million. These diseases are known to reduce fiber quality as well.

The symptoms of bunchy top disease were first observed in Albay (Bicol Region) in 1910 and 1911 [8], then in abaca plantations in Silang, Cavite, in 1915. The disease was not a serious threat to abaca cultivation until 1923 [9]. Since that time, increased virulence caused the abandonment of plantations in the provinces of Cavite and Laguna (Paete). Presently, bunchy top which is widespread in abaca-growing areas is considered the most destructive of the abaca diseases because the plants are very much stunted (Fig. 12.2) and are not productive. The most striking characteristic of bunchy top is the crowding of the leaves into more or less a rosette arrangement [8], accompanied by a transparent appearance of the main and secondary veins of the leaves.

Disease	Symptoms	Transmission
Abaca Bunchy Top 	• Yellowish-white, chlorotic areas on lamina and margins of unfurled leaf • Mature leaves become dark green, stiff, narrow, erect and necrotic • Petioles begin to rise from the same plane at the upper end of the pseudostem resulting to a rosette or bunchy appearance • Infected plants may remain alive for years but they gradually become smaller until their leaves and leaf sheaths turn brown and die	• by insect vector, banana brown aphid, *Pentalonia nigronervosa* Coq. • can be found on pseudostem, youngest unfurled leaves and at the underside of old leaves • a single aphid can transmit abaca bunchy top virus (ABTV) • ABTV can be retained in the vector from 5 to 12 days
Abaca Mosaic Disease 	• Alternate green and yellow streaks, spindle-shaped patterns or dashes on leaves • Mottling on leaf sheaths and pseudostem • Chlorotic areas develop rusty brown borders and extend from midrib to leaf margins • Pale green areas turn orange to brown and later dry out	• by sap • Insect vectors (9 species): *Aphis gossypii, A. maidis, A. glycines, Rhopalosiphum nymphaceae, R. maidis, R. prunifoliae, Toxoptera citricidus, Schizaphis graminum, S. cyperi* • a single aphid can transmit the abaca mosaic virus (AMV) • it takes only 15 seconds to acquire and transmit the virus
Abaca Bract Mosaic 	• Stringing of young leaves • Spindle-shaped chlorotic streaks running parallel to the veins • Older leaves show raised leaf veins originating from the midrib • Greenish to yellowish streaks or spindle-shaped lesions in petioles • Dark-colored mosaic pattern on bracts of the inflorescence	• by sap • by insect vectors: A. gossypii, Pentalonia nigronervosa, Rhopalosiphum maidis

Fig. 12.2 Symptoms and methods of transmission of different abaca diseases

The disease itself is caused by a virus very similar to the banana bunchy top virus (BBTV) and transmitted by the aphid *Pentalonia nigronervosa* Coq. [10]. The similarity of the abaca bunchy top virus (ABTV) with the BBTV was observed by comparing the sequences of three genes of the replication initiation protein, the coat protein, and the movement protein. These genes of the abaca bunchy top virus shared 99 % homologies with the BBTV [11].

A mosaic-like disease in abaca has been known to exist since 1925; however, the abaca mosaic disease was first described from an infection observed at the Odell Plantation in Tagum, Davao del Norte, in 1933 [12]. In 1941, the Japanese planters in Davao claimed that 50 % of abaca grown in Eastern Davao was infected because of poor cultural management. The spread of the diseases was rapid for three reasons. First, several aphid species can harbor and transmit the virus. Second, the abandonment of plantations during the World War II left the disease free to spread. Third, after the war, when the price of abaca fiber was good, there was a frenzy to expand abaca production areas. Due to poor information, the planting materials used were diseased. The economic cost of the disease is often estimated from the reduction in fiber yield. There is also loss in income due to poorer fiber quality. Fibers from mosaic-infested plants have higher percentage of stretch which was attributed to change in chemical constituents. In addition, recent reports confirmed that abaca mosaic not only reduced the tensile strength of abaca fiber but also reduced biomass yield, fiber yield, plant height, stalk diameter, and, more importantly, farmer's income.

Not much is currently known about abaca bract mosaic disease. The first report of natural infection of abaca with banana bract mosaic virus was reported in the Philippines in 2000 [13]. The symptoms of abaca bract mosaic disease are expressed at any growth stage; an infected plant exhibits stringing of young leaves with chlorotic stripes. Leaf lamina symptoms consist of spindle-shaped chlorotic streaks running parallel to the veins which may not be prominent in younger leaves in recent infection. Older leaves also show raised leaf veins originating from the midrib which appear like continuous ripples. Greenish to yellowish streaks or spindle-shaped lesions are present in the petioles but may be absent on petioles of older leaves showing leaf lamina symptoms (Fig. 12.2). When the dead leaf sheaths are pulled away from the pseudostems, distinctive dark-colored mosaic patterns, stripes, or spindle-shaped streaks are visible [11]. The characteristic dark reddish brown mosaic pattern on the bracts of the inflorescence is the distinguishing mark for the disease. In the absence of the bracts, abaca bract mosaic symptoms may be mistaken for abaca mosaic symptoms.

Taxonomy, Domestication, and Genetic Resources of Abaca

Taxonomy

Abaca, (*Musa textilis* Nee) or Manila hemp, is endemic to the Philippines. It belongs to the Musaceae family, a large family that includes majority of the cultivated banana species and cultivars. The genus *Musa* is comprised of 30–50 species and many hybrids, majority of which are triploids. Musaceae is divided in five sections wherein *M. textilis* belongs to the section *Australimusa*. It has been proposed to reduce the sections of this genus to three sections according to the number of chromosomes and amplified fragment length polymorphism (AFLP) analysis.

The general morphological structure of *M. textilis* is similar to that of the edible banana cultivars, but the plant is more slender, the leaves are smaller, and the fruits are seeded (Fig. 12.3). Only 20 of the more than 400 abaca cultivars in the Philippines are of commercial importance. Further taxonomic study of the species is needed.

Spanish friar and botanist Manuel Blanco was the first to classify the Philippine bananas which also included the description of the wild bananas "butuhan" and "saging maching," the abaca, and the "virgin" banana which were all classified under *M. troglodytarum* Linn. Abaca was listed by Fr. Blanco with botanical variety *textoria* [14].

Fig. 12.3 Typical *Musa textilis* plant

A reclassification of Fr. Blanco's Key to *Musa* species in the Philippines was done by Dr. Nicanor G. Teodoro in 1915. Dr. Teodoro used the collections of the College of Agriculture, University of the Philippines Los Baños (UPLB), as working materials for the reclassification. Teodoro's Key to Species and varieties of the Genus *Musa* were extensively used in describing banana cultivars grown in the Philippines, until it was superseded by the taxonomic scheme of Cheesman [15], Simmonds, and Shepherd [16] and lately by the taxonomic classification adapted by the curators of the national banana variety collections of Southeast Asia [14] (Fig. 12.4).

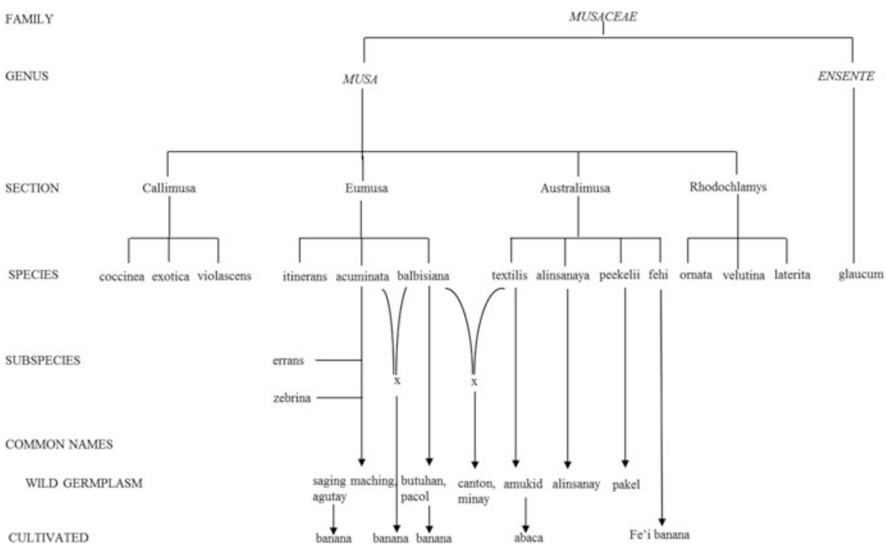

Fig. 12.4 Classification and grouping of Musaceae and its cultivated and wild forms (Reprinted from Valmayor et al. [14] with permission from Ramon V. Valmayor)

Domestication

Abaca is native to the Philippines and northern Indonesia. It was introduced to Sumatra in 1925 [17]. There were unsuccessful attempts to introduce the crop in India in 1822, as well as in German East Africa, West Indies, and Florida, USA. Prior to the 1920s, abaca cultivation is unknown outside of the Philippines, and it is believed that Filipinos are the first to domesticate abaca [3]. Successful cultivation has been reported in other Southeast Asian countries as well as in Central America and Ecuador. At present, it is also grown in Equatorial Guinea and Kenya.

Genetic Resources

Abaca is believed to have the Philippines as its center of origin, from where it then spread southward to Borneo [3, 18]. Based on the Vavilonian crop centers of origin, the abaca is known to be from the Indo-Malayan center. The Philippine archipelago lies within the area of greatest *Musa* diversity. *Musa balbisiana* Colla, *Musa acuminata* Colla, and *Musa textilis* Nee are indigenous to the Philippines (Fig. 12.3). Their natural distribution overlaps, and since they are cross compatible, several interspecific hybrid forms are known to occur in nature, adding to the great wealth of *Musa* germplasm in the country [14].

Historically, the first germplasm collections of *Musa* species in the Philippines started during the Spanish era with the initiative of Spanish friar Manuel Blanco, author of the illustrated book *Flora de Filipinas*. An extensive banana collection program was started by the Philippine Bureau of Agriculture in 1911–1912, during the American occupation of the Philippines. The initial germplasm assemblage consisted of 276 accessions of 22 species.

The collections from the Bureau of Agriculture, and those of Dr. Teodoro, as well as the descriptions of Fr. Blanco early on, were further studied and compared by Dr. Eduardo Quisumbing, a professor of UPLB, in 1919. Widespread synonymy and duplications were found; thus, there was a reduction of the germplasm collections. During World War II (1941–1945), many of the plant and animal germplasm collections of the country were lost due to war-related atrocities. The wild and cultivated *Musa* accessions of UPLB and the Bureau of Plant Industry then had increased to 298. After the war, the country launched a program for the rehabilitation of the abaca industry. During the time, the abaca plantations in Davao and Bicol regions were severely affected by the abaca mosaic disease. Chemical sprays did not control the malady. The long-term solution was believed to be the use of resistant hybrids, and a breeding program utilizing resistant, wild *Musa* relatives was initiated by UPLB and the Bureau of Plant Industry.

At present, the National Abaca Research Center (NARC), based at Leyte State University in Leyte, Philippines, holds the world's largest collection of *Musa textilis* germplasm, with more than 600 accessions of both cultivated and wild types. Abaca accessions are also conserved in vitro. The collection at NARC has been characterized with respect to fiber morphology, chemical composition, fiber quality, and physical properties. Though *Musa textilis* is a genetic contributor in certain edible seedless hybrid banana varieties, it has not been used in any formal breeding program for edible bananas [19].

A research project that examined the genetic diversity of the Philippine abaca germplasm using microsatellite markers found that the germplasm collection in Luzon island has the highest diversity based on the Shannon diversity index (H) [20].

Also in an attempt to conserve the diversity of Philippine abaca, Villavicencio et al. [21] initiated the establishment of an in situ and on-farm conservation in Lake Sebu, South Cotabato. In situ and on-farm conservation through conservation field schools (CFS) is envisioned to enhance the capacity of farmers and stakeholders on in situ conservation and its sustainable use. With the active participation of local farmers, local government unit (LGU) technicians, and researchers from institutions concerned with conserving the abaca, identification of traditional varieties was conducted in the center of abaca production in the area. Five traditional varieties were identified, namely, Tangonon, Maguindanao, G'nolon, Maguindanao black and Wogu, and wild abaca. These varieties were multiplied and established in the on-farm conservation sites. At the time of this activity, 80 % of the abaca plantations in the Philippines have already been infected by abaca mosaic virus.

Abaca Breeding in the Philippines

History of Abaca Breeding

Musa textilis is cross compatible with several Musa species including *M. acuminata*, *M. balbisiana, M. lolodensis*, and *M. borneensis* [22]. Their hybrids are often partially or highly sterile. Cross fertilization in abaca is facilitated by the stigma remaining receptive for about 2 days. Once fertilized, the flower turns brown and shrivels within 24 h. The heart or panicle containing the male flower may be gathered and kept in the shade for 7 days with the pollen remaining viable and effective for fertilization [5, 23]. Figure 12.5 shows the general method for pollinating abaca to develop hybrids.

The indigenous *Musa* species – *M. acuminata, M. balbisiana*, and *M. textilis* – overlap and natural hybrids among these species exist. One cultivar of *M. balbisiana* known as Pacol produces fiber of low quality that it has been used as an adulterant to abaca. Natural hybrids of Pacol and abaca exist in the Bicol Region and are known as Canton and Minay [24]. The basic chromosome number for the section Eumusa to which the edible bananas belong is $n = 11$, whereas the section Australimusa to which abaca belongs is $n = 10$. The natural hybrid between the diploid banana and abaca called Minay/Minary/Minray has $2n = 21$ [25, 26] and Canton has $2n = 20$ [24].

Canton is highly sterile but Minay occasionally produces seeds. Crosses between *M. balbisiana* and *M. textilis* have produced hybrids with morphological characteristics and chromosomal numbers similar to those of Canton and Minay

Fig. 12.5 Pollination method to develop abaca hybrids

[27]. Hybrids between Minay and abaca, with the latter serving as male parent, have been produced. The hybrids resemble the Minay parent more than the abaca parent [18]. Artificial hybridization proceeds more effectively when the abaca is the male parent.

A triploid and three tetraploid *Musa* which produce low-quality fiber have been studied and used in breeding [27–29]. Two abaca varieties, Inosa and Laguis, were found with chromosome numbers varying from $2n = 17$ to $2n = 23$ and $2n = 16$ to $2n = 24$, respectively [30].

As of 1928, there were already hybrids developed for the varietal improvement of abaca (Table 12.3). Crosses between Libuton and Itom, as well as Canorajan and Lagurhuan, were developed [31]. There were 54 different crosses developed from 1928 to 1931; however, only 29 crosses were successfully planted, 19 in Guinobatan Abaca Experiment Station and 10 in Silang, Cavite [5]. Screening for disease resistance was also carried out in 39 clones. Heterosis was observed in the F_1 abaca hybrids. The F_1 hybrids produced greater number of abaca suckers than either parent. Crosses with Maguindanao were better adapted to different conditions and possess stronger root system.

In 1974, abaca hybrids developed in 1939 were field tested, and they were named after the name of the parental line. The hybrid from Linawaan × Laylay was named as Linlay, Linawaan × Libutanay as Linlib, and Linawaan × Inosa as Linino [32]. Oyardo [33] also field tested and named some abaca hybrids such as from Itom × Lausigon as Itolaus, Itom × Maguindanao as Itomag, and Lausigon × Maguindanao as Lausimag.

The abaca varietal improvement program in UPLB was started in the early 1950s initiated by the university's College of Agriculture (UPCA) and the Bureau of Plant Industry (BPI) with emphasis on varietal collection, classification, evaluation, establishment of disease observation nurseries, clonal selection, and intra- and interspecific hybridization. The cooperative work was centered on the development of resistant abaca varieties, and the most notable achievement was the identification of *Pacol* as a source of resistance. Hybridization was done between *Pacol* and abaca; however, the project was terminated in the 1960s. The abaca collection was then maintained by the UPLB Forestry Abaca Gene Bank and was turned over to the UPLB Experiment Station in 1981.

Diaz [34] generated F_1 hybrids of Mininonga crossed with six varieties of abaca and screened for bunchy top resistance. Of the different crosses developed, only the following crosses produced F_1 seedlings: Malaniceron × Mininonga, Mininonga × Itolaus 39, Mininonga × Layahon, Mininonga × Putumag 22, Mininonga × Tinawagan Puti, and Sogmad Pula × Mininonga. The reaction of these F_1 hybrids to abaca bunchy top varied; Malaniceron × Mininonga, Mininonga × Itolaus 39, and Mininonga × Layahon have resistance to bunchy top virus, while Sogmad Pula × Mininonga hybrids has moderate resistance.

In 1999, six abaca hybrid genetic stocks (Itolaus 39 × Magsarapong 2, Itolaus 39 × Magsarapong 3, Itolaus 39 × Magsarapong 4, Itolaus 39 × Magsarapong 7, Itolaus 39 × Magsarapong 8, and Tetraploid × Ilolaus 39) were identified by the Institute of Plant Breeding. These genetic stocks were developed by conventional

Table 12.3 Review of the breeding works from 1928 to present

Researchers	Year developed	Crosses
Labrador	1928	Libuton × Itom
		Canorajan × Lagurhuan
Torres and Garrido	1939	Bulao × Lausigon
		Bulao × Maguindanao
		Bulao × Tangongon
		Carnajon × Samina
		Inisarog × Maguindanao
		Inisarog × Samina
		Itom × Lausigon
		Itom × Maguindanao
		Itom × Tangongon
		Jolo-lambutin × Putian
		Kinalabao × Putian
		Kinalabao × Sinibuyas
		Lausigon × Bulao
		Lausigon × Maguindanao
		Lausigon × Tangongon
		Libutanay × Tangongon
		Maguindanao × Kinalabao
		Maguindanao × Lausigon
		Maguindanao × Putian
		Maguindanao × Tangongon
		Punukan × Putian
		Putian × Jolo-lambutin
		Putian × Jolo-tigasin
		Putian × Kinalabao
		Putian × Maguindanao
		Putian × Sinibuyas
		Putian × Tangongon
		Puti-tumatagacan × Lausigon
		Puti-tumatagacan × Maguindanao
		Puti-tumatagacan × Libutanay
		Samina × Bulao
		Sinibuyas × Kinalabao
		Sinibuyas × Putian
		Magsarapong × Inisarog
Bernardo and Umali	1956	Putian × Kurisan
		Putian × Magsarapong
		Ugaram × Magsarapong
		Bulaoluna × Magsarapong
Bernardo	1957	Putian × Jolo
Cruz and Balingkit	1974	Linawaan × Laylay (Linlay)
		Linawaan × Libutanay (Linlib)
		Linawaan × Inosa (Linino)

(continued)

Table 12.3 (continued)

Researchers	Year developed	Crosses
Oyardo	1974	Itom × Lausigon (Itolaus 35)
		Itom × Lausigon (Itolaus 39)
		Itom × Lausigon (Itolaus 45)
		Itom × Maguindanao (Itomag 3)
		Itom × Maguindanao (Itomag 16)
		Lausigon × Maguindanao (Lausimag 24)
		Lausigon × Maguindanao (Lausimag 32)
		Lausigon × Maguindanao (Lausimag 35)
Tabora and Carlos	1978	Pacol × CES No. 3
Alcober	1986	Pacol × CES No. 3
Diaz	1997	Malaniceron × Mininonga
		Mininonga × Itolaus 39
		Mininonga × Layahon
		Mininonga × Putumag 22
		Mininonga × Tinawagan Puti
		Sogmad Pula × Mininonga
Engle et al.	1999	Itolaus 39 × Magsarapong 2
		Itolaus 39 × Magsarapong 3
		Itolaus 39 × Magsarapong 4
		Itolaus 39 × Magsarapong 7
		Itolaus 39 × Magsarapong 8
		Tetraploid × Ilolaus 39
Moreno	2001	Canarahon × Korokotohan
		Canarahon × Samoro
		Tangongon × Samoro
Manguiat et al.	2000	BC1 hybrids
Lalusin et al.	2006	BC2 hybrids

crossing Magsarapong, Tetraploid 1, and Itolaus 39, an abaca possessing moderate resistance to mosaic and bunchy top virus. Itolaus 39 is a commercial hybrid between Itom and Lausigon, but the appearance is more of a *Pacol*. All the stocks were moderately resistant to mosaic and resistant to bunchy top under greenhouse and highly resistant under field evaluations, but the fiber quality and recovery were lower than the abaca hybrids. Hybridization between abaca varieties and relatives has been done. Table 12.3 shows the history of breeding works since 1928.

The Institute of Plant Breeding of UPLB started its abaca breeding program in 1981. In 1986 the first six F1 hybrids between *Pacol* and abaca were released by the institute. These hybrids have resistance to bunchy top virus, but the fiber quality is quite poor. The crossing work was ended due to unavailability of funds. It was only in 2006 that the breeding work was continued, although to a limited extent, and several BC1 crosses were evaluated. A total of 196 BC_2 progenies have been developed and evaluated for bunchy top resistance and fiber qualities. Six promising clones have both the *AbBTV* resistance and good fiber quality.

During the evaluation, 1,300 seedlings from four BC_2 populations were manually inoculated with viruliferous aphids (*Pentalonia nigronervosa*). Each plant was inoculated with 10 aphids that fed for 24 h on abaca leaves infected with the bunchy top disease. Majority of the inoculated seedlings did not show any symptoms of the bunchy top virus after 2 months. One hundred sixty-six inoculated seedlings (12 from BC_1-19 × Abuab; 132 from BC_1-20 × Abuab', and 22 from 'BC_1-19 × Musa tex 51) were selected based on bunchy top virus resistance, plant vigor, and resemblance of morphological characters to true abaca. The seedlings were re-inoculated with the aphids for further confirmation of resistance.

To screen for desirable morphological traits, the BC_2 abaca hybrids were selected and planted in the field with 2.5 × 2.5 m planting distance under coconut trees as partial shade. The abaca hybrids were used for the evaluation of morphological traits, fiber qualities, and field resistance to bunchy top virus disease. These abaca populations were also used to screen the primers and to identify crosses with resistance to abaca bunchy top virus at the same time with good fiber qualities.

Recent Advances in Abaca Breeding

Marker-Assisted Breeding

Plant improvement, either by natural selection or through the efforts of breeders, has always relied upon creating, evaluating, and selecting the right combination of alleles. The manipulation of a large number of genes is often required for improvement of even the simplest of characteristics. With the use of molecular markers, it is now possible to trace valuable alleles in a segregating population and mapping them. These markers once mapped enable dissection of the complex traits into component genetic units more precisely, thus providing breeders with new tools to manage these complex units more efficiently in a breeding program.

Genetic marker systems have numerous applications in *Musa* improvement. These include increasing heritability of difficult to select characters via indirect genotypic selection; complex quantitative traits may be resolved into simple Mendelian loci; gene pyramiding for pest and disease resistance genes can be performed; detailed genetic linkage maps can be constructed [35], and a map-based gene cloning may be performed. Other uses include accurate identification of clones [36, 37]; the determination of evolutionary pathways between clones [38]; the identification of duplications in germplasm banks; and monitoring of somaclonal variation in micropropagated material for commercial use [39]. Identification of PCR markers for detection of A and B genome sequences in *Musa* was also reported [40, 41]. Three 10-mer RAPD primers produced unique banding profiles for the differentiation of *M. acuminata* (A genome) and *M. balbisiana*

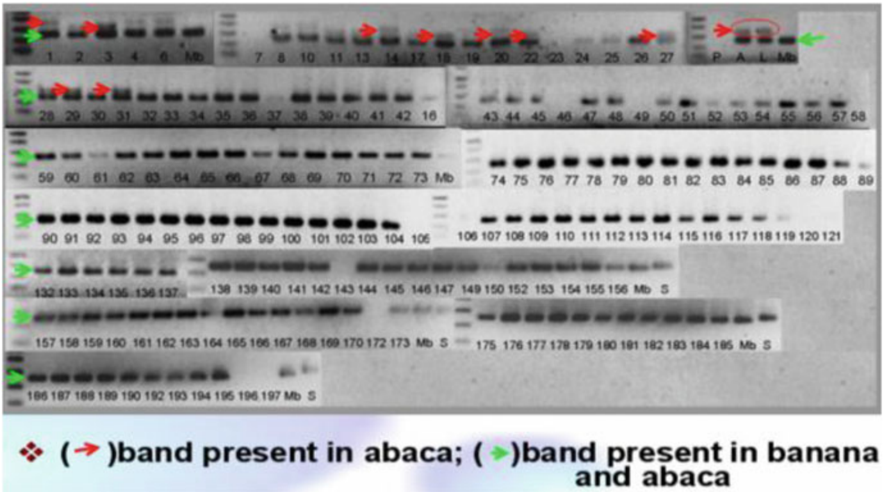

Fig. 12.6 DNA fingerprinting of the 196 BC2 hybrids using mMaCIR45. Abuab (A) and Lausigon (L) (abaca check) were run in parallel with the BC2 samples; *Musa balbisiana* (*Mb*) and “Seniorita” (*S*) were used as positive controls

(B genome). Molecular techniques such as isozymes [42–44], restriction fragment length polymorphisms (RFLP) [36, 45], random amplified polymorphic DNA (RAPD), repetitive elements, diversity of rDNA spacer length (IGS) [46], sequence-tagged site markers (STS), and AFLP [47] have been used to study the origin, relationships, and variability among and within genomic groups in *Musa*.

No studies to date have been done to identify molecular markers that are linked to disease resistance or to high yield of abaca and bananas. At present, the UPLB’s Institute of Plant Breeding is developing molecular markers to fast-track the breeding of abaca varieties with high fiber yield and resistance to abaca bunchy top virus. The genetic background and relationships of different abaca accessions are being determined by fingerprinting BC_1 and BC_2 populations using a specific primer set (mMaCIR39, mMaCIR40, and mMaCIR45). This was done to facilitate the screening for resistance to abaca bunchy top virus and the selection of clones with high fiber quality (Fig. 12.6).

Abaca accessions collected from FIDA Bicol, NARC in Leyte, Negros Occidental, and FIDA Davao were also subjected to PCR analysis using the primer set. Fingerprinting analysis was carried out to establish the genetic relationship among the different accessions.

Tissue Culture and Genetic Engineering

The basic protocol for abaca in vitro culture has been published. Production of numerous disease-free abaca varieties through tissue culture has been long realized, and this technology has been transferred to farmer's level. However, the effectiveness of this technique is limited by the presence of residual and alternative sources of inoculum in abaca plantations, making the absolute eradication of the virus diseases almost impossible. Often, the initially disease-free planting materials will get infected within a few growing seasons. It is therefore of great importance that new abaca cultivars which are resistant to pests and diseases be developed.

Genetic engineering utilizing plant transformation and gene cloning are becoming important tools in plant improvement. However, the success in utilizing the potentials of the technique is largely dependent on the development of efficient and reproducible protocols for the establishment of cell suspension cultures, induction of somatic embryogenesis, and protoplast fusion.

Excellent progress has recently been made in obtaining regenerants from somatic embryoids and recently gene expression in abaca. The technique involves adventitious shoot induction, shoot multiplication in the medium supplemented with BA or 2,4D and coconut water. Addition of 2,4D also induced callus formation. Subsequent root induction in adventitious shoots was also obtained in MS medium supplemented with IAA, NAA, and IBA [48]. Buds and shoots were induced in young floral sections and floral apices in MS medium supplemented with Ki in combination with NAA, IAA, or IBA. The formation of embryogenic (nodular) structures which developed into shoots was first observed in explants grown in MS medium supplemented with 2-ip and Ki. Somatic embryos have been included from cell suspension cultures derived from globules that formed from meristematic buds (scalps) or leaf sheaths in modified liquid MS medium supplemented with 2,4D, zeatin, and L-cysteine. These methods of producing somatic embryos are essential to the process of genetically engineering abaca.

Transient expression of the GUS reporter gene has been observed in transformed meristematic globules of abaca [49]. Researchers at the FIDA and the University of the Philippines Diliman (UPD) and Los Baños (UPLB) campuses are collaborating to genetically engineer abaca bunchy top-resistant and abaca mosaic-resistant abaca.

Opportunities/Prospects and Developments

The Philippine abaca industry is expected to continue making a stronghold in both the domestic and international markets. The growing concern for environmental protection and forest conservation worldwide has further provided demand opportunities to natural raw materials like abaca. Considering its superior fiber qualities over other natural materials, the utilization of abaca for industrial applications is expected to increase.

The total world abaca demand averaged 73,917 MT per year, 85 % of which was supplied by the Philippines. The Food and Agriculture Organization (FAO) of the United Nations projects that global consumption of abaca will increase further to more than 85,000 MT.

Since 1989, the abaca pulp sector registered a growth rate of 6.6 and 7.9 % per annum in terms of export volume and earnings, respectively. This is expected to increase further as the technology and formulations developed and used by the specialty paper manufacturers are becoming principally abaca based. Likewise, demand for specialty papers such as currency notes, tea bags, meat and sausage casings, cigarette papers, and the like will continue to grow as economies of the major consuming countries improve and new markets open up.

Abaca pulp can also be substituted for coniferous pulp in most paper products on the ratio of 4 to 1. Majority of the world's pulp and paper companies use wood pulp with global demand estimated to be at 200 million MT. This is equivalent to about 50 million MT of abaca pulp.

The fiber craft sector is another growth area registering a 4.4 % improvement in earnings per annum. To sustain the increasing demand for fiber crafts, however, functional and innovative designs should continuously be introduced in the market.

Growing awareness and interest on abaca fabrics for décor and wrapping purposes, as well as for fashion, have increased the demand for this product. Since 1989 until the present, the export volume registered a remarkable growth rate of 121.4 % per year. It is expected that demand would be long term due to the growing popularity of environment-friendly materials especially in developed countries.

While the market of abaca cordage, ropes, and twines would not be as promising compared with other sectors of the industry, demand will remain stable as it has specific markets to serve. Abaca cordage is highly preferred in oil dredging/exploration, navies, and merchant shipping as well as in the construction business because of its non-slipping characteristics.

Abaca production is expected to improve in response to the encouraging developments in both the local and world markets.

Direction of Abaca Breeding in UPLB

There are only two agencies in the Philippines doing abaca breeding – the Institute of Plant Breeding Crop Science Cluster, UPLB, and the National Abaca Research Center (NARC), Visayas State University (VSU). Therefore, abaca breeding in UPLB will have a significant contribution in the viability of the Philippine abaca industry. Abaca breeding in UPLB will continue as long as there are researchers, technicians, and laborers who are dedicated to pursue the objective of rehabilitating the Philippine abaca industry. Abaca breeding will concentrate more on the development of high-yielding and virus-resistant varieties using conventional and non-conventional methods and the mass propagation and dissemination of these high-yielding and resistant hybrids to abaca farmers and other interested stakeholders.

Considering that the area devoted to abaca production is more than 144,000 ha, UPLB needs to produce and disseminate about 230,400,000 planting materials in different abaca-growing areas in the country to rehabilitate the abaca industry.

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