

Harnessing the Potential of Banana and Plantain in Asia and the Pacific for Inclusive Growth

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Abstract

Banana and plantain was one of the earliest crops domesticated by man and it continues to be an important food crop for millions of smallholders as well as an important high-value crop in international trade, providing nutritional and economic security. It is grown in around 150 countries across the world, with around 128 million tonnes produced annually on an area of 10 million hectares. Asia contributes 55-60% of the global production, and has in the last 6 years recorded a production growth rate of 11%. India, the largest producer of banana in the world, witnessed unprecedented growth during this period, due to improved production technologies, which include adoption of high-yielding clones, high-density planting, integrated management of water, nutrients, pests and diseases, and use of disease-free, in-vitro propagated planting material. Similar is the case in other Asian countries, with Taiwan and the Philippines producing mainly for export through contract farming systems and the other Asian countries producing mainly for domestic consumption and trade by small farmers. BAPNET, the regional banana and plantain network for Asia and the Pacific, is fostering collaborative banana research among its 13 member countries and two research institutes. Looking at the strengths, weaknesses and opportunities for banana in Asia and the Pacific, it is evident that the region has a rich diversity of *Musa* which needs exploitation. The main thrust of the network has indeed been collection, conservation, evaluation and utilisation of banana diversity, testing of new hybrids, exchange of germplasm and capacity building. At the same time, biotic and abiotic stresses are many. Biotic problems include viruses, fungal and bacterial diseases and insect pests, while abiotic stresses include drought, salinity and various vagaries of climates. Fusarium wilt is but one example of a devastating disease, with no transboundary restrictions. Race 4 of Fusarium wilt has already spread to China, Taiwan, Malaysia and Australia. In this regard, BAPNET and its member countries are drawing management strategies, including internal and transboundary quarantine, sanitation, early detection, improving soil health, biological control and altered crop production systems. Production of disease-free tissue-culture planting material and diagnostics and the establishment of a certification system in some of the countries have been milestone achievements. International initiatives on genetic resources, management of diseases and insect pests, water productivity and nutrition, post-harvest management and processing remain crucially important to ensure nutritional and livelihood security and enhance the income of smallholders. Efforts of Bioversity International have, through various programmes, improved the understanding of genomics, diversity, biotic and abiotic stresses and augmentation of genetic resources for gene transfer. The horizontal and vertical integration with National Agricultural Research Systems allows to better address the many problems of smallholder banana farmers.

INTRODUCTION

Banana is the world's most important fresh fruit commodity in terms of volume of trade. The global banana industry is now little more than a century old, having started in late 1800s as a result of technological advances, like refrigerated shipping. Compared with other agricultural products, banana exhibits colonial, economic nationalism and contemporary neoliberal stages of growth and evolution in the world economy. Banana has grown in popularity for its versatility in adaptation to many agroclimatic conditions, non-specificity in season for fruit production (fruit is available year round), high potential productivity per unit area (up to 40-60 t/ha), and, if well managed, long lifespan of plantations (up to 10-20 years). Banana and plantain are grown in more than 150 countries. Production has almost doubled in a decade, from 64 million tonnes in 1997-98 to 128 millions tonnes in 2008, produced on an area of 10 million hectares (FAOstat, Table 1). Asia contributes 55-60% of total banana and plantain production.

MULTIFACETED USE OF BANANA

The importance of banana as a food-fruit crop can hardly be exaggerated. The crop has a multifaceted use, such as for food, fibre and therapeutic purposes. Fresh banana leaves serve as plates, while dried banana leaves are used for fire wood by Indian folks. The use of dried banana leaves has also been reported as better substrate than paddy straw to grow oyster mushrooms. Banana is free from sodium and can thus be a component of a salt-free diet. Banana contains various vitamins and has therapeutic value for the treatment of many diseases. In North Eastern India, banana powder is used as a baby food, and across the country, it is used as preventive measure for many disorders. The pseudostem core has been well recognised as a medicine for dissolving kidney stones.

BANANA AND PLANTAIN PRODUCTION IN ASIA AND THE PACIFIC

Banana has its origin in Asia and has a long history of domestication. Banana exploration missions, study of cytogenetics and advanced molecular cytogenetics have confirmed the origin of banana and plantains as South and South East Asia, including the Pacific Islands. Globally, production is classified between banana and plantain. In Africa, plantains occupy two thirds of the production while the reverse is true for Latin America and Caribbean. But the situation is more complex in Asia and the Pacific as, here, plantains are not differentiated from bananas. Many Asian cultivars possess some characteristics that transcend, which are unique either to banana or plantains. So in Asia, all cultivars are referred to as banana, except for some very specific cases in Southern India and the Pacific Islands. Though bananas are often grown for commercial purposes, plantains are a staple food for many ethnic groups and continue to be the crop providing nutritional and economic security in most of the Pacific Islands and the Southern states of India in Asia.

Individually, each Asian country has witnessed its own growth owing to several factors. India, the largest producer in Asia, has witnessed a spectacular growth of its banana industry over the last 50 years (Fig. 1). Indian banana production contributes 20% of total global banana production. Although backyard cultivation is still the rule in most of Southern, Eastern and North-Eastern India, expansion of area into marginal lands, hilly zones and abandoned sodic soils accompanied by an improved package of practices has resulted in appreciable growth. Very fast growth in production of banana in India is

attributed to the adoption of high-yielding cultivars, nutrient and irrigation management, integrated pest management, and better pre- and post-harvest practices. Use of tissue-culture planting material and efficient plant health management have significantly contributed to increased quality of production, especially for the Cavendish types.

China, the next largest producer in Asia with an annual production of 8 million tonnes, has experienced a big increase in production in the last 6 years. Though it has historical and cultural background of banana cultivation, the systematic cultivation is of recent origin. Because of extreme weather conditions, production is restricted to southern China. But efforts to look for cold-tolerant bananas in their diverse germplasm might lead to extended cultivation northward.

The Philippines has also significantly increased its production in the last decade. Although banana is grown across the country, the largest production is in Mindanao province where more than half of the country's bananas are produced, followed by Western Visayas and Isabella of Cagayan Valley. The high production in Mindanao is attributed to the use of improved technology and inputs. More than 85% of Philippine banana production is under smallholders while the rest is under corporate farming for export to Japan, Saudi Arabia and the United Arab Emirates. Major cultivars are of the Cavendish type. Important processed products include chips, sauce and catsups.

In Malaysia, banana covers 11% of the total area under fruit production. A total of 600,000 tonnes are produced on 27,000 ha, of which 15% is exported. Corporate farms grow Cavendish clones for export business. The rest is grown in polyclonal production systems by small and marginal farmers for local consumption.

Indonesia, Thailand and Vietnam have shown marginal growth. Indonesian banana is cultivated in backyard farms with an annual production of 5.7 million tonnes. Small holding farmers and polyclonal systems are the main features. Export is almost nil and the whole produce is consumed locally.

PRODUCTION SYSTEMS IN ASIA AND THE PACIFIC

Global production systems for banana and plantain differ from region to region, and the same holds true for Asia. Growth of the industry is also the manifestation of changes in the production system. Three major systems are predominant. The first is backyard cultivation, where farmers grow a diversity of cultivars, mainly for home consumption. This system is also the basis of continued growth of the banana industry withstanding the threat of a number of biotic and abiotic stresses. Asia, home to a rich spectrum of diversity, offers a wide choice of cultivars to small-scale and marginal farmers. South and Southeast Asia are the cradle of *Musa* diversity and exhaustive evolutionary studies are well described (Simmonds, 1962). *Rhodochlamys* is distributed over Malaysia, Thailand, Indonesia, India and surrounding areas. *Callimusa* is restricted to Malaysia, Borneo and Indochina, and *Australimusa* to the southeast (Borneo, Indonesia, Australia and Pacific and Philippines). *Eumusa* species cover the entire region from the Indian peninsula to the Pacific and from northern Australia to China. Except for the *Eumusa* diversity, especially for plantains and East African highland bananas in Africa, the rest of the world's *Musa* diversity is restricted to Asia and Pacific. Diversity among cultivated varieties is equally vast. Details of commercial cultivars in Asia with group and subgroup classification are provided in Table 3. India has delicate AA diploids nurtured in backyard farms, like 'Matti' and 'Sanna Chenkadali'. Triploid AAA Cavendish clones, especially 'Grand Naine', are the main stay of the industry but AB/AAB cultivars are still the mainstay of Southern and North Eastern states, like

'Poovan', 'Rasthali', 'Pome', 'Ney Poovan', plantains etc. Starchy ABB triploids, like 'Monthan' and 'Bluggoe', are the basis of the cooking banana industry most predominant in the country. 'Pisang Awak' is spread throughout the country and is the basis of nutritional and economic livelihood. BB diploids are popular for nutritional and therapeutic values. In Malaysia, 'Pisang Ambon' (AAA), 'P. Mas' (AA), 'P. Rasthali' (AAB), 'P. Embun' (AAA) and 'P. Berangan' (AAA) are the popular dessert cultivars, while 'P. Awak' (ABB), 'P. Tandok' (AAB), 'P. Nangka' and 'P. Abce' are popular cooking types. In the Philippines, 'Lakatan' (AAA), 'Latundan' (AAB), 'Berangan' (AAA), 'Amas' (AA) and 'Morado' (AAA) are used for dessert purpose, while 'Saba' (ABB/BBB), 'Cardaba' (ABB/BBB), 'Tindok' (AAB) and 'Laknau' (AAB) have starchy fruits, consumed after cooking. Indonesia has 'P. Ambon' (AAA), 'P. Raja' (AAB) and 'P. Berangan' (AAA) as dessert cultivars, while 'P. Kepok' (ABB), 'P. Oli' (AA), 'P. Kosta' and 'P. Tanduk' (AAB) are eaten cooked. Thailand has 'Kluai Khai' (AA) and 'K. Lep Mu Nang' (AA) as dessert types, while 'K. Namwa' (ABB) and 'K. Hakmuk' are preferred for cooking. Vietnam has 'Chuo Ngu' (AA), 'C. Tien' (AA), 'C. Tay' (ABB) and 'C. Bom' as dessert and 'C. Mat' (ABB) and 'C. Sap' (BBB) as cooking bananas.

The second system is the small commercial plantations, which predominate in most countries showing fast growth of the industry. This is true for India, China and others. Mixed farm and polyclonal situation is being replaced by monoclonal commercial banana farms of 2-10 ha. Even marginal, uncultivated lands are drawn for banana cultivation under high-input conditions.

The third system is large plantations spread over hundreds of hectares, mainly under contract farming by large companies and with a high level of organisation. This is mostly run by corporate firms, is capital intensive and gives high productivity with good quality as the main concern.

Thus, production systems in Asia are defined in terms of production practices, resource availability, traditions, consumer preferences and existing marketing systems. Climatic, biotic, abiotic and socio-economic situations decide the cropping patterns, cultivars grown and production inputs. Unlike in Ecuador and other Latin American countries where banana is mainly grown for export, the Asian banana industry is not only market driven but also culture driven.

BANANA IMPROVEMENT

Natural mutation selection and perpetuation have been the basis of evolution in vegetatively propagated crops like *Musa*. A large number of local man-made selections for specific traits, especially for higher yield, parthenocarpy and resistance to biotic and/or abiotic stresses, have been under cultivation. 'Gandevi', a tall mutant of 'Giant Cavendish', is selected for its high yield potential of up to 70 kg per bunch in India. Though it has a long crop cycle, it produces a good mass for processing. 'Udhayam' is a selection of P. Awak for higher yield (35% higher than local 'Karpuravalli'). Similarly, 'Kozhikkodu' and 'Bangladesh Malbhog' are selections of Silk, while 'P. Ceylan' is a Mysore type. 'GCTCV-115' and 'GCTCV-218' are Cavendish selections with resistance to Fusarium wilt race 4.

Apart from these natural selections, efforts are underway to improve banana and plantain through classical breeding. Although difficult because of sterility, parthenocarpy and polyploidy, several hybrids were developed by breeding programmes through profuse funding. 'FHIA-01', 'FHIA-03', 'FHIA-17', 'FHIA-21' and 'FHIA-23' from Honduras are still doing well and expanding because of their resistance to one or several biotic

stresses. 'CRBP-17' and 'CRBP-39', two hybrids from CARBAP, Cameroon, are high-yielding plantains with resistance to black leaf streak. 'PITA- 3', 'PITA-13', 'PITA-27', 'TMB 15' and 'TMB 38' are improved banana hybrids from Nigeria and Uganda. Most of these are highly suited for niche markets and still find a broad spectrum of users because of their processing qualities. 'BRS-1', an improved Pome hybrid, and 'BRS-2', an improved Mysore hybrid, both released from KAU, India, have been commercialised for their resistance to Sigatoka leaf spot, especially important in humid areas where Sigatoka leaf spot is the major threat.

PRODUCTION TECHNOLOGY

Growth in production and productivity has different causes in different places. In India, high density planting is coupled with improved production system management. A density of 4500 plants per hectare is practiced in some parts of India on vertisol, while in other places, 3000-3500 plants are planted in three crop cycles. A double-row planting system is advocated and practiced in western India. In this system, row-to-row distance is maintained at 1.2 m and distance between two rows at 1.8 to 2.0 m. Plant-to-plant distance is kept at 1.2 m. A plant population of 5200 plants per ha has been accommodated by this system. A modified high-density planting system developed by NRC Banana, with three suckers per hill at a spacing of 1.8 x 3.6 m or 2.0 x 3.2 m, accommodates 4500-4600 plants per ha. Fertigation has increased productivity by 50% and reduced production costs by saving 30-40% on fertiliser and 40-50% on water. The double-row system provides ample space and scope for growing intercrops, like green manure crops, in the initial stages. The system has also helped in reducing the cost of laterals when drip irrigation is used.

PRODUCTION CONSTRAINTS – BIOTIC AND ABIOTIC STRESS

A global research system was set up realising the susceptibility of this crop to a wide spectrum of biotic and abiotic stresses. In Asia, biotic stresses, like fungal diseases (including wilt and leaf spot disease), bacterial diseases, viral diseases, insects and pests, and abiotic stresses, like drought, salinity and vagaries of climates, are common. Of these, Fusarium wilt has emerged as the main problem after the devastation of 'Gros Michel' and the threat to the export industry in the 1950s. Fusarium wilt is now affecting Cavendish types which replaced 'Gros Michel' in the global export industry. Race 4 of the pathogen is threatening Cavendish cultivars, while race 1 and race 2 are already known to cause havoc in Silk, P. Awak and cooking bananas, thus holding 80% of the banana industry at stake. Almost all countries in Asia and the Pacific (Malaysia, Indonesia, India, China, Bangladesh, Australia, Vietnam, Cambodia and Sri Lanka) are affected by Fusarium wilt. In countries like China, Taiwan, Malaysia and Bangladesh, the situation is more alarming due to the presence of the aggressive and destructive race 4 strain. Race 1 and race 4 are serious constraints for banana production in Queensland and New South Wales in Australia. Fortunately, India has not recorded the presence of race 4, but its geographic proximity to countries with race 4 and with no transboundary quarantine regulation means it is a real threat. So is the situation with other countries in the region. Other major fungal diseases, like the Mycosphaerella leaf spot complex, minor diseases like Cordana leaf spot and freckle are also cause of concern in terms of enhanced production costs towards their containment at lower threshold levels. Irrespective of the production system, the presence of inoculum load, weather conditions that trigger sudden

outbreak and susceptibility of most commercial clones are threatening both backyard and commercial plantations.

Among the viruses, *Banana bunchy top virus* (BBTV) is a serious threat in traditional production systems. Perennial plantations, failure to control insect vectors and incentives to remove virus-affected clumps have deteriorated the existing conditions. One such example is the slow erosion of the popular 'Hill Banana'. Its area came down from 20,000 ha to 2000 ha within the last 1 to 2 decades. Similar are the conditions where perennial banana cultivation is a way of life in most developed and developing Asian countries. Banana streak viruses (BSV), integrated in the host genome and eventually in various production systems, pose another threat. As a slow killer, its effect is felt only with passage of time in terms of overall reduction in productivity, especially in Mysore clones which form the basis of economic security in many countries, like India, Sri Lanka and Bangladesh. *Banana bract mosaic virus* (BBrMV), a relatively new virus, has slowly but systematically spread from Sri Lanka to India and from Southern states of Kerala to many other neighbouring states in India. It is also reported in the Philippines and other countries. Lower productivity and eventual deterioration, affecting all cultivars, has opened a new threat. It is recorded on all plantain ecotypes, Mysore, Cavendish, cooking bananas, Silk, P. Awak and all other landraces. Ignorance and indifference have worsened the situation. Although *Cucumber mosaic virus* (CMV) has not been alarming, its occurrence in tissue culture-raised plantations due to failure in field detection and least prioritisation for indexing is expected to get worse over time.

Nematode pests are omnipresent, irrespective of the production system, climate, soil and cultivars. If not managed timely and strategically, they can lead to production losses of 20-80%. Nematode and nematode-wilt complex interaction can seriously hamper production and productivity of a plantation. Weevils and borers are also becoming serious pests. Earlier only restricted to southern states of India, the pseudostem weevil has reached Northern India across the state boundaries bringing down the productivity. Though cultivar preferences are reported, weevils spare no cultivars, irrespective of genomes and ploidies.

Abiotic factors like low temperature, flooding, typhoons, salinity, etc., are equally devastating. Unlike biotic factors, climatic vagaries seldom give scope for preparedness. Reframing the production system (in terms of season) alone can provide orchard protection. Simultaneously, disappearance of species, ecosystems and cultures which are unique are far more alarming due to overharvesting of natural resources, rapid population growth, invasive species supported by climate change having impacts on livelihood and economies. With the above spectrum of problems, the situation of banana industry needs a holistic analysis regardless of the regional imbalances, and opportunities need to be exploited to overcome the threats.

Despite these constraints, banana production has grown in Asia, due to improved production technologies as mentioned above. In addition, the polyclonal production system in Asia and the Pacific and the region's vast diversity of *Musa* species, many of them unique, harbours genes conferring resistance to many stresses. Status of cultivar mixtures in small-holder plantations has always been a safeguard against major disease and pest outbreaks. This situation has stabilised the banana industry from collapsing under serious conditions. This situation needs to be capitalised under various programmes.

INTERNATIONAL AND REGIONAL COOPERATION

Many of the NARS, like in India, have many programmes wherein coordinated research involving other countries is funded. So also are the many bilateral programmes, like Indo-Australian joint research ventures, supported by the respective governments. Such opportunities need to be exploited to reduce exclusive dependency on global donors. In India, networking projects on genomics, Fusarium wilt, leaf spot disease and viral disease are ongoing, which have provided better dividends in terms of understanding and managing the problem in a regionally differentiated manner. Under the All India Coordinated Research, germplasm and production technologies are tested in different agro-ecological zones. Irrespective of advanced production technologies, pest and disease management, post-harvest management, low productivity and poor quality of produce still reign and defy the banana industry in Asia. The importance of banana and plantain for food security and income makes it imperative to rehabilitate the industry with strategic planning.

Adoption of most of the improved technologies in Asian countries has been by trial and error, driven by necessity. Sporadic attempts by various countries were assembled under a single umbrella by INIBAP (now a programme of Bioversity International) to draw the global attention. INIBAP was established in 1985 to coordinate the fragmented nature of work going on at various global centres. It started functioning as a networking organisation with regional offices in Asia and the Pacific, Latin America and the Caribbean, Eastern and Southern Africa and West and Central Africa. With its recognition as a programme of Bioversity International, it aims at organising and coordinating global research efforts to increase the production and productivity of smallholders. The ProMusa programme is a landmark in the history of banana research.

Establishment of BAPNET at regional level played a pivotal role in establishing effective mechanisms for the identification of regional research priorities through partnership, collaborative projects and regional cooperation. It has developed a stronger partnership with NARS to pursue agreed research agenda of mutual interest. BAPNET in coordination with Bioversity aids in identifying regional problems in consultation with NARS of member countries and prioritise the work in network mode involving effective participation. A major priority is the collection of the diversity which till date is elusive due to its difficult geographic distribution and quite often remains inaccessible. Although many commercial clones, landraces and to some extent wild species have been collected, many others are still missing. Many of the collections in the Pacific Islands, Malaysia and India have offered new additions to the existing collected diversity.

GENETIC RESOURCE MANAGEMENT AND UTILISATION

Many exploration and collection missions have been funded by Bioversity and NARS resulting in a better understanding of the large diversity. Recently, collection missions and human capacity involved in these missions have been shrinking with importance being shifted to applied research. More attention has been given to related activities of genetic resource management. In view of emerging pest and disease problems, collection is however still an essential activity in the search for new resistant gene sources. Before it is too late, programmes are to be redefined to keep the collection spirits alive through the support to researchers involved in this mission. The related genetic resource management activities, like morphological and molecular characterisation, has been very systematic and has seen a growth in terms of funding and human resources. Although well initiated across the globe as MGIS (*Musa* Germplasm

Information System), continuous involvement with systematic data uploading is being hampered by the non-availability of trained manpower. Some of these activities need to be identified by NARS as essential, and continued support needs to be extended.

Though field conservations are a mandate of NARS, in-vitro conservation of non-seeded crops like banana is an expensive activity. Very few institutions have this backup facility. Basic core funding needs to be developed to support smaller countries with a rich *Musa* germplasm diversity. Although Bioversity is supporting important collections to regenerate and conserve, these programmes are time bound beyond which smaller countries will struggle for want of support. Permanent solutions are to be drawn to follow up this continuous activity. Cryopreservation for perpetuity has been identified as an important activity to conserve *Musa* germplasm and is being supported largely at the International Transit Centre (ITC), KULeuven, Belgium. This activity is also extended to India under the Global Crop Diversity Trust-funded programme. The process of cryopreservation, though tedious, offers a long-term solution to conservation. Although protocols have been standardised for banana and plantain, understanding biophysical and metabolic processes underlying sensitivity/resistance of plant tissues to cryopreservation is still expected to lead to a more rational, scientific and cost-effective strategy.

BAPNET has identified the understanding of cultivars used by farmers, by developing profiles and descriptions of cultivars and varieties, as an important regional activity. Each member country is developing cultivar profiles of banana in their country. This also helps to identify synonyms, thereby enhancing efficiency of research. Conservation has been a global priority activity supported in various forms.

Evaluation of germplasm for various important traits has been in progress. Gene sources for resistance, alternative varieties for existing agronomically poor cultivars, nutritionally rich ecotypes etc., have been identified. Effective exchange mechanism across the countries through the single window system of ITC is well established. But more countries need to be brought under this umbrella with effective dialogue at higher levels, especially with respect to germplasm exchange.

Effective utilisation of germplasm at national and international level is promoted through strategic networking supported by both NARS and Bioversity. Several hybrids, clones and cultivars developed by breeding programmes across the world are tested for resistance to Fusarium, Sigatoka, nematodes and for yield. Many Asian countries are participating in this programme and have benefited from the intervention of BAPNET. Implementation of this activity in a project mode with funding and fixed responsibilities is expected to overcome operational problems and to yield better dividends. Active information dissemination and documentation is the basis of any research system, for a coordinated approach and to create synergy. It helps to match regional with international priorities, keeping in view the R&D needs of national systems. BAPNET is thus acting as a catalyst to build stronger partnerships among NARS to pursue an agreed research agenda for mutual benefit through coordination, publication of original material, information dissemination and fund sourcing to major global research initiatives.

QUALITY PLANTING MATERIAL

Use of disease-free, tissue culture-multiplied quality planting material is an important step. Although these are commercial ventures which need the support of the local government, creating awareness among poor smallholders to use disease-free planting material needs to be prioritised. Countries like Australia, India, China and Taiwan have already been sensitised, resulting in 4-20% of the planting material coming

through tissue culture. Production of disease-free planting material needs the diagnostic system to be in tune with the prevailing viral diseases in the respective regions/countries. BBTV and BSV are the common targets in many countries, while India, the Philippines and Sri Lanka need additional indexing for BBrMV. Viruses, being so serious, invite legal interventions when inadvertent overlooks happen with tissue-culture industries. To safeguard the farmers, entrepreneurs and the banana industry in general, a certification system for tissue culture-developed banana planting material is introduced in some countries, like e.g. India. This involves a series of steps before certificates of “good health” are issued to the industries. This success story with all protocols has been documented. Developing diagnostic kits and its commercial exploitation is feasible but monitoring becomes difficult at field level. Hence this gap in diagnostics and monitoring needs to be intervened by government support with proper guidelines. Under such NARS programmes on virus indexing and fidelity testing, national/state institutions can be recognised, strengthened in terms of infrastructure and manpower to rehabilitate the banana industry. Required technical input in terms of capacity building and technical consultations can be provided to other member countries by the already established leaders like Australia, China and India. It is soothing to understand that the Pacific Islands are among the beneficiaries from the Australian government through bilateral initiatives with the intervention of BAPNET.

Most countries, including countries in Asia and Pacific, are realising the importance of disease-free quality planting material for enhanced production and productivity. An FAO survey indicated that traditional suckers as planting material are used by 92% of the growers across the world; only about 8% have access to tissue-cultured plants. Emphasis should be on the cost effectiveness of tissue-culture plants with access to all strata of growers. Presently, major Asian countries produce less than 100 billion plants annually of which China, India, Philippines and Australia contribute 0.25, 0.15, 0.1 and 0.1 billion respectively. Many countries in Asia have strong support from the government in establishing national facilities for quality and virus testing of tissue-culture plants. Bioversity, in collaboration with BAPNET, is supporting rationalisation of virus-indexing techniques in Asian countries through regular workshops and trainings. Though indexing and fidelity testing is strictly followed in international germplasm transfer, its day-to-day application in the local commercial banana industry is yet to gain momentum.

BAPNET has shouldered the responsibility of conducting extensive surveys of seed systems among its members and to develop a common strategy applicable at national level. This will be coordinated by Bioversity and BAPNET with the help of member countries. Success reaped in other countries will be considered to develop a national system and to finetune an already existing system. Many such thrust areas identified at the 16th BAPNET meeting and their effective monitoring and implementation are expected to improve the status of banana and plantain in the region.

SOIL AND PLANT HEALTH MANAGEMENT

Foliar diseases, of which Sigatoka is very serious, are important in banana. Cryptic outbreaks are far more damaging than systematic ones. BAPNET has emphasised the need for effective control through better NARS system. But a systematic regional survey and data analysis can provide an insight about the diversity status and population structure which will be useful in drawing breeding strategies. Estimation of durability of host

resistance, pathogen adoption to alternate hosts is needed in drawing effective control measures.

Soil health management is yet another important area that needs more attention to enhance the health status of the plant which in turn improves resistance to biotic and abiotic stresses. However, research efforts in this area have been meagre. A clear analysis of the dynamics of the existing systems in the area of soil health, soil moisture, microflora, their antagonistic and synergistic interactions, fate of applied nutrients, solar radiation profile, etc. would open up new vistas for intervention to make the system self generating and cost effective. Microlevel manipulation in water harvesting, soil conservation, organic matter generation through recycling, supplementing with favourable microflora, is expected to substantially enhance the production and productivity of banana.

Repetitive application of control measures have led to a world-wide biodegradation syndrome not acceptable from an environmental, toxicological and consumer point of view. Microbe-based strategies, like biocontrol, biotisation and use of plant growth regulators, are promising research activities in progress. Antagonists mixtures with diverse mode of actions, identification of effective antagonists through molecular tools complemented with redesigning of the cropping system supporting natural biological systems are most promising. In some countries, like India, natural endophytes with better disease suppression activity have been identified. Since they are identified from regions where the disease and the host have co-evolved, efficiency of local strains is well proven and they are released at the national level from NRCB and TNAU.

EMERGING THREATS AND APPROACHES TO ADDRESS

With the scenario of existing problems and emerging threats, all stakeholders should work together to accelerate *Musa* improvement. In view of the declining financial resources being devoted to *Musa* improvement research, and the scale of the problems, it is important to strengthen collaboration between the different institutions already involved around the world. It is also very important to maximise all the resources and support already available to develop research on *Musa*. Networks like ProMusa and BAPNET aim to bring together all the contributors in *Musa* genetic improvement research, including social scientists. The approaches need to be multidisciplinary and convergent to focus on common problems. Some of the issues listed are not new but need emphasis and implementation, some need interregional support for expression of better dynamism which will be visible in terms of output. Broadening the genetic base through intensification of collection missions and development of a strong Asian breeding programme, development of cultivars to suit the regional needs of small and marginal farmers, innovation of cultivars with a broad spectrum of adaptability to limited water resources utilisation, biotechnological tools of improvement, fertiliser tailoring and judicious water harvesting, and use of technologies to economise on the production cost are some of the issues which need attention. Ensuring quality of planting material using indexing and fidelity testing tools and an efficient supply chain system with integration of quality control is also needed. Development of quick ex-vitro multiplication methods using conventional planting material would also benefit smallholders.

It is essential to develop quick diagnostic tools for banana diseases and rationalise existing diagnostic protocols to suit the regional needs and disease strains and understand vector management through genetically modified technologies, using RNAi technology.

Elimination of BBrMV from the germplasm maintained in several regional genebanks for efficient utility and exchange needs to be prioritised. Tools to eliminate viruses from host systems (from valuable germplasm) through cryo- or chemotherapy need to be developed. Fusarium race 4 is threatening several countries in the region. To contain its spread, knowledge on common disease forecasting models with information on distribution, spread, strains and dispersal pathways are essential. In case of its inadvertent entry into a new region, it is essential to be ready with contingency plans to combat the situation of disease outbreak. It is necessary to accelerate characterisation and mapping of diversity in the pathogen to establish transborder quarantining and sanitation. Development of a non-chemical control strategy, in terms of resistant cultivars, improved crop dynamics, biotisation with endophytes and non-pathogenic Fusarium forms, would be one of the approaches.

LEARNING FROM EACH OTHER'S EXPERIENCE

Knowledge sharing in terms of human resource development programmes, development of rationalised techniques for disease diagnostics and other molecular biology tools to tackle banana production constraints would strengthen efforts to improve banana production in the region. Over the last couple of years, with the intervention of the Indian Council of Agricultural Research (ICAR), Ministry of Agriculture and other governmental programmes in India, expertise has been developed in various fields. The efforts have led to the development of an excellent 'Seed Delivery System' which involves the maintenance of virus-free mother blocks, sequential indexing, fidelity testing and certification standards. Certification is also enforced on tissue-culture industries and the planting material. A farmer-friendly mass production protocol for the multiplication of planting material at their own farm nurseries with minimum infrastructure has been standardised. This needs minimum infrastructure and needs to be easily adoptable. Training and necessary guidance can be extended to other countries. Application of molecular tools for genetic diversity analysis, development of markers using various marker systems has all been well standardised. Expertise is also available in terms of diagnostic tools for three major diseases (BBTV, BBrMV and BSV) for which the indexing protocols have been rationalised with international procedures. With the assistance of Bioversity and FAO, India is already conducting international training programmes on cryopreservation techniques. This technique has been well standardised for banana and plantains, and its routine application has been initiated. Functional genomics for several traits is another important field where India has expertise. A networking project on 'Study on Functional Genomics and Development of transgenic crops' is progressing well. Functional genomics studies on Sigatoka leaf spot and Fusarium wilt resistance are being carried out with strong bioinformatics support. The experience of India can be well utilised for the benefit of partner countries in the region.

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Simmonds, N.W. 1962. The Evolution of the Bananas. Longman, London, UK.

Tables

Table 1. Area, production and productivity of banana and plantain in major banana-producing countries in 2008 (FAOstat, downloaded February 2010).

Country	Area harvested (000 ha)	Production (million tonnes)
India	709	26.2
Uganda	1815	10.0
Philippines	439	8.7
China	311	8.0
Ecuador	327	7.2
Brazil	513	7.0
Indonesia	106	5.7
Colombia	487	5.4
Tanzania	788	4.1
Ghana	319	3.4
Nigeria	462	2.7
Rwanda	370	2.6
Cameroon	341	2.2
Costa Rica	51	2.2
Mexico	78	2.2
Others	3,108	30.0
Total	10,223	127.7

Figures

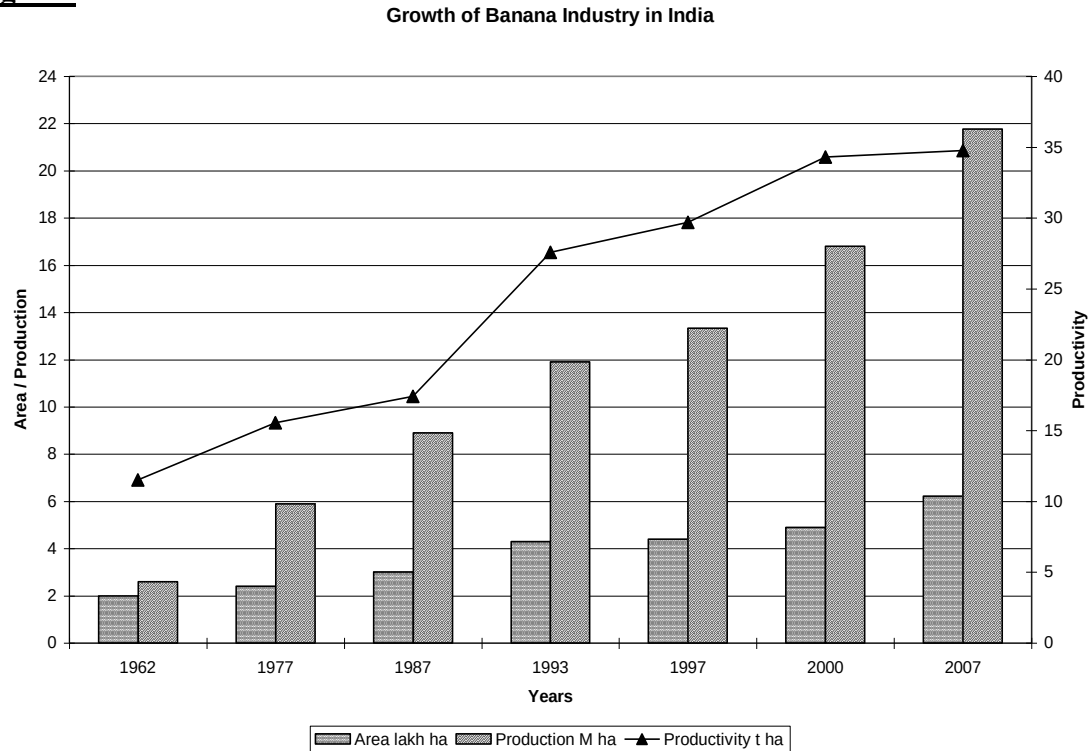


Fig. 1. Growth of the banana industry in India from 1962 to 2007.