PROCEEDINGS

Steering Committee Meeting

of the

Banana Asia Pacific Network (BAPNET)

May 7-9, 2019

Venue: Hotel Yanling, Guangzhou, PR China

Organized by

Bioversity International -India
&
Guangdong Academy of Agricultural Sciences (GDAAS), Guangzhou, China

1. Introduction

A Banana Asia Pacific Network (BAPNET) Steering Committee meeting was held at the Yanling Hotel, Guangzhou, Guangdong, China, from May 7-9, 2019. The meeting was attended by the majority of members of the BAPNET committee Asia-Pacific countries *viz.*, India, China, Philippines, Papua New Guinea, Taiwan, Malaysia, Bangladesh, Vietnam etc. Besides, Dr. Altus Viljoen, from Stellenbosch University (SU) and Honorary Research Fellow for the Bioversity International. From Bioversity International: Dr. Nicolas Roux, *Musa* Genetic Resources Team Leader and MusaNet Coordinator, Dr. Inge van den Bergh, Banana cultivar and knowledge sharing Team Leader and ProMusa Coordinator, Dr. Guy Blomme, *Musa* Pest and Disease Team Leader, and Dr. Sijun Zheng. In addition, various scientists and research scholars from Guangdong Academy of Agricultural Sciences (GDAAS) participated. This meeting was jointly organized by Bioversity International–India and GDAAS, China under the chairmanship of Dr. N. K. Krishna Kumar of Bioversity International, India and Dr. Yi Ganjun, Vice President, GDAAS, Ghungzhou, China.

On the first day of the meeting, Dr. Yi extended his warm welcome to all the members of the steering committee meeting. He was thankful to Bioversity International and the BAPNET family for selecting China as the host country for the meeting. He briefly narrated the progress of China regarding the infrastructure, science and policy atmosphere. He was happy to facilitate the space, guidance, financial support, and joint project proposal through the academy to advance the research and development of banana for food and nutritional security.

In his welcome Dr. Yi mentioned that:

i) Among 35 provinces in China, Guangdong is the biggest province with more than 100 million people
ii) The Chinese government is spending 30 million US $ every year for R & D activities and more than 300 people are involved in various research works related to banana and about 11 scientists are working to solve the problem of *Foc* TR4
iii) GDAAS publishes many papers in various research journals with a high impact factor
iv) China is carrying out exploration of banana germplasms against *Foc* TR4
v) China is producing 7 million tissue cultured plants every year
vi) In China, researchers are evaluating East African Highland Bananas (EAHB) for

their adaptability and quality. They introduced a cooking banana which is becoming popular in China

vii) Researchers have developed five different *Foc* TR4 resistant/tolerant varieties and among these ZJ9-triploid was completely resistant to *Foc* TR4 in China (developed by crossing diploid with tetraploid–FHIA01)

viii) They have developed rapid propagation of banana plants and by which 20 plants can be produced from a single sucker as against 4 plants per sucker

ix) They have developed technology to mass produce TC plants using small polythene bags

x) They are promoting the implementation of the innovation-driven development strategies and construction of One Belt One Road (OBOR).

Dr. Kumar also welcomed all the delegates. He thanked Dr. Yi for the hospitality and meticulous arrangements. Further, he expressed the sincere appreciation of Bioversity International and the BAPNET community at large to Dr. Gus Molina for decades of dedicated service in advancing the all-round research and development of the banana industry. His dedication to identify and profile the pathogen and identify TR4 resistant clones and its mainstreaming for commercial cultivation was worthy to emulate. In his recognition an appreciation letter will be sent to him. He emphasized the significance of OBOR, a flagship policy of the Chinese Government, and how valuable the research on banana can be for the commercial and nutritional security of the region and beyond. There is a need to publish a global status paper on TR4 with inputs across the regions from different workers. It was decided to circulate the first draft and others can add the inputs of their specialization and regional advances. Dr. Van den Bergh suggested a lot of this information is uploaded in the Musapedia pages and it can be updated from inputs of all workers. It is free and can be fully utilized by all.

Dr. Kumar made a brief presentation on the progress in the BAPNET activities since the last meeting at Guangzhou in 2016. He indicated that two of the genotypes (Saba and Namwa Khom) shared by Bioversity International were evaluated by the National Research Centre of Banana (NRCB) in India. Both genotypes were evaluated at the national level through coordinated, multi-locational trials. Subsequently they were released as varieties to the national system by NRCB acknowledging the contribution of Bioversity International. He also indicated that there is a need to investigate the impact of such work.

Subsequent to the last meeting on the importance of TR4, several sensitization meetings by Bioversity International in collaboration with NRCB were conducted in different parts of India (Karnataka, Tamil Nadu, North-East, Uttar Pradesh, Bihar etc.). As a result of continuous effort by Bioversity International and the national system, successful sensitization of different stakeholders on the importance of the *Foc* TR4 was possible. In that regard the Director General of the Indian Council of Agriculture Research (ICAR) conducted a meeting in December 2017, followed by subsequent meetings at a different level to highlight the importance and action plan that needs to be developed in mitigating the spread of the TR4 at country level. Despite the several sensitization meetings and the discussions at various levels it is unfortunate that TR4 which was originally reported from Bihar has spread to the state of Uttar Pradesh in several districts. Similarly, Bioversity International has also played an important role in the facilitation of the resistant clone from Philippines. There was a lot discussion with regard to the import of germplasm from Taiwan and due to political sensitivities, it was decided that the best course of action was to involve the private sector. Private sector had a one to one discussion with Dr. Gus Molina and visited the Philippines and they are negotiating for the import of the germplasm. In parallel, excellent work is being carried out in several parts of Uttar Pradesh on the biological control and initial reports indicate very good opportunities for biological control in suppressing the pathogen. In collaboration with the Indian Space Research Organization and the Indian Institute of Science, efforts are also being made to use satellite and drone technology in remote sensing the spread of TR4. In addition to this, the work in collaboration with IITA for the improvement of banana in Great Lake region of Africa is also being carried out by NRCB through interspecific breeding and evaluation of TR4 resistance. The aspect pertaining to the races- R1, race-2, TR4 is often confusing and it appears that R1 and race-2 are present in southern India, where as TR4 is present in U.P and Bihar.

As a follow-up of the last year's meeting, a few discussions have taken place and an International Conference with a special *Foc*us on TR4 is being planned in January or February 2020. However, it must also be acknowledged that several regions of South Asia, the North-Eastern parts of India, Bangladesh, Sri Lanka, Pakistan, and many other regions have not yet been profiled for presence or absence of TR4. In depth studies must be carried out. Dr. Kumar will be visiting Bangladesh and will seek possible collaboration through the SAARC network and BARI to take this kind of research forward in other countries.

An important question that has being asked by the policy holders and others is does the pathogen move through the export chain; this is an aspect that is being investigated by

the national research system. At this point of time there is no clear scientific data on the movement of the TR4 pathogen through the export of fruits to different countries. While the *Foc*us has remained largely on the Cavendish G-9, there is a particular need to profile the incidence of TR4 and its damage in regionally important varieties such as Nendran in Kerala, Karpuravalli in Tamil Nadu, Chakkrakeli in Andhra Pradesh, Patkapura in Orissa and Rasbale in Karnataka and many other region-specific varieties. In some cases, the banana leaves are used as plates, consumed and thrown away. The flow of pathogen through use of banana leaves is to be explored. One of the paradoxes about the management of TR4 that needs to be addressed has been the involvement of resistant clones and whether to import them as a mitigation strategy. This is because of the observed increase in their susceptibility over time, even among the resistant clones. We are very happy to share that a very high-power delegation, including the Minister of Agriculture Government of Bihar and his chief Secretary and many others visited the Bioversity International offices in France, Belgium and Italy, where they had discussions with the scientists and senior management staff. The Government of Bihar made an announcement immediately after the visit that the they would like to collaborate with Bioversity International in mitigating the spread of TR4. Subsequently presentations were made for key officials, the project has been submitted for mitigation of TR4 and it is expected that after the elections positive results should emanate from Bihar. Because of the number of activities, it was thought that the aspects will be explained at the right time of time by the respective workers.

One of the excellent contributions that came out since the last BAPNET meeting has been two peer reviewed research papers from the Indian subcontinent on the presence of TR4 based on VCG markers. This is the first time the presence has been acknowledged, which will catalyze other countries in profiling their pathogen and damage.

There were also certain reports coning from Bangladesh regarding the presence of Fusarium wilt that needs to be still confirmed. It is very interesting to note that since last BAPNET meeting the confirmation of *Foc* TR4 has also been reported in Laos, Vietnam and Myanmar by Zheng *et. al*. of Bioversity International.

Foc TR4 is threatening banana production and the main reason might be shrinking diversity. As the *Foc* TR4 is a transboundary disease, we all have to work together by interdisciplinary and international means to tackle this problem holistically at a global level. In addition, cross country policies and quarantine procedures should be developed for this problem. Also, all the members of BAPNET are requested to carry out an impact analysis

of the contribution of BAPNET in the R&D of banana research and to prioritize the problems being faced in banana.

2. Presentations

Presentation by Dr. Reynaldo Ebora of DOST-PCAARRD, Philippines:

In the Philippines, bananas are grown over 446,764 ha wherein Cavendish occupies 20 percent, Saba 41 percent, and Lakatan 12 percent. TR4 was first observed in 2002 in the Mindanao area and by growing GCTCV 219, which is the selection from GCTCV 119, there has been 100 percent reduction in disease incidence. GCTCV 219 takes 8 months for shooting and gives yield of 21 kg/bunch; however, peel splitting is the main problem in this variety. With regards to GCTCV 218, about 2.3 million plants were planted by commercial banana companies in 2017. It has 90 percent resistance to *Foc*TR-4, with a heavier bunch (27 kg), and more uniform hands. Integrated disease management packages have been developed using VAM (Vesicular Arbuscular Mychorrhizae) and *Trichoderma harzianum* and the application of these bio-agents resulted in 73 percent reduction in disease incidence. This practice is being followed for the variety GCTCV 218 but not for GCTCV 219 as it has 100 percent resistance to *Foc* TR4. In addition to growing cover crops such as peanut, kudzu and ornamental sweet potato, burning of *Foc* infested plants with rice hull, quarantine measures are being followed to manage the disease. However, Dr. Yi said that GCTCV 218 has not performed well in China and during cold temperatures, the growing cycle extended up to 14 months and fruits did not ripen.

Presentation by Dr. Babul Chandra Sarker of BARI, Bangladesh:

In Bangladesh, the major fruits are jackfruit, mango, banana and papaya and bananas are grown mainly in Rangamati, Barioul, Rangpur, Dirajpur, Noacheli and Faridpurin over a total of 48,665 ha and the annual production is about 0.8 million tonnes. BARI-1 which is a Cavendish type and BARI-5, a cooking type, are mainly grown in this country and the productivity is only 16.6 tonnes. The wild type banana *Musa textilis* is grown for fibre purposes. Although *Fusarium wilt* R1 is present across the entire country, there was no incidence of TR4 so far. Other problems noted were low yield, dearth of disease-free suckers, fruit scarring beetle, leaf spot disease and nematodes. A local seeded banana cultivar is resistant to R1. Application of poultry litter @ 6-8 per pit and drenching the plants with Carbendazim are the management practices being followed to tackle the disease. VCGs 0124/5, 01220, 0123, 0128, 01217 and 0124/01222 are identified in Bangladesh. *R1* in Cavendish was also observed but there was no confirmation of presence of TR4 in

Bangladesh.

Presentation by Dr. Razali Bin Mustafa of MARDI, Malaysia:

In Malaysia, the banana which occupies 2nd position among fruits is grown in 35,156 ha and 678,042 tonnes are produced annually; the average yield per hectare is 13.22 tonnes. The province Johor Pahang Sabah is the major banana producing region in Malaysia and *Fusarium wilt* R1 is the most serious problem particularly in Pisang Mas (AA) and Berangan (AAA). The management practices being followed are good agricultural practices, application of Lixiviate 5.2 lit/10kg of FYM, use of encapsulated Streptomyces S12 strain in calcium alginate beads, intercropping and fumigation of soil with methyl bromide.

Presentation by Dr. Birte Komolong of NARI, Papua New Guinea:

In Papua New Guinea, the bananas are produced throughout the islands and the average yield is 9-12 tonnes per ha. Less than 1 per cent of TC plants are used in this country. Among banana 80 per cent are cooking types and 20 per cent are dessert types. Although there is no TR4 incidence detected so far, the Banana Wilt Associated Phytoplasma (BWAP) disease caused by phytoplasma is the major problem in banana especially those grown in coconut gardens. The disease is transmitted by vector leaf hoppers and plant hoppers of Despidae, Lophopidae and Flatidae. The Loop Mediated Isothermal Amplification (LAMP) method has been developed to detect BWAP at an early stage. It is important to note that no banana or other plant material should be collected from PNG to avoid the introduction of BWAP to other countries. Dr. Kumar from Bioversity International expressed that publication on BWAP would be more useful for quarantine purposes.

Presentation by Dr. Agus Sutanto of ITFRI, Indonesia:

In Indonesia, about 7 million tonnes of bananas are produced every year and the most popular varieties grown are Saba, Berangan and Gros Michel. More than 90 per cent of banana produced are consumed locally and remaining 10 per cent are exported. *Foc* TR4 has destroyed 28 per cent of banana and the annual loss is US $105.7 million/year. The GCTCV variants such as CJ30, CJ40 and DM2 have been developed to tackle the disease. The *Foc* management practices developed are bio-agents such as *Gliocladium+Trichoderma* spp. + organic matter, *Foc* tolerant variety Ambun Kuning which was developed by gamma irradiating of var. Pisang Ampyang, *Foc* TR4 resistant variety INA03 was developed by crossing BARIF-0025 and Barif-0130. There was no incidence of *Foc* TR4 observed in the main crop of the hybrid INA03 developed. Another important problem in banana is blood

disease caused by bacteria and for the management the country has identified a mutant of var. Saba called Kepok Tanjung which is budless.

Presentation by Dr. S. Uma of NRCB, India:

In India, a brief presentation on R&D of banana in the context of TR4 was made by Dr. S. Uma, Director of NRCB. She quoted that production is 30 million tonnes from an area of 9 million hectares. The value of the banana in the country is around 50 thousand crores of rupees. As per the reports from the pathologists of NRCB, TR4 presence ranges from 0-24% and an average highest can be even up to 100%. The approximate loss per year is 500 crores of rupees in general wilt; with respect to production also it is almost consistent. Production is declining every year from the last few years, however this is not attributed only by *Fusarium* wilt alone, it is also due to climate, especially drought.

Dr. Uma mentioned that the major Cavendish banana growing areas represent a polyclonal system of cultivation. Areas like Uttar Pradesh, where Cavendish banana is replacing sugar cane cultivation and southern Rajasthan near the Saharan desert and the Northern India, where temperatures go as low as 2-4^0 C were also growing bananas, showing the adaptability of the crop. Major varieties grown are Grand Naine, which occupies almost 50-60% of the area, followed by Cavendish clones - Robusta, Dwarf Cavendish and Harichal. The Red banana is very famous in Tamil Nadu, Kerala and Andhra Pradesh, and other AAB types - Silk type, Mysore type and Plantains, also make up a great percentage of production in the country. Among the ABB group, Monthan, Karpuravalli, and Sakkai are also popular traditional varieties. Among all varieties, the Cavendish comprises about 63% of the area followed by the Mysore and then the others.

Dr. Uma also highlighted the problems and priorities identified at the Bogor meeting in 2012; *Fusarium* wilt was also then the top problem in Indian banana, followed by leaf spot diseases and viral diseases. Dr. Uma said viral diseases are not a serious problem because we follow different production systems, i.e. annual or biannual production systems and use quality planting materials. *Fusarium* wilt is the major problem and so they are working on different approaches to improve bananas at a national level. About 263 accessions were introduced from ITC in the last 15 years and they have been evaluated for agronomic, breeding and disease traits. Approximately 120 accessions are in the NRCB genebank and they have been evaluated for R1 in 4 replications. They have been planted in the diseased field and real time evaluation is done for the main crop under ratoon crop.

Secondly, 430 accessions along with few accessions from ITC are being evaluated in Bihar, 2000 km away from Trichy (NRCB). First crop results will be presented by Dr. Thangavelu.

Dr. Uma explained how the Cavendish banana is being replaced by the other varieties of banana, especially red banana and plantain resistant to the R1 in the state of Tamil Nadu. Wherever the Cavendish is affected by R1, it is being replaced by these resistant varieties. In the TR4 screening trials in Bihar, some of the varieties are showing resistance to TR4. Many more wild species have been multiplied and taken to the diseased field for screening. This is a next stage of our work. During this process one of selections looks like but is not a Cavendish banana. In the process of rejuvenating it through tissue culture, we found this high yielding variant that is resistant to both R1 and TR4 so multiplied it on large scale and now hundreds of plantlets have been taken to the diseased plots in Bihar and Theni for evaluation. NRCB is well equipped with large scale production systems, either using public product partnerships (tissue culture company) or high throughput production. Now we are in position to multiply this selection on a large scale and take it to the diseased field for evaluation and eventually to the farmer's fields.

Dr. Uma elaborated research on conventional breeding of banana: 1. Ongoing institutional programme: Development of *Fusarium wilt* resistant bananas, development of Sigatoka resistant bananas. For this they have excellent data base with respect to the varieties, clones, combinations, and the best combination with high seed setting and high germination efficiency. Based on this database they are trying to cross these varieties through primary tetraploids to produce direct triploids. 2. Development of superior bananas for the Great Lakes area of Africa supported by Bill and Melinda Gates Foundation and facilitated by Bioversity International. Development of superior diploids and sharing and screening of materials is in progress. A couple of superior diploids have been developed which we are sharing with the partners. Materials developed from different breeding schemes are also being imported and screened in the diseased plots for both R1 and TR4.

At NRCB, they have standardized a technique in tissue culture in which one embryo is multiplied to no less than three plantlets, whereas it is normally one embryo to one plantlet. This will reduce the time taken to screen the materials. They are also carrying out embryo culture, embryo rescue, multiple shoot induction and utilizing the diploids both indigenous diploids and diploids introduced from ITC. In this programme, Inbogo and TNB series are excellent materials for breeding.

The hybrids developed at NRCB must be screened before they go to the field. In the

case of tissue culture if it is large-scale multiplication, in vitro screening has to be done using Fusaric acid and Beauvericin. Those that survive this initial screening, go to pot culture. In pot culture, a minimum of 10 replications should be maintained for each and only those found promising in this screening are taken to the diseased field plot. With this procedure, they have developed some of the progenies found to be resistant to R1 and also developed some of the progenies with good agronomic traits taken for *Foc* screening in pot culture. Development of synthetic diploids and the chromosome doubling is also in progress though it is not very promising so far.

Triploid x Diploid breeding scheme - NRCB developed a couple of primary tetraploids, especially for Pisang Awak group which are promising with respect to agronomic traits. They are trying to cross and develop the progenies using the superior diploids.

Plantain Breeding Programme: NRCB developed two plantains which are very promising. Plantains in India are eaten only after cooking to improve the palatability. They have developed a plantain like banana with high carotenoids, but which has dessert characters and that can be eaten raw instead of cooking. Another plantain developed is high yielding, with bunch weight around 20-23kgs. Some hybrids were also developed which were screened and shared in an IITA project. In cooking bananas, ITC Saba-based progenies were found to be promising with respect to tolerance to R1.

Application of molecular breeding: NRCB developed and maintains a *Musa* SSR database and trans SSR database, both freely available on the NRCB website. It also gives different pathways in biotic and abiotic stress resistance mechanisms and role of gene regulators in resistance mechanism is also predicted.

Mutation breeding facility: Initially chemical mutagens were used, but now they are developing a Gamma chamber at NRCB, and at the same time maintain embryo cell suspension for targeted mutation. They have cell suspensions for almost 10 commercial varieties. These commercial varieties can go to mutation next year onwards. They developed a Cavendish clone resistant to R1, which is under a screening stage for TR4 and is being multiplied on a large scale using a Tissue Culture Company. Around a thousand clones will go to the diseased plot and farmers' fields for evaluation this year. Another mutation breeding outcome is Silk, which is resistant to *Fusarium* wilt R1. Two others are in the pipeline, one is very good with respect to agronomic traits, and this clone is also going for large scale multiplication, diseased plot screening and farmers' fields evaluation. NRCB

has excellent high throughput production bio-reactors and within few months have developed thousands of plantlets using the male bud system.

Transgenic approaches: Full length genes and preliminary work on Leucine rich receptors like protease have been identified and amplified. And cloning and confirmation of the RGA-2 gene has been done.

National Agriculture Research System -

1. All India coordinated research programmes, of which there are 11 centers (SAUs), are attached to NRCB- whatever the relevant material which found promising they will be first evaluated at NRCB and that technology developed will be shared with all the collaborated institutes. Depending on the trait of interest, institutions may take it up and this information will be compiled after 3-4 years of evaluation. Once the technology has been identified it will be released in the state variety release committee and then it will go to the central variety release committee. In this process the two accessions received from ITC were released as varieties last year, but when accessions are introduced, they have to be released as a package of practices. So as a part of package of practices, Kerala Agricultural University has identified 5-6 varieties like TNP and Engram.

2. Other outreach programmes exist, like All India Coordinated Programmes, Networking of ICARs, SAUs, ASRP and extension linkages. All these will also go through the state departments.

Presentation by Dr. Chen, Yi-Jeng of TBRI, Taiwan:

In Taiwan, the banana is grown in 15,000 ha and produces 299,000 tonnes /yr. The productivity is 20 to 30 tonnes/ha and about 1,000 to 3,000 tonnes of bananas is exported every year. Cavendish banana alone is grown in 9,000 ha and about 40 per cent of planting material is from TC plants. TR4 was identified in 1967 and at that time about 5,000 plants were infected and by 1976 it had affected 1,200 ha of banana. The VCGs identified are 0121, 0124/05, 0128 and 01213/16. The other biotic stresses are BBTV, CMV, Freckle disease and Stem borer. They maintain 200 isolates of TR4 and carrying out the pathogenicity in different hosts. For the management of the disease they have developed a pathogen-tested seedling program, *Foc* resistant variety Formosana (GCTCV-218), bio-priming with endophytic biocontrol agents and effective crop rotation using rice to reduce *Foc* inoculums.

Presentation by Dr. Nicolas Roux of Bioversity International, France:

Dr. Nicolas Roux, MusaNet coordinator and the *Musa* genetic resources team leader for Bioversity International presented a lecture on MusaNet activities relevant to BAPNET communities.

The objectives of MusaNet are:

i) To conserve the entire *Musa* gene pool in *ex-situ, in-situ* and on farm,

ii) To access the *Musa* genetic diversity,

iii) To maximize the *Musa* genetic diversity through characterization, identification and evaluation and

iv) To apply genomic tools to banana. In average, every day the ITC sends 3 to 4 accessions to different countries. There are about 300 users in 110 countries. The important activities accomplished are Virus ring test, diversity gap filling through collection, early screening methods for *Fusarium wilt*, BLS and drought, tools for identification and characterization and the *Musa* Germplasm Information System (MGIS) database.

Presentation by Dr. Inge Van den Bergh of Bioversity International, Belgium

Dr. Inge van den Bergh, ProMusa coordinator, mentioned that ProMusa is involved in sharing information and knowledge on banana. There are about 900 members and every two years a banana symposium is arranged in collaboration with ISHS. They maintain three databases: Musalit, Musarama and Musacontacts for the benefit of the banana community.

Presentation by Dr. Altus Viljoen, Stellenbosch University, South Africa:

Dr. Altus Viljoen from Stellenbosch University (SU) and consultant on *Fusarium wilt* for Bioversity International made a presentation on the importance of molecular diagnostics in identifying R1. He presented an overview about the recent detection technique for *Foc* TR4. In his lecture he has mentioned that in Africa, Plantain and EAHB are the major varieties and big companies are starting TC industries and spreading Cavendish banana in different areas, which at present is grown in 30,000 ha. TR4 was detected recently in Mozambique and has infected 6,500 acres of banana. The main vector for TR4 is the people moving from infected to uninfected areas. The farm Matanuska in Mozambique was completely destroyed by TR4 which can move through vehicle flood water and planting materials. The techniques being followed for the detection and diagnosis of TR4 are DArT

markers, full genome sequencing, multi-gene sequencing, DAFs, RFLPs, RAPDs and AFLP. The markers from six genes are used for the surveillance. He stressed that the kit which can detect all VCGs is to be developed and that it is very difficult to detect *Foc* in banana fruit exported to other countries. In Mozambique at present the Cavendish banana is replaced with GCTCV 218 and so far no incidence of the disease has been observed. The government has purchased the TR4 infected areas and is implementing all quarantine measures.

Dr. Viljoen also mentioned that in Vietnam, TR4 symptoms were observed in Pisang Awak, Pisang Mas and Cavendish varieties. Poor drainage and flooding accelerated the TR4 incidence. Intercropping with maize, diverse tree crops and nursery crops like medicinal plants is being followed to manage the disease. In Laos, the *Foc* moves through soil, adhering to vehicle and animals, and that more than 50 per cent incidence was observed. The people don't generally eradicate the plants, which leads to the spread of the disease. Hence, to manage the disease, measures such as disease-free nurseries, vehicle disinfection, involvement of extension and quarantine people to contain the spread of the disease are being followed.

Presentation by Dr. Guy Blomme, Bioversity International:

Dr. Blomme presented a new project entitled "Combating Fusarium TR4 in Southern Africa and Northern India"-a new RTB-funded project under the subheading of rapid response to Transboundary and emerging diseases. He has proposed a project in India that is led by Bioversity International-India and in Africa led by IITA. The total budget of the project is 50,000 US $ and the duration is for one year.

The participating institutes and their activities were elaborated:

- **Stellenbosch University (SU) (South Africa) -** Diagnosis and VCG (vegetative compatibility group) analysis, reviewing awareness raising and training materials

- **Ministry of Agriculture (Tanzania) -** *Foc* TR4 surveillance in Southern Tanzania; translation of awareness-raising material into Kiswahili, awareness raising activities in Tanzania

- **Ministry of Agriculture and Food Security (Mozambique) -** *Foc* TR4 surveillance in Northern Mozambique; awareness raising activities in Mozambique

- **FAO-** Coordinator of the planned Global *Foc* TR4 initiative. *Foc* TR4 awareness materials and making sure the work has global significance

- **ICAR-** National Research Center for Banana, Tiruchirappalli, Tamil Nadu, India *(Foc* TR4 surveillance in Northern India; awareness raising activities in India)

- **ICAR, Horticulture division, New Delhi, India-** *Foc* TR4 surveillance in Northern India; awareness raising activities in India)

- **CISH (Central Institute for subtropical Horticulture), Lucknow, India-** *Foc* TR4 surveillance in Northern India; awareness raising activities in India

- **ProMusa-** Contribute to development of training and awareness-raising materials, and knowledge sharing activities.

Presentation by Dr. Sijun Zheng of Bioversity International, China:

In China, two types of banana production systems are present - flatland and sloping land. The majority of land is mountain slope land and only a small percent is flatland. Growing banana on slope land is a labor intensive, thus why some farmers have to make large investments to maintain the farm operations. In China, they have 24 ethnic groups and 15 unique groups of banana. Miao, Hani and Dai are some of the ethnic groups in Yunnan region. *Fusarium* wilt TR4 is one of most important factors that affect Chinese banana industries and the stability of agricultural ecosystems. In 2013, the direct economic losses due to TR4 reached 750 million Yuan in China and 250 million Yuan losses at Yunnan.

Dr. Sijun also mentioned that in Vietnam, the current cultivar mix has provided some buffering against *Foc* R1, but it will not be very effective against TR4. In the Red River delta region, they are growing three major cultivars which are Pisang Awak, Pisang Mas and Cavendish. Among these, Pisang Awak is susceptible to R1, while Pisang Mas is primarily resistant and Cavendish is immune. All three cultivars have susceptibility to *Foc* TR4, so cultivar substitution with available options will be difficult. Production on the soils of the delta lowers costs of production, but somewhat poor drainage, little use of drainage channels and flooding may accelerate the severity of *Foc* TR4. Diversity of production enterprises will reduce the impact of TR4 for farmers, since they have other options. However, the production of nursery plants for sale may contribute to the spread of TR4. Fields with serious levels of *Foc* can be converted to annual crops such as maize, diverse tree crops and nursery crops. No land is idle, but the uprooting of nursery plants for sale poses a risk that infected soils could be moved to new regions.

In Laos, TR4-infected Cavendish plantations (with more than 50% of disease incidence) appear to be a huge threat to banana production with high inoculum pressure and minimal to no biosecurity measures. Dissemination to surrounding local backyard bananas could occur by numerous means: sucker smuggling, streams in plantations and overland flow into nearby lowland rice, vehicles, animals, migrant labor from other areas.

How to manage Fusarium wilt?

Disinfecting the vehicles carrying bananas from Laos, Myanmar and Vietnam to China via Yunnan customs. Conducting many awareness meetings, workshops, conferences with the different stakeholders of banana.

Fusarium wilt and its prevention and control measures:

1. Indoor and outdoor workshops for training local farmers
2. Indoor workshop for training local plant quarantine and protection staff
3. Screening beneficial microorganisms and antagonistic activity against disease
4. A number of antagonistic active bacteria strains have been collected. After screening and further fermentation, the active compound from product obtained has been confirmed by activity assay.

Presentation by Dr. Thangavelu NRCB, India:

Dr. Thangavelu presented the importance of *Fusarium* wilt in India with respect to the farmers' perspective. He explained the spread of the disease and shared the facts of TR4 in India and confirmed the presence of TR4 in Bihar and Uttar Pradesh. TR4 was also confirmed recently in Gujarat, Madhya Pradesh, Tamil Nadu and in Maharashtra, recently collected samples confirmed the presence of *Fusarium* wilt. TR4 was recorded in Purnea, Katihar and around 20-30 per cent incidence in one farmer's field in Vaishali district. During the survey all farmers, scientists from universities, Panchayat heads, Village president, progressive farmers, KVK scientists were involved and were shown how to diagnose the disease, isolate it and how to prevent fungal diseases in the field itself.

All 5-6 methods for characterization of disease samples, quantitative, VCG analysis, molecular markers, sequencing, and microscopy examination are followed. The biogenetic analysis by sequencing clearly indicated the presence of subtropical TR4 and R1.

In *Foc* infected areas, several awareness meetings and sensitization programmes were conducted involving all the stake holders: scientists, extension personal, quarantine

personal and students in Purnea district of Bihar. Due to these sensitization meetings, progressive farmers in Madhya Pradesh and Gujarat were eager to follow their advice. Farmers started initiating healthy plants and burning the infected plants to reduce the *Foc* inoculum and make demarcations of the infected areas. They developed several posters on the 'do's and don'ts' to distribute to the stakeholders and to the tissue culture companies, who will then distribute them to the farmers.

More than 215 varieties have been evaluated for 2 years at NRCB both in Theni area where R1 is prevalent and in Bihar where TR4 is the major problem. In Theni, both main crop and ratoon crop were evaluated; in the AAA subgroup, 3 accessions were resistant and in the AAB subgroup 6 accessions were resistant, 11 diploid plants showed resistance to R1. In Bihar, in the AAA subgroup, 7 accessions were resistant; in the AAB subgroup, 12 accessions were resistant; and for diploids, 17 accession were resistant to TR4. In the AAA subgroup, Jahaji, Bhagmoni, and Hariyala Cavendish types showed resistance and Nendran and Red banana group were also resistant. The main crop has been evaluated and ratoon crops are being evaluated this year. In Bihar, Poovan type Mysore, Alfan and some ecotypes showed resistance to TR4. All commercial Red bananas were screened under pot culture conditions against TR4. Among these, Saba and Red banana showed some resistance, recorded 1.7 on a 1-6 scale.

At NRCB, the *Foc* working group have isolated 9 different bacterial endophytes as well as Trichoderma (3-4 sp) against TR4 and they have shown to be very effective under *in vitro* conditions. Now they are evaluating them under pot culture, and once shown resistant, they will take them to the diseased field in Bihar. Apart from that they also are working on the bacteria involved in nutrient salvation phosphate, potash and silicate and have identified some effective nutrient solvent bacteria.

Presentation by Dr. B. K. Pandey, Horticultural Science Division, ICAR, India:

Dr. Pandey presented the biological control method developed at ICAR–CSSRI, Regional Station, Lucknow and ICAR-CISH, Lucknow. He presented a brief account of biological control results in which he has mentioned that they have achieved more than 90 per cent control in the *Foc* TR4 infected field. He did not reveal the details of the consortium due to patent issues.

3. Field Visit

On the second day of the meeting, all the steering committee members were taken for a field visit to see the facilities and research works carried out at GDAAS, Guangzhou. During the visit several posters depicting their research activities were displayed. In addition, the *Foc* TR4 resistant varieties such as ZJ9 and ZJ4 were displayed and available for tasting. Later Dr. Yi explained about low cost technology of multiplying the TC plants using poly bags instead of bottles. In the afternoon, all members visited the germplasm block and were told about different banana varieties maintained at the farm in Guangzhou.

4. Next Steps

Finally, on the evening of third day, the entire BAPNET Steering Committee was divided into two groups. One group was assigned to plant genetic resources and their management and another group on *Foc* TR4. Both groups were asked to prioritize the activities in their respective group for the next two years.

PGR Action points:

1. Safety backup of important accessions in the ITC including their passport data and other characterization and evaluation data (resistance for P&D like *Foc*) to be uploaded to MGIS; Sharing of evaluation data (drought screening, TR4, other *Fusarium* races, etc);
2. Gap filling collecting missions to be planned; other missions are already happening in the Pacific (PNG, Cook Islands, Samoa); important to do this in India and for those collections to be backed up in ITC, especially in the light of the incursion of TR4; to be planned for 2020: China, India, Indonesia, Myanmar, Cambodia, Vietnam and Bangladesh in 2021
3. Beneficial to look at priority traits in the region for which banana PGR should be evaluated or screened
4. Publication of evaluation protocols (technical guidelines for black sigatoka, drought and *Fusarium wilt*) end of 2019
5. Characterization of PGR – every country should provide names of the top 10 cultivars in the markets (like at MARDI training from MusaNet) to Agus (Indonesia); to catalogue synonyms; another MusaNet characterization and documentation workshop planned for 2020 in the Pacific region;

6. Multi-location trials – use simple participatory approaches to evaluate larger sets of cultivars relevant to different countries (no funds at the moment; need to mobilize funding)

Key bilateral projects:

- BBTV project in Indonesia – collecting wild *M. acuminata* to look for resistance in wild relatives; will also be deposited in ITC (same time as material from the gap filling mission)
- Collecting mission in PNG – evaluation of wild relatives for drought
- RTB project on *in-situ* conservation (including PNG)
- Generation of improved diploids for dissemination to other countries to improve plantains – Bill and Melinda Gates Foundation (India)
- Project with GDAAS China (coordinated by Bioversity) to be a collaborative programme with India for BB diversity.

***Foc* TR4 -Action Points:**

1. Status paper on *Foc* TR4 with full report across the world (banana growing countries).
2. Screening of available germplasm against *Foc* TR4
3. Presence and absence of traceability of *Foc* TR4 in the fruits and confirmation of pathogenicity.
4. Capacity building, training programmes, including nursery management and creating awareness regarding symptoms, mitigation measures of *Foc* TR4
5. Satellite imaging, epidemiology and mapping of disease.

Presentation Links:

1. **Presentation by Dr. Reynaldo Ebora of DOST-PCAARRD, Philippines** https://drive.google.com/file/d/1InOl5XXQckAigkVZFCSZkGHq2CUGuJz7/view?usp=sharing_eil&ts=5d1c7b55
2. **Presentation by Dr. Babul Chandra Sarker of BARI, Bangladesh** https://drive.google.com/file/d/1lQ4NONee9aRSzQyCfFiqZCievwWl1bEh/view?ts=5d1c7b55
3. **Presentation by Dr. Razali Bin Mustafa of MARDI, Malaysia** https://drive.google.com/file/d/1bpaEMKALPshMGobQOcc6aY_kiMGohxX0/view?ts=5d1c7b55
4. **Presentation by Dr. Birte Komolong of NARI, Papua New Guinea** https://drive.google.com/file/d/1ulY6jDY0DOQrCW9bRjUEbH9Vc_0BrKh7/view?usp=sharing_eil&ts=5d1c7b55
5. **Presentation by Dr. Agus Sutanto of ITFRI, Indonesia** https://drive.google.com/file/d/1gICd3SH6aP1H7iefJkUMkM8wOxVTdrEr/view?ts=5d1c7b55
6. **Presentation by Dr. S. Uma of NRCB, India** https://drive.google.com/file/d/1cmnmF8efJtSNAyiAIUItl7xkhpXZlGBU/view?ts=5d073bbe
7. **Presentation by Dr. Chen, Yi-Jeng of TBRI, Taiwan** https://drive.google.com/file/d/1ekT33No8CdSWNgb7QjLPwSzE_lb9QsL_/view?ts=5d1c7b55
8. **Presentation by Dr. Nicolas Roux of Bioversity International, France** https://drive.google.com/file/d/1eNB1INaE_fQ8zdXe0AK5Wvr8Ss4iI_4B/view?ts=5d1c7b55
9. **Presentation by Dr. Inge Van den Bergh of Bioversity International, Belgium** https://drive.google.com/file/d/18PWW4xYPsnc7PmkslhKr5GW-DYzTSrnw/view?ts=5d1c7b55
10. **Presentation by Dr. Altus Viljoen, Stellenbosch University, South Africa** https://drive.google.com/file/d/1vetZdfV6HThhjsfhYjEmzkseLWXZ9ywt/view?ts=5d1c7b55
11. **Presentation by Dr. Guy Blomme, Bioversity International** https://drive.google.com/file/d/1_jT3J5DhRcJT6MwphjLVDsGXMvNmHBPa/view?ts=5d073bbe
12. **Presentation by Dr. Sijun Zheng of Bioversity International, China** https://drive.google.com/file/d/1PhJhVaFcccisihmBZ1NcezXa8MtcvwWm/view?ts=5d1c7b55
13. **Presentation by Dr. Thangavelu NRCB, India** https://drive.google.com/file/d/16SZvWLYiw9djHmHZ7BPVKxqepAp9qmGq/view?ts=5d1c7b55
14. **Presentation by Dr. B. K. Pandey, Horticultural Science, ICAR, India** https://docs.google.com/presentation/d/1eGGImKwOdPZLUXHHuQD2NC-RzyQz8BEqfbPjY-_hgjM/edit#slide=id.p1

Annex 1. BAPNET Steering Committee meeting, May 7–9, 2019, Guangzhou, China

List of Participants and email ID

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Annex 2. Programme for the BAPNET Steering Committee meeting, May 7–9, 2019, Guangzhou, China

DAY			
7-May-19			
Duration	Time	Particulars	Facilitator/ Presenter
30’	8.30-9.00a.m.	Registration	Celine+Gao
30’	9.00-9.30a.m.	Welcome, opening Remark	Yi +Kumar
30’	9.30-10.00a.m.	Round of introductions	
30’	10.00-10.30a.m.	Presentation on BAPNET activities	Yi+Kumar
Break	10.30-11.00a.m.		
~6 presentations @ 20’ =2hrs	11.00-1.00a.m.	Country presentations	Country representatives
Lunch	1.00-1.30p.m.		
~6presentations @ 20’ =2hrs	1.30-3.30p.m.	Country presentations	Country representatives
Break	3.30-4.00p.m.		
30’	4.00-4.30p.m.	Presentation on MusaNet	Nicolas
30’	4.30-5.00p.m.	Presentation on ProMusa	Inge
60’	5.00-6.00p.m.	Discussion on regional / global networking, regional priorities,	Yi+Kumar
End of day 1			

DAY			
8-May 19			
FIELD TRIP-start	8.00AM	To be decided by Gao/Dr.Yi	Gao/Yi
FIELDTRIP-end	4.00PM		

DAY 9-May-19			
Duration	Time	Particulars	Facilitator/Presenter
~2hrs	9.00-11.00a.m.	Range of presentations on *Fusarium wilt*, and specifically TR4 in other regimes and significance	Guy/Altus/ Gus/Sijun /Thangavellu / B K Pandey
Break	11.00-11.30a.m.		
~2hrs	11.30-1.30p.m.	Break-out sessions to discuss specific topics related to FW TR4	Kumar/Yi
		(could be by sub regions, or by thematic area,)	
Lunch	1.30-2.00p.m.		
~2hrs	2.00-4.00p.m.	Reporting back to plenary/Discussions	Ige/Nicilas/Yi

Break 60’	4.00-4.30p.m. 4.30-5.30p.m.	Defining action points for 2019-2020	Yi/Kumar
30’	5.30-6.00p.m.	Closing session	Yi/Gao
End of day 3			


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