

applications and stressed the need for horizontally sharing the data science expertise, across disciplines. Paul Meller (Economic and Social Science Research Council, UK) pointed out the challenges of open science and open data, while emphasizing on security concerns. He suggested that appropriate policies and procedures be adopted with incentives and rewards through capacity building and training.

Neeta Verma (NIC) talked about the open data initiative of GoI and open data platform developed by NIC. Over 18,000 datasets available on this platform (<http://data.gov.in>) can be accessed by anyone for academic, research and development purposes. Each dataset published on this platform has a unique URI/UUID, which can be used for citation purposes. She also discussed technologies and tools that can be deployed for big data analytics of government data and highlighted the need for cloud-enabled data infrastructure.

Jagdish Arora (INFLIBNET) discussed the current status of ICSSR data repository–policy framework and shared the procedure to cite data from ICSSR Data Service. M. Haridas (Centre for Land Warfare Studies) spoke on execu-

tion challenges of big data applications by the defence and security forces.

H. K. Kaul (DELNET) discussed the need for training in big data in library science and also making Ph D research data accessible to users for further analysis from different dimensions. Debasisa Mohanty (NII) spoke on the development of structural bioinformatics methods for analysis of protein interaction network as the nucleic acids research datasets are to be released to the public. Roshan Lal Raina (JK Lakshmi Pat University, Jaipur) discussed the increasing credibility and effectiveness of data, and suggested provision of data for citing practices. Harpreet Singh (ICMR) discussed the medical data that can be collected from hospitals, the sequencing format, research paper citation, data reliability and data standards. Biplav Srivastava (IBM Research, India) opined that data must be integrated, while pointing out the challenges of applying analytics and linked data.

In the concluding session, a detailed presentation on the deliberations clearly brought out how the presentations of speakers helped spell out a set of recommendations for further consideration. Some of these were:

- Emphasis on the need for new courses on data science and technology like M Tech must be ensured to strengthen S&T activities in this domain.
- There is an urgent need to organize international schools in this field with experts from across the globe, covering all aspects.
- The scientific data which emerge out of projects sponsored by Government agencies like DST, DBT and other funding bodies should be put in the public domain, preferably in a national database.
- Continuous international collaboration will greatly benefit the data community. These collaborations could be inter-academy as well as inter-governmental. South–south collaboration is important.
- Collaboration between S&T sector and social science sector should be initiated and strengthened.

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MEETING REPORT

Management of *Phytophthora* – a deadly plant pathogen*

Stramenopile pathogens of the genus *Phytophthora* cause devastating diseases

*A report on the Third International Symposium on *Phytophthora*: Taxonomy, Genomics, Pathogenicity, Resistance and Disease Management held at the Indian Institute of Horticultural Research (ICAR-IIHR), Bengaluru during 9–12 September 2015 and jointly organized by the Association for Advancement of Pest Management in Horticultural Ecosystems, ICAR-IIHR, Bengaluru and ICAR-Central Plantation Crops Research Institute (ICAR-CPCRI), Kasaragod, Kerala. The symposium was preceded by a workshop on ‘Rapid diagnostics for *Phytophthora* in Horticultural Crops’ conducted by Jean Ristaino (North Carolina State University, USA), D. E. L. Cooke (The James Hutton Institute, UK) and P. Chowdappa (ICAR-CPCRI, Kasaragod) on 8 September 2015 at ICAR-IIHR, Bengaluru for the benefit of 40 young researchers. A laboratory manual on this topic was provided to all participants.

on a wide range of agricultural and horticultural crops, natural vegetation and forestry worldwide. There are over 140 species in the genus and many have wide host range. *Phytophthora infestans*, which caused the great Irish Potato Famine during late 1840s, still remains the most destructive pathogen of potatoes and tomatoes, causing crop losses of up to US\$ 6.7 billion annually. This famine caused by *P. infestans* in 1845–57, changed the history of many countries. Other notable species that have emerged in more recent times are *P. ramorum* on oak, *P. alni* on alders, *P. kernoviae* on ornamentals, *P. cinnamomi* on forest crops, *P. agathis* on kauri, *P. cactorum* on hardwood trees, *P. capsici* on solanaceous and cucurbitaceous vegetables, *P. fragariae* on strawberries, *P. megakarya* on cocoa, *P. palmivora* on palms, and *P. meadii* on arecanut, small cardamom

and rubber from different parts of the world.

Despite the above records, *Phytophthora* continues to be a major pathogen. One of the major reasons for the spread of pathogens is the difficulty in implementation of quarantine regulations in the open trade regime. The knowledge base on *Phytophthora* research and extension methodologies needs proper reorientation to meet the demands of farming community. To address these issues, an international symposium was organized.

The symposium began with a welcome address by M. Anandaraj (ICAR-Indian Institute of Horticultural Research (ICAR-IIHR), Bengaluru). P. Chowdappa (ICAR-Central Plantation Crops Research Institute (ICAR-CPCRI), Kasaragod) highlighted the recognition of 140 species of *Phytophthora*, challenges

from quarantine perspectives and expectations from the symposium. According to Sophien Kamoun, sharing of knowledge on basic research on *Phytophthora* genome on a global platform and learning *Phytophthora* problems in India could be translated into management strategies.

Chowdappa gave a keynote address on 'Phytophthora: an Indian perspective'. He highlighted the emergence of 13_A2 mating type of *P. infestans*, the recently emerged serious pathogen, which hitherto was not observed in India on potato and tomato; *P. boehmeria* on hot pepper; *P. nicotianae* on brinjal, cucurbits, ridge gourd; outbreak of *P. meadii* on arecanut, rubber and cardamom, and *P. palmivora* in cassava that have resulted in serious production constraints in recent years.

In the session on 'Emerging diseases and impact in horticulture, forestry and natural ecosystems', Andre Drenth (University of Queensland, Australia) spoke on 'Current and emerging *Phytophthora* diseases – research challenges and impact'. He emphasized on the importance of addressing issues like emergence of new virulent strains, fungicide resistance, distribution of pathogen to new geographical location, long-term funding for resistance screening, etc.

Suseela Bhai (ICAR-Indian Institute of Spices Research (IISR), Kozhikode, Kerala) gave an overview of abnormal leaf fall in nutmeg due to *P. meadii*. Rikta Dhali (West Bengal State University, Kolkata) spoke about *Phytophthora* diseases of *Philodendron xanadu* (*P. nicotianae*), *Nerium indicum* (*P. citrophthora*) and spathiphyllum (*P. nicotianae*).

The session on 'Taxonomy and phylogeny' was chaired by D. E. L. Cooke (The James Hutton Institute, UK). Jean Ristaino (North Carolina State University, USA) in her presentation explained the history of late blight in the United States, indicating how new lineage US23 has emerged following the earlier lineage US22 and how it differs from the 19th century specimens (lineage HERB1) available in herbaria. Anandaraj spoke about *Phytophthora* species causing black pepper disease in India. Leaf blight and rapid wilt of pepper is a destructive disease. Molecular analyses using MLST and whole genome sequencing show that the causal agent should be named as *P. tropicalis*, which hitherto was considered as *P. capsici*. Santhosh Eapen (ICAR-

IISR) emphasized on constructing an ambitious database collating data on *Phytophthora* diseases on Indian horticultural crops. The comprehensive database will include features such as full data on accessions in the national culture collection, lists of primers available for molecular detection and a key-based tool for morphological identification of *Phytophthora* species.

The session on 'Population biology and gene flow' was chaired by Ristaino. In the plenary talk, Cooke dwelt upon late blight in Europe and the 'Euroblight' network. The dominant mefenoxam-resistant clonal lineage 13_A2, first found in the Netherlands, is now widespread throughout Europe. In recent years, a second dominant lineage, 6A1 Netherlands, has also emerged that is mefenoxam-sensitive. Detailed discussions on blue lineage strain, its entry into various geographical locations, including India, haplotypes and SSR markers for its identification, etc. followed.

There were two presentations, one on rubber confirming the identity of the pathogen as *P. meadii* and *P. botryose*, and the other on *P. boehmeriae* as an emerging foliar pathogen in red and bell pepper.

In the session on 'Genetics and genomics' chaired by Brett Tyler (Oregon State University, USA), Sophien Kamoun (Sainsbury Laboratories, UK) reviewed the genome evolution in oomycete plant pathogens and properties of the genes encoding proteins of *P. infestans* involved in host interactions utilizing *R* genes. Monica Chandran (ICAR-IISR) presented the comparative genomics of *Phytophthora* from black pepper. Comparison of secretomes of *Phytophthora* from black pepper with other species suggested that taxonomic placement of the pathogen needs to be refined and the genome assembly has to be improved. Species-specific detection of *Phytophthora* spp. infecting coconut and arecanut crops using ITS-based primers was presented by V. H. Prathibha (ICAR-CPCRI). S. Sundaresha (ICAR-CPRI, Shimla) presented the comparative genome analysis of the Irish famine lineage of *P. infestans* with Indian *P. infestans* isolates. Ghosh (ICRISAT, Hyderabad) presented an efficient method for zoospore production, infection and reliable detection and quantification of *P. cajani* infecting pigeon pea. C. Mathu Malar (CSIR-Indian Institute of Chemical Biology, Kolkata) presented the improved

genome assembly of *P. ramorum* by third-generation sequencing technology, by reducing the gaps resulting in an increased assembled gene size and increased numbers of $R \times LR$ genes.

In the session on 'Pathogenesis and plant innate immunity' chaired by Kamoun, talks were mainly focused on molecular mechanisms of plant-*Phytophthora* interactions in several pathogen systems. The pathogens included *P. sojae*, *P. capsici*, *P. palmivora*, etc. Tyler started the session with an overview of *Phytophthora* genomics, effector biology and how this knowledge could be used to improve plants. Many of the projects on the black pepper system were at the stage of generating lists of candidate genes and are now ripe for functional analyses. Abishek Chatterjee (Cambridge University, UK) informed that an astute application of genome-wide association studies showed that a GRAS transcription factor defined resistance to *P. palmivora*.

The session on 'Epidemiology and decision support systems' was chaired by Andre Drenth (University of Queensland, Australia). Sanjeev Sharma (ICAR-CPRI, Shimla) gave an overview of 'Indoblighcast', a forecasting model for blight in India. This model requires daily minimum and maximum temperatures and relative humidity as inputs. A traffic light-like system was developed to aid farmers in decision making. In another presentation by V. Sridhar (ICAR-IIHR, Bengaluru), global distribution of late blight (*P. infestans*) in the present as well as under future climate change scenarios was projected using a bioclimatic modelling software CLIMEX.

Cooke chaired the session on 'Host plant resistance, molecular breeding and variety development'. Y. R. Sarma (Former Director, ICAR-IISR) presented an overview of management of destructive foot rot and leaf blight in black pepper. As no resistance source has been found so far, grafting with *Piper colubrianum* as root stock can be exploited. E. J. Suraby (ICAR-IISR) explained the use of degenerate primer-based PCR amplification for the identification of resistance gene in *P. nigrum* and *P. ornatum* using transcriptome database.

Prathiba (ICAR-CPCRI) mentioned that wild host plants, *Areca triandra* and *A. concinna*, showed resistance to *P. meadii* affecting arecanut in India. Sanjeev Sharma presented studies on inter-specific

cross between *S. tuberosum* and late blight resistant *S. bulbocastanum* (RPI-b1b1) that showed offspring carrying resistance to late blight. During the discussions, it was pointed out that this *RB* resistance had broken down in parts of Europe and caution was expressed about an indiscriminate release of a potato cultivar with such a single resistance gene, as its failure may result in serious crop losses and fuel further criticism of GM approaches.

The session on 'Disease management – fungicide and biological control' was chaired by David Guest (University of Sydney, Australia). In his plenary address, he highlighted the tools available for management of *Phytophthora* diseases and factors that affected their adoption by industry and stakeholders, including technical, financial, health and socio-political matters, with the ultimate aim of farming and food production being sustainable and profitable. The lead presentations included development of integrated approaches to managing *Phytophthora* diseases in cucurbits and bell pepper industries in Illinois (Babadoost) and avocado industry in Australia (Dann). Francine Govers (Wageningen University, Netherlands) spoke about a cell-biology approach towards identifying novel cellular targets for managing *Phytophthora* pathogens, potentially leading to the development of new fungicides, a high priority for industry and farmers. Sixteen short presentations then covered a spectrum of research activities focused on *Phytophthora* disease management across India. This revealed the intensity of research work on fungicide screening and the development of bio-control agents for horticultural and estate crop industries.

An exclusive workshop on oomycete databases was chaired by Brett Tyler

(Oregon State University, USA). He made a presentation on FungiDB, mainly concentrating on oomycete database resources from FungiDB, EumicrobeDB (previously VMD), PhytophthoraDB, DOE JGI Mycosm, Comparative Fungal Genomics Platform and Ensembl. An overview of data types and analysis tools was done. For identification of *Phytophthora* species, PhytophthoraDB should be used as it is based on morphology and molecular data of authentic cultures, NCBI data are not reliable as sequence data lack authenticity.

The session on 'Interactive meeting between scientists and stakeholders' was chaired by Y. R. Sarma. In this session the need for new molecules like oxathiapiprolin targeting oxysterol-binding protein for tacking pathogens on crops like citrus, cassava, taro, palms, rubber, ornamental and spice crops and fungicide-resistance management issues were discussed. Supply of disease-free quality planting material, cultural practices and application of copper-based fungicides is effective in the management of diseases in tuber, fruits, spices and plantation crops. Biocontrol systems for management of soil-borne diseases and *Trichoderma* coir pith cake for management of bud rot of palms and stem canker on cocoa were highlighted. There is a need for strictly following label claims in horticultural crops.

The plenary and valedictory session was chaired by Kamoun and Chowdappa.

In his valedictory remarks N. K. Krishna Kumar (ICAR, New Delhi) highlighted the success of Indian horticulture in terms of increased horticultural production and cautioned about the rising problems such as pests and diseases, particularly viruses besides *Phytophthora* diseases, due to changes in pathogen populations and climate change, and

global trade. He stressed that strengthening of biosecurity in agricultural trade is the need of the hour to avoid introduction of invasive pests.

The major points that emerged out of the symposium for combating the *Phytophthora* pathogens were developing more collaborations in research, both at the national and international level, wider adoption of bio-intensive Integrated Disease Management practices and exploring chemicals with new modes of action like oomycetes-targeted fungicides. Keeping in view various concerns raised in the symposium in tackling the pathogen, the following recommendations were made: international symposia on *Phytophthora* (ISP) to be conducted once in four years; maintenance of world *Phytophthora* collections (WPC) at University of California, USA and with collaborators from India; global initiative on *Phytophthora*, genome sequencing of tropical *Phytophthora* species, strengthening bio-security in agricultural trade; exploring the deployment of GM crops wisely for disease management and use of new technologies such as CRISPR/Cas9 system gene editing; adequate human capacity building programmes to encourage young researchers and women scientists; synergy between researchers and policy makers so that the fruits of research are made available to the farmers at the earliest.

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