



A new era in plant pathology in Japan: incorporation of the Phytopathological Society of Japan and research reform directed by genomic studies

Tsutomu Arie¹

Received: 1 September 2020 / Accepted: 7 September 2020 / Published online: 12 October 2020
© The Phytopathological Society of Japan and Springer Japan KK, part of Springer Nature 2020

Introduction

When the first reports of an outbreak of the new coronavirus (SARS-CoV-2) came from China at the end of 2019, who would have expected this global and terrible impact? Because we have not been able to prevent the spread of the virus even now in August 2020, careful, restricted behavior is required to prevent infection, and people are feeling crippled. The Phytopathological Society of Japan (PSJ) was forced to cancel the Kagoshima Annual Meeting scheduled for March 2020 and thus unable to give presentations and awards and hold social gatherings. At Kagoshima, although PSJ planned to obtain the final approval of the transition to a general incorporated association, we were unable to do so; however, we finally received the approval by email from the members. The last cancellation of the annual meeting we experienced was in March 2011, which was to be held at Tokyo University of Agriculture and Technology, due to the Great East Japan Earthquake and the accompanying accident at Fukushima Nuclear Power Plant #1. Although the damage related to the earthquake was great, the subsequent impact on PSJ was limited. The impact of COVID-19 on PSJ is much greater, and all district meetings in 2020 and the 8th Asian Society for Plant Pathology (ACPP2020) and the 5th Japan-Korea Joint Symposium on Plant Pathology (both was planned to have in September 2020 in Tsukuba) have already been cancelled. And, realizing the possibility that the annual

meeting in March 2021 cannot be held face-to-face, we are starting to create a platform on the PSJ website to hold the meeting online.

The year 2020 is the International Year of Plant Health (IYPH) led by the Food and Agriculture Organization (FAO) of the United Nations (<https://www.fao.org/plant-health-2020/home/en/>, accessed 01 Sept 2020). Under the Sustainable Development Goals (SDGs) concept spearheaded by the United Nations, the premise of the IYPH is to promote the importance of protecting plant health to help end hunger, reduce poverty, protect the environment, and boost economic development. It is a pity that the IYPH has been diminished as COVID-19 directly threatens human health. However, thanks to the farmers and other essential workers involved in food production and plant protection, human beings do not have to worry too much about food supply under such circumstances.

This paper is a substitute for the Presidential lecture planned for the canceled 2020 Annual PSJ Meeting in Kagoshima. Now, I am led to think about what "next steps" we should take after COVID-19 and incorporation of PSJ.

Incorporation of PSJ and its future

Created by about 10 or more members in 1916, PSJ has now grown to about 1,900 members, and its annual budget and assets have also been growing. During the past several years, the Presidents, Secretariat, Committee on Future Problems of PSJ, and Council have been discussing future plans of PSJ, administration, articles of incorporation, and other matters. With the approval of PSJ members at the Annual Meeting in 2019, we decided to become a socially recognized, general incorporated association rather than a voluntary organization. According to the schedule, The General Incorporated Association PSJ was established in January 2020. The voluntary organization of PSJ was dissolved on

This article is an abstract of the Presidential Address paper which was going to be presented at the 2020 Annual Meeting of the Phytopathological Society of Japan in Kagoshima

✉ Tsutomu Arie
arie@cc.tuat.ac.jp

¹ Graduate School of Agriculture, Tokyo University of Agriculture and Technology (TUAT), 3-5-8 Saiwaicho, Fuchu, Tokyo 183-8509, Japan

March 31, 2020 and transitioned to The General Incorporated Association PSJ on April 1, 2020, and PSJ again has begun to mark its 105th year. I take this opportunity to thank the members of the above committees, the secretariat of PSJ, the Japan Plant Protection Association (JPPA), related academic societies, and accounting firms for their hard work.

As a result, PSJ is now a corporation, which is socially recognized and trusted, but at the same time, PSJ has social responsibility. Based on "promoting and disseminating plant pathology", which has been the objective since the foundation, PSJ's social responsibility for the future is contribution to achieve the Sustainable Development Goals through research, education and information transmission in the field of plant pathology, and plant health management to support stable agricultural and forestry production by developing and spreading technology related to plant protection. One of the important responsibilities of PSJ is establishing ways to disseminate the research results and knowledge of members of PSJ beyond PSJ; presenting the work only in PSJ journals and at meetings is not broad enough to reach all those who can benefit. Several other issues confront PSJ that need to be examined, such as how to increase the number of members especially young members, how to maintain the diversity and internationality of members, how to improve the quality of researches by the members by improving poorly designed studies, how to encourage and support the activities of the study groups in PSJ, how to handle the publishing business, how to increase the value of the journals through strategies such as improving the English skills of members so they can be primary authors. The Committee on Future Problems of PSJ need to discuss with the members how to transform the Society into an even more attractive, more ambitious organization (Tsuge 2019).

Plant pathologists observe plant diseases, analyze disease epidemiology, elucidate the mechanisms of new pathogens, develop specific diagnostic techniques, establish control strategies that may include pesticides, predict disease outbreaks, and prevent horizontal and vertical transmissions, for example, by using pesticides, monitor pathogens and set up domestic and international quarantines, instruct farmers, and consider economic aspects of plant protection. These responsibilities are mostly identical with those of the specialists working on COVID-19. Watching the daily reports and social conditions regarding COVID-19, I see the great difficulty in conveying the analyzed data so that the public can understand them and in predicting future infection trends and economic impacts. Similar difficulties face us as we disseminate our knowledge and explain research results on plant diseases to people with different backgrounds and knowledge bases. However, fortunately, because the host we handle is a plant, inoculating healthy plants, breeding disease resistant plant varieties, and removing diseased individual plants from infested fields are relatively easy. This

can be advantageous for us to communicate with society in a scientific manner. By having active members with diverse philosophies, multifaceted discussions and programs will be accelerated by leaders in PSJ and lead to greater advancements and recognition from society. To that end, I envision the members of local agricultural research stations and private companies to give feedback to PSJ. Now is the time to improve and develop PSJ with your ideas and cooperation.

From "the world of the loupe" to the world of genomic sciences

I have often remembered the PSJ Presidential Address in 1987, "The world of the loupe in plant pathology" by the late Dr. K. Kishi. Dr. Kishi emphasized that no matter how advanced electron microscopy, immunological, biochemical, and analytical instruments are, we must not neglect observing diseased plants and pathogens with a loupe or magnifying glass (Kishi 1987). Continually observing and diagnosis with a loupe leads to the development of the "observation eye" of plant pathologists. I have been involved in research and education in plant pathology for more than 30 years since then, and I still believe that the importance of this "observation eye" remains unchanged. Of course, diagnosis is not all about current phytopathology. Although research areas in plant pathology have expanded to epidemiology, evolution, pathogenicity factors, molecular plant–pathogen interactions, control technologies, the "observation eye" is necessary in all areas of study. Thus, I want to convey the teachings of Dr. Kishi to researchers especially to the younger generation. Although we tend to use the latest and glamorous techniques and devices, they will not lead to great research unless they are supported by a solid foundation.

Recent advancements in research techniques and equipment have been amazing. Molecular biology analyses have become possible since the 1990s, enabling analyses of gene function, pathogenicity mechanisms and plant–pathogen interactions, molecular phylogeny of pathogens, drug mode of action and drug resistance mechanism, and specific diagnosis of diseases and pathogens. Progress in these areas and more was largely due to the establishment and universalization of technologies such as PCR, DNA sequencing, gene disruption/recombination, gene expression analysis, and microarrays. Then whole genomes were sequenced for several model plant pathogens including *Pyricularia oryzae* (Dean et al. 2005) and *Cochlioborus heterostrophus* (Condon et al. 2013; Turgeon and Condon 2017), and in the last few years, single-molecule real-time (SMRT™) sequencing has enabled the whole genome of an isolate of plant pathogen to be determined in a few weeks, even in a university laboratory. Decoding of the sequences, which had required a specialized bioinformatician, can now be done

by a graduate student. These technological innovations are rapidly changing the way we do research. For example, PCR, cloning, screening pathogenicity-related genes using gene-tagged mutants, SNP analysis, and molecular identification of pathogens, which have been the conventional methods for plant pathology, can be replaced and completed by SMRT™ genome sequencing. The era of whole-genome analysis instead of PCR is upon us.

In my study of *Fusarium oxysporum*, I started using PCR in 1994. Thanks to techniques including PCR, sequencing using ABI sequencer, gene-tagging by the REMI method, gene-disruption, and gene-expression analyses, my study of molecular mechanisms of pathogenicity, evolution of pathogenicity, host determination and mating has greatly progressed (Arie et al. 1991, 1995). Regarding disease diagnosis, I worked to establish detection techniques for soil pathogens using immunological methods in the 1990s, and since 2000, we have been able to rapidly detect specific soil pathogens and their races using PCR, real-time PCR, and LAMP™ (Hirano and Arie 2006; Inami et al. 2010; Kashiwa et al. 2017). In the past several years, based on the results of comparative genomic analyses of isolates, we also established a technology for the specific detection of race-determining SNPs (Arie 2010, 2019; Ayukawa et al. 2017, 2018). In these series of studies, the fungi that I isolated and the pathogenicity assay system using the plants and the fungi have played important roles. Although techniques in molecular and genome biology can be used by any researcher, plant–pathogen assay systems are a specialty of plant pathologists. I am convinced that the “the world of the loupe” through keen observation and amazing skill will continue to be important for plant pathologists.

Stepping into the future

Now in 2020, the number of positive cases of COVID-19 infection by PCR is reported daily. PCR is a well-established and convenient technique that yields positive or negative results for a template sample even though citizens do not understand how PCR works. I cannot imagine what would have happened if the COVID-19 pandemic had hit us 25 years ago when PCR could be used only in limited experiments. Did universalization of PCR contribute to public welfare?

As I already mentioned, advances in technology are changing research approaches in plant pathology. Currently, supported by Grant-in-Aids for Scientific Research from the Japan Society for the Promotion of Science (JSPS), I am working with two young plant pathologists, Drs. Arazoe T and Asai S, on the functional analysis of small chromosomes involved in the determination of pathogenicity and host specificity in *F. oxysporum* based on genome analyses.

We are searching for genes involved in the evolution and divergence of races using combined experiments on the emergence of pathogenicity mutants and genomic analyses of the mutants. Moreover, we are trying to predict the emergence of new races by analyzing mutation frequencies. Up to now in epidemiology, we have analyzed mutations that had occurred in the past; however, we are proposing to forecast the new races of pathogens based on genome comparison of pathogen isolates and/or mutants, and to establish detection and control techniques before they cause an epidemic, and designated this new research strategy as Mirai-Ekigaku™ (Japanese trademark meaning future epidemiology).

The Phytopathological Society of Japan has stepped into the future as an incorporation. At the same time, research in plant pathology will step into the new era using new technologies. My two young collaborators, Drs. Arazoe and Asai were amazingly awarded the 2020 PSJ Young Scientist Awards at the same time. I am very pleased. These two are representative of the young researchers in PSJ, skillfully incorporating new technologies into their research. I strongly expect that all young members will continually contribute to the future development of plant pathology and PSJ by refining the root values of “the world of the loupe” in plant pathology through new technologies and ideas.

Acknowledgements I express my deepest gratitude to all my colleagues and students for their enthusiastic collaboration and cooperation. I also present special thanks to Dr. Beth E. Hazen who provided suggestions not only on the composition of the English text but also on the issues of PSJ that she has noted while editing for JGPP and others over many years. Most of the work mentioned in the text was supported by Grants-in-Aid for Scientific Research from JSPS or MAFF. SMRT (Single Molecule, Real-Time) and LAMP (Loop-Mediated Isothermal Amplification) are registered trademarks of Pacific Biosciences of California and Eiken Chemical, respectively. Mirai-Ekigaku (in Japanese) is a registered trademark of Tokyo University of Agriculture and Technology (TUAT).

References

- Arie T (2010) Phylogeny and phytopathogenicity mechanisms of soil-borne *Fusarium oxysporum*. *J Gen Plant Pathol* 76:403–405
- Arie T (2019) *Fusarium* diseases of cultivated plants, control, diagnosis, and molecular and genetic studies. *J Pestic Sci* 44:275–281
- Arie T, Hayashi Y, Nagatani A, Furuya M, Yamaguchi I (1991) Production and partial characterization of monoclonal antibodies against *Fusarium oxysporum* 860926a. *Ann Phytopathol Soc Jpn* 57:696–701
- Arie T, Hayashi Y, Yoneyama K, Nagatani A, Furuya M, Yamaguchi I (1995) Detection of *Fusarium* spp. in plants with monoclonal antibody. *Ann Phytopathol Soc Jpn* 61:311–317
- Ayukawa Y, Hanyuda S, Fujita N, Komatsu K, Arie T (2017) Novel loop-mediated isothermal amplification (LAMP) assay with a universal QProbe can detect SNPs determining races in plant pathogenic fungi. *Sci Rep* 7:4253
- Ayukawa Y, Komatsu K, Taga M, Arie T (2018) Cytological karyotyping of *Fusarium oxysporum* by the germ tube burst method (GTBM). *J Gen Plant Pathol* 84:254–261

- Condon BJ, Leng Y, Wu D, Bushley KE, Ohm RA, Otiillar R, Martin J, Schackwitz W, Grimwood J, MohdZainudin N, Xue C, Wang R, Manning VA, Dhillon B, Tu ZJ, Steffenson BJ, Salamov A, Sun H, Lowry S, LaButti K, Han J, Copeland A, Lindquist E, Barry K, Schmuts J, Baker SE, Ciuffetti LM, Grigoriev IV, Zhong S, Turgeon BG (2013) Comparative genome structure, secondary metabolite, and effector coding capacity across *Cochliobolus* pathogens. *PLoS Genet* 9:e1003233
- Dean RA, Talbot NJ, Ebbole DJ, Farman ML, Mitchell TK, Orbach MJ, Thon M, Kulkarni R, Xu J-R, Pan H, Read ND, Lee Y-H, Carbone I, Brown D, Oh YY, Donofrio N, Jeong JS, Soanes DM, Djonovic S, Kolomiets E, Rehmeier C, Li W, Harding M, Kim S, Lebrun M-H, Bohnert H, Coughlan S, Butler J, Calvo S, Ma L-J, Nicol R, Purcell S, Nusbaum C, Galagan JE, Birren BW (2005) The genome sequence of the rice blast fungus *Magnaporthe grisea*. *Nature* 434:980–986
- Hirano Y, Arie T (2006) PCR-based differentiation of *Fusarium oxysporum* ff. sp. *lycopersici* and *radicis-lycopersici* and races of *F. oxysporum* f. sp. *lycopersici*. *J Gen Plant Pathol* 72:273–283
- Inami K, Yoshioka C, Hirano Y, Kawabe M, Tsushima S, Teraoka T, Arie T (2010) Real-time PCR for differential determination of the tomato wilt fungus, *Fusarium oxysporum* f. sp. *lycopersici*, and its races. *J Gen Plant Pathol* 76:116–121
- Kashiwa T, Kozaki T, Ishii K, Turgeon BG, Teraoka T, Komatsu K, Arie T (2017) Sequencing of individual chromosomes of plant pathogenic *Fusarium oxysporum*. *Fungal Genet Biol* 98:46–51
- Kishi K (1987) The world of loupe in plant pathology. *Ann Phytopathol Soc Jpn* 53:275–278
- Tsuge T (2019) Toward the establishment of the Phytopathological Society of Japan (in Japanese). *Plant Prot* 73:473
- Turgeon BG, Condon B (2017) *Cochliobolus heterostrophus* and maize: a model for genome wide integration of iron homeostasis, oxidative stress management, and virulence. In: Wolpert T, et al. (eds) *Genome-enabled analysis of plant-pathogen interactions*. APS Publications, St. Paul, pp 149–159

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.