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FUTURE EXPECTATIONS FOR GALL-MIDGE STUDIES IN THE ORIENTAL REGION

Junichi Yukawa

Entomological Laboratory, Kyushu University, 744 Motooka, Nishi-ku, Fukuoka-shi 819-0395, Japan
Email: cecid_galler_jy@yahoo.co.jp

First, I appreciate the contribution by M. S. Mani to gall-midge studies in Japan. He described two Japanese pestiferous Cecidomyiidae in response to the request from Japanese entomologists. His book *Ecology of Plant Galls* encouraged young Japanese students, who just started to study gall-inducing insects. Secondly, the importance of genetic data is emphasized in this paper to support morphological identification of the Cecidomyiidae of the Oriental region. Species identification is essential to establish methods of control measures against invasive Cecidomyiidae. Thirdly, I expect young Indian entomologists to challenge *via* ecological investigations benefiting from the convenience of plentifully available Cecidomyiidae and the galls they induce in the Indian subcontinent. Ecological data on tropical and subtropical Cecidomyiidae is highly necessary.

Key words: Cecidomyiidae, ecology, genetic data, identification, M. S. Mani, phylogeny, taxonomy

CONTRIBUTION BY M. S. MANI TO GALL MIDGE STUDIES IN JAPAN

First of all, I refer to a great cecidologist of India, Dr. M. S. Mani, who contributed to the Japanese Cecidomyiidae. Mani described two Japanese species of the Cecidomyiidae in response to the request of species identification from Japanese entomologists. They were *Contarinia inouyei* Mani (Mani, 1954a) and *Dasineura wistariae* Mani (Mani, 1954b). *Contarinia inouyei* induces galls on the needles of *Cryptomeria japonica* (Pinales: Cupressaceae). The specific name *inouyei* was dedicated to Dr. M. Inouye who was a forest entomologist in Hokkaido Forest Experiment Station, Japan and sent the specimens to Mani for species determination. In turn, Inouye (1959) described a Japanese gall midge infesting needles of *Abies* (Pinales: Pinaceae) as *Agevillea manii* Inouye dedicating the specific name to Mani. Later, this species was combined with *Paradiplosis* (Tokuda and Yukawa, 2003). *Dasineura wistariae* was described by Mani (1954a) based on specimens sent by Prof. K. Yasumatsu, who was my supervisor at Kyushu University. Larvae of *D. wistariae* live in the flower buds of *Wisteria floribunda* (Fabales: Fabaceae) and prevents blooming and induce early flower-bud drop (Yukawa and Masuda, 1996).

In April 1963, I started the taxonomic study of Japanese gall midges (Diptera: Cecidomyiidae) as a graduate student at the Entomological Laboratory of Kyushu University, Fukuoka, Japan. Next year, I visited the Zoological Survey of India, Calcutta (Kolkata, presently) to meet Dr. Mani on the introduction of Yasumatsu and Inouye. It was a valuable opportunity for me to study plant galls. He explained me the essence of important chapters of his then new book *Ecology of Plant Galls* (Mani, 1964). After I returned to Japan, I read this book together with two other Kyushu-University students who were studying gall-inducing Psyllidae (Hemiptera) and Cynipidae (Hymenoptera). We were particularly interested in the chapters describing arthropod communities centered upon gall inducers and their host plants. This book certainly encouraged young students of Japan to pay attention not only to taxonomic studies but also to ecological aspects of gall inducers and their host plants. Thereafter, my colleagues and I cited his book in some of our articles on the Cecidomyiidae (*e.g.*, Yukawa, 1983, Yukawa and Haitsuka, 1994, Yukawa and Masuda, 1996, Yukawa and Tokuda, 2021).

At this juncture, I leave these memories, and solicit scientific co-operation between Indian and Japanese entomologists.

TAXONOMIC AND PHYLOGENETIC STUDIES

Cecidomyiidae are supposed to be the most speciose family in Diptera (Hebert et al*.,* 2016, Borkent et al., 2018, Brown et al., 2018). Nearly 7,000 species and at least 800 genera have been described in the Cecidomyiidae (Gagné and Jaschhof, 2021). However, the actual number of species seems to be far more abundant. This family exhibits diverse feeding habits such as saprophagy, mycophagy, phytophagy, and zoophagy (predacious and endoparasitic) (e.g., Möhn, 1955, Harris, 1968, 1973, Gagné, 1994, 1995a, Skuhravá, 1997, Roskam, 2005, Jaschhof and Jaschhof, 2009, 2013, Gagné and Jaschhof, 2021).

Up to the present, at least 370 cecidomyiid species have been known to occur in India (Gagné and Jaschhof, 2021). They were described mainly by R. Chandra, V. D. Deshpande, E. P. Felt, R. J. Gagné, P. Grover, V. Kashyap, J. J. Kieffer, M. S. Mani, K. K. Nayar, S. N. Rao, R. M. Sharma, D. Vasanthakumar, and their co-authors (see reference list in Gagné and Jaschhof, 2021). Naturally, their descriptions were based solely on morphological features. These are great works and informative to confirm morphological features of the described species, many of which are representatives characterizing the Cecidomyiidae of the Oriental Region.

In the late 1980s, methods of genetic analysis were introduced into taxonomic and phylogenetic studies. Then, genetic data support results of morpho-taxonomic studies and phylogenetic trees were constructed based on genetic data (e.g., Hebert et al., 2003). Unfortunately, most recent taxonomic and phylogenetic papers on the Cecidomyiidae did not include genetic data of the Indian species, although they treated those of other countries (e.g., Dorchin et al., 2019; Elsayed et al., 2018a, 2018b;Tokuda et al., 2008, Uechi et al., 2017;Yukawa et al., 2020). This is because genetic data of most of the Indian Cecidomyiidae have not yet been registered with GenBank. In addition, co-operative taxonomic studies by Indian entomologists with those of foreign countries are quite difficult because of strict rules preventing the outflow of genetically important materials, by which foreigners cannot observe and analyze Indian specimens in their own countries even under short-term loan conditions.

Previously taxonomists of the Cecidomyiidae were occasionally consulted by Indian applied entomologists to determine the Cecidomyiidae infesting fruit and vegetable crops. Nowadays, international trade expansion and globalization trends have increased potential invasion risks (Tokuda et al., 2018). Therefore, applied entomologists need to identify foreign Cecidomyiidae that were accidentally introduced particularly from tropical or subtropical regions together with ornamental plants or fruit trees, such as an orchid and mango. Identification of pestiferous species is essential to establish control measures against them, but presently it is difficult without sharing specimens and genetic data.

Following the stimulation of recent progress in gall midge studies in Africa (Dorchin and Gullan, 2007), Australia (Kolesik et al., 2005), and South America (Maia et al., 2014), I expect young Indian entomologists would pay more attention to genetic analysis of the Cecidomyiidae and register the data with GenBank for worldwide use. I also would like to ask the Indian authorities to permit short-term loans of Indian specimens for the purpose of species identification based on morphological and genetic data, with which foreign taxonomists can contribute to increase agricultural productivity in India.

ECOLOGICAL STUDIES

Ecological way of thinking is essential under recent conditions of global environment (Yukawa and Tokuda, 2021). I think entomologists can learn more easily from an ecological way of thinking through ecological data obtained from diverse interrelations between herbivorous insects and their host plants. The Cecidomyiidae include many gall-inducing species, which have tight associations with their host plants and induce galls with species-specific shapes. Therefore, the gall-inducing Cecidomyiidae are suitable materials to obtain ecological data in the field and interesting study subjects to clarify interaction with the host plants (Yukawa and Rohfritsch, 2005, Yukawa, 2018). In particular, galls provide life table data in a convenient way (Redfern and Cameron, 1978).

Fortunately in India, host plants of gall-inducing cecidomyiids include many species of evergreen broad-leaved trees. On such host plants, gall midges adopt life history strategies categorized as types IIA and IIB (Yukawa, 1987, note that this article was published in the first issue of a then new Indian journal *Phytophaga* edited by T. N. Ananthakrishnan). Unlike gall midges on deciduous host plants with type IA or type IB life-history strategy, larvae associated with evergreen broad-leaved trees do not exit galls, and the gall-bearing organs do not drop to ground before pupation. Instead, the larvae live in galls attached to host plants throughout their life cycle. Therefore, galls can be easily counted continuously from early to final stage of the gall and the gall-inducer's development because of their outstanding features and immobility (Yukawa et al., 2016). The evaluation of population density of gall midges is the first step of ecological study in the field. By benefiting from this advantage, I strongly hope young Indian entomologists try to undertake challenging ecological investigations of the Cecidomyiidae.

Mani (2000) is one of the ideal references to find galls and gall midges as suitable study targets in India. I also recommend the investigators to consult with Yukawa (2018) and Yukawa and Tokuda (2021) for

further details of ecological methods, such as timing, intensity, and interval of field surveys, dissection of galls, identification of mortality factors, rearing of adults, direct field observations of adult behaviour, and evaluation of phenological data of host plants. To analyze life-table data, the method of key-factor/key-stage analysis (Yamamura, 1999, 2012; Yukawa et al., 2016) is recommended. With this method, we can detect density-dependent and independent forces operating on the Cecidomyiidae populations and assess the relative strength of top-down and bottom-up effects. Ecological data facilitate better understanding of speciation of gall midges. I expect to see ecological data of representative the Oriental Cecidomyiidae.

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