Aecidium cinnamomi (Uredinales) has an endocyclic life cycle on *Cinnamomum* spp. (Lauraceae) in Indonesia

Dono Wahyuno · Makoto Kakishima

Received: 10 March 2014 / Accepted: 23 November 2014 / Published online: 12 December 2014
© Australasian Plant Pathology Society Inc. 2015

Abstract A rust fungus of cinnamon trees is found throughout the year in Indonesia and seriously damages the trees, especially seedlings in nurseries. The causal rust fungus attacks leaves, petioles, shoots and young fruits. Morphological observations and inoculation experiments confirmed *Aecidium cinnamomi* is an endocyclic rust fungus.

Keywords Cinnamon · Plant pathogenic fungus · Spice

Cinnamomum spp. (Lauraceae) are mainly distributed in forests of Asia and Australia (Dao et al. 1999). *Cinnamomum burmannii*, *C. cassia*, *C. loureirii* and *C. verum* (syn. *C. zeylanicum*) are widely cultivated in South East Asia (Dao et al. 1999) because they are drought tolerant and offer shade. These trees are also economically important as sources of the spice cinnamon, which is produced from the inner bark. In Indonesia, *C. burmannii* is the dominant species commonly found as wild or cultivated trees in areas of 500 to 1,500 m above sea level.

A rust fungus of *Cinnamomum* spp. has been observed in the Sukabumi District, West Java Province, Indonesia since 2009. This rust fungus caused leaf malformation, necrotic spots on leaves and premature leaf defoliation

(Fig. 1a). The rust was also observed on leaf petioles, young shoots and young fruits (Fig. 1b, c, and d). Serious damage occurred to nursery seedlings and to adult trees.

Aecidium cinnamomi was first described on *Cinnamomum* sp. over 100 years ago in Indonesia (Raciborski 1900), where it is relatively common (Boedijn 1960; Semangun 1992; Kobayashi 2001). *Aecidium cinnamomi* was recently considered a taxonomic synonym of *Monosporidium machili* (synonyms *Endophyllum machili*, *Aecidium machili*), which causes rust on *Machilus philippinensis* (Lauraceae) in the Philippines (Hiratsuka et al. 1992; Sato et al. 2010). The synonymy of *A. cinnamomi* and *M. machili* was based on spore germination patterns and position of the spermatogonia in specimens collected in Japan and the Philippines. However, Buriticá (1991) reported *Endophyllum machili* as the causal agent of the rust fungus of *Machilus philippinensis* (Lauraceae) found in the Philippines, and treated *Aecidium machili* and *Aecidium nakanishiki* as its synonyms. Thus, further observations of specimens collected from other areas are required to confirm the taxonomic status of the rust fungus of *Cinnamomum*.

In this paper, we present the results of morphological studies and inoculation experiments to clarify the life cycle of *A. cinnamomi* in Indonesia. There are no previously reported morphological observations nor inoculation experiments with *A. cinnamomi*.

The specimens studied were preserved in the Herbarium HBI-Bal (Table 1). For light microscopy, spores and free hand sections of spermatogonia and sori of infected leaves, were placed on glass slides and mounted in a drop of lactic acid solution. The types of fungal structure were determined based on the ontogenic systems proposed by Cummins and Hiratsuka (1983; 2003).

The spore surface structures were observed under a scanning electron microscope (SEM) (JEOL JSM 5310 LV)

D. Wahyuno (✉)
Indonesian Spice and Medicinal Crops Research Institute, IAARD,
Tentara Pelajar No. 3, Bogor 16111, Indonesia
e-mail: dwahyuno@yahoo.co

M. Kakishima
Engineering Research Center of Chinese Ministry of Education for
Edible and Medicinal Fungi, Jilin Agricultural University,
Changchun, Jilin Province 130118, China

M. Kakishima
University of Tsukuba, Ibaraki 305-8572, Japan

Fig. 1 *Aecidium cinnamomi* on *Cinnamomum*. (a) Symptoms, (b) Sori on leaf petiole, (c) Sori on young shoot, (d) Sori on young fruit, (e) Spermatogonium (→) on adaxial, (f) Spermatogonium, (g) Sori (HBI-Bal 529), (h) Teliospores (i) Teliospores surface structure under SEM

observation (HBI-Bal 529), (j) Peridial cell walls (HBI-Bal 529), (k) Germinating teliospore (HBI-Bal 529), and (l) Telial on adaxial after artificial inoculation

Table 1 Specimens of *Aecidium cinnamomi* on *Cinnamomum* spp. collected in West Java, Indonesia

Specimen No.	Host	Locality	Date
HBI-Bal 60	<i>C. zeylanicum</i>	Manoko, Lembang	Jul 2, 1990
HBI-Bal 175	<i>C. zeylanicum</i>	Manoko, Lembang	Mar 24, 1992
HBI-Bal 488	<i>C. burmannii</i>	Cicurug, Sukabumi	Dec. 2009
HBI-Bal 527	<i>C. burmannii</i>	Cicurug, Sukabumi	Oct 15, 2010
HBI-Bal 528	<i>C. burmannii</i>	Cicurug, Sukabumi	May 22, 2012
HBI-Bal 529	<i>C. burmannii</i>	Cicurug, Sukabumi	Feb 7, 2013
HBI-Bal 530	<i>Cinnamomum</i> sp.	Pakuwon, Sukabumi	Sep 19, 2013

HBI-Bal (Herbarium of Balitro, Indonesian Agency for Agricultural Research and Development, Indonesia)

operating at 20 kV. Spores and leaf pieces were attached to specimen holders and coated with gold using an E IB-2 Ion Coater.

Spores on *C. burmannii* collected from Sukabumi, West Java Province (HBI-Bal 529) were used for germination and inoculation experiments. The germination test was performed by placing the spores in drops of distillate water on glass slides, and then incubated for 24 h in dark room at 22–25 °C. The germinating spores were mounted in lactic acid solution, covered by cover glass and observed with a compound light microscope.

Artificial inoculation was followed the method of Morin et al. (1993). Naturally infected leaves collected from Sukabumi, West Java Province were used as the inocula. These leaves were placed in nets above the seedlings of *C. burmannii* in a dark humid chamber (80–90 % relative humidity; 22–25 °C) for 48 h to release basidiospores. The inoculated seedlings were transferred to a glasshouse at 24–28 °C for further observation.

The spermogonia of *A. cinnamomi* subcuticular, adaxial, flask-shaped, 30.0–32.5 µm wide, and light to dark brown in colour (Fig. 1e and f). This type of spermogonium is defined as type seven (Cummins and Hiratsuka 1983, 2003). The sori have aecia-like structures with peridia, and occur predominantly on the abaxial (Fig. 1g). No other soral structure was observed in the specimens. Spores were 20.0–27.5×18.8–22.5 µm in size, one-celled and catenulate. The spore cell walls were 1.0–2.5 µm thick, and uniform (Fig. 1h). The spore surface structure was verrucose with refractive granules (Fig. 1h and i). The peridial cell walls were hyaline, verrucose, hexagonal to irregular, and 25.0–30.0×22.5–27.5 µm in size (Fig. 1j).

The spores formed basidium-like structures after germination. These structures were considered as four-celled basidia (Fig. 1k). The basidiospores produced from basidia were hyaline and globose.

Artificial inoculations revealed similar symptoms, and sori were formed on inoculated leaves. One to two weeks after inoculations, blister-like structures developed on the leaf surfaces and three to four weeks after inoculation orange sori were observed (Fig. 1l).

Our results show that *A. cinnamomi* only produces telia and has an endocyclic life cycle. The spores produced in aecia functioned as teliospores that formed basidiospores. Hiratsuka et al. (1992) reported an endocyclic rust fungus, *Monosporidium machili* on *C. japonicum*, *Machilus japonica* and *Machilus khunbergii* and treated *A. cinnamomi* as its synonym. In Japan, *M. machilii* was also reported on leaves of *C. pseudopedunculatum*, *M. boninensis*, and *M. koku* (Sato et al. 2010). The morphological characteristics of the spore surface structure ornamentation, type of the spermogonia and life cycle type of the rust fungus on *Cinnamomum* spp. collected in Indonesia are similar to those of *M. machili* by Sato et al. (2010). However, Cummins and Hiratsuka (2003) treated *Monosporidium* as synonym of *Endophyllum*, and they also considered that *Endophyllum* is composed of microcyclic species that morphologically resembles *Aecidium*. *Aecidium cinnamomi* is the earliest name for the rust fungus reported on *Cinnamomum* (Raciborski 1900).

Until now, *A. cinnamomi* was reported only on *C. burmannii* and *C. zeylanicum* in Indonesia. In Indonesia, this rust fungus is found at altitude 500 m above sea level where *Cinnamomum* species are commonly distributed. However, the only control method to reduce its severity and spread is pruning of infected leaves and stems.

Acknowledgments Thanks to Ms. Tika and Ms. Yuni of Indonesian Institute of Sciences, Cibinong for sample preparation and SEM pictures.

References

- Boedijn KB (1960) The Uredinales of Indonesia. Nova Hedwigia 1:463–495
- Buritica P (1991) Familias del Orden Uredinales con ciclo de vida completamente reducido. Rev Acad Colomb Cienc 18(69):131–148
- Cummins GB, Hiratsuka Y (1983) Illustrated genera of rust fungi. APS Press, St Paul, p 152
- Cummins GB, Hiratsuka Y (2003) Illustrated genera of rust fungi. APS Press, St Paul, p 225

- Dao NK, Hop T, Siemonsma JS (1999) *Cinnamomum* Schaeffer. In: de Guzman CC, Siemonsma JS (eds) Plant Resources of South-East Asia, vol 13. Backhuys Publishers, Leiden, pp 94–99
- Hiratsuka N, Sato S, Katsuya K, Kakishima M, Hiratsuka Y, Kaneko S, Ono Y, Sato T, Harada Y, Hiratsuka T, Nakayama K (1992) Rust flora of Japan. Tsukuba Shuppankai, Tsukuba, p 1205
- Kobayashi T (2001) Diagnostic manual for tree diseases in the tropics. With some diseases of agro forestry crops. Japan Int. Forestry Promotion and Coop. Centre (JIFPRO) Soubun Printing Co. Ltd, Tokyo, p 76
- Morin L, Auld BA, Brown JF (1993) Host range of *Puccinia xanthii* and post penetration development on *Xanthium occidentale*. Can J Bot 71:959–965
- Raciborski M (1900) Parasitische algen und pilze java's. Bibliotheca Mycologica. Reprint 1973. J. Cramer, New York, p 39
- Sato T, Uzuhashi S, Hosoya T, Hosaka K (2010) A list of fungi found in the Bonin (Ogasawara) Islands. Ogasawara Research Committee of Tokyo Metropolitan University 35:59–69
- Semangun H (1992) Host index of plant diseases in Indonesia. Gadjah Mada University Press, Yogyakarta, p 351