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Taxonomic revision and phylogenetic analyses of rubber powdery mildew fungi

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ABSTRACT

Powdery mildew is a fungal disease that infects a wide range of plants, including rubber trees, which results in a reduction of latex yields of up to 45%. The causal agent of powdery mildew of rubber was first described as *Oidium heveae*, but later morpho-molecular research suggested that in the past, *O. heveae* has been confused with *Erysiphe quercicola*. However, it is still under debate whether the causal agent should be classified as a species of the genus *Erysiphe* emend. or *Golovinomyces* and *Podosphaera*, respectively. Therefore, the aim of this study was to undertake the morpho-molecular characterization of powdery mildew species associated with rubber trees, thus resolving these taxonomic issues. Morphological observation under light and scanning electron microscopes (SEM) clearly identified two morphotypes of the rubber powdery mildew. With the support of morphological and phylogenetic data, one of the two morphotypes was identified as the asexual morph of *E. quercicola*, while the second morphotype is still insufficiently known and according to the morphological results obtained we assume that it might belong to the genus *Golovinomyces*. More collections and additional molecular data are required for final conclusions regarding the exact taxonomic position of the second morphotype of rubber powdery mildew and its relation to the name *O. heveae*. The haplotype analysis identified eight haplotype groups of *E. quercicola* indicating the high genetic diversity of the species.

1. Introduction

Powdery mildew disease has emerged as a serious threat to rubber plantations worldwide [1,2]. The leaf fall caused by this disease is also referred to as “secondary leaf fall” because the infected tree loses its leaves a second time, in the period when it would normally be re-growing after winter [3]. The causal agent of powdery mildew of rubber was first described as *Oidium heveae* by B. A. Steinmann in 1925 [4–8]. Powdery mildew infects newly formed rubber leaves, buds, inflorescences and other young tissues, resulting in shading of leaves, leaving the petioles attached to the twigs, which then drop off after a few days [9,10]. Liyanage and Kuruvilla [9] pointed out that a severe attack of powdery mildew leads to extensive defoliation and depleted canopies (Fig. 1). The infection can result in a loss of up to 45% of latex yield, reduced girth of the young rubber trees and slower bark renewal after harvesting [3,11]. Moreover, rubber flowers are more susceptible to powdery mildew than the leaves, resulting in a poor fruit pod set. This can result in seed loss of up to 100% [3]. This pathogen grows better under conditions of high humidity and temperatures between 25 °C and 28 °C [12,13]. Therefore, rubber powdery mildew disease is a significant limiting factor in the expansion of rubber plantations in humid areas worldwide [1,14].

The morphology of *O. heveae* was first reported by Steinmann [4] who described ellipsoid to cylindrical conidia, 25–33 × 12–17 μm, often in long chains. Later Subramanian [5], and Sivanesan [15] also reported the morphology of *O. heveae* as white, hyaline, branched, septate mycelium and ellipsoidal or barrel-shaped, very variably sized (25–42 × 12–17 μm) conidia,

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Fig. 1. Powdery mildew colonies on rubber trees; **a.** in its natural habitat **b-c.** on the leaf surface, **d.** on the flower surface, **e.** on upper leaf surface, **f.** on the lower leaf surface, **g.** Mycelium mat on the leaf surface, **h**. Infected young leaflets with curled, crinkled and rolled margins, **i.** Rubber tree branches after secondary leaf fall, **j.** Infected rubber plantation with sparse canopy.

formed in basipetal chains. Braun and Cook [8] classified *O. heveae* as morphologically insufficiently understood, and repeated Steinmann's [4] original description. They further noted that it is unclear whether or not fresh conidia contained conspicuous fibrosin bodies (structures present in the cytoplasm of the conidia of species of the genus *Podosphaera* Kunze and some other powdery mildew genera). Braun and Cook [8] reported that *Hevea brasiliensis* Willd. ex A. Juss. is a common host for the plurivorous *Erysiphe quercicola* S. Takam. & U. Braun, which is known to cause powdery mildews in certain other mostly tropical or subtropical tree species. Thus, the authors suggested that *O. heveae* was being confused with *E. quercicola* (asexual morph: *Pseudoidium anacardii* (F. Noack) U. Braun & R.T.A. Cook).

However, Limkaisang et al. [6] described the specimens that they collected from a rubber tree as having single (non-catenate) conidia without fibrosin bodies. The asexual form had simple to lobed hyphal appressoria and a germ tube of the polygoni (*Pseudoidium*) type, indicating that the rubber mildew belongs to the genus *Erysiphe* DC. (= *Pseudoidium* Y.S. Paul & J.N. Kapoor, anamorph-typified heterotypic synonym). Boesewinkel [16]