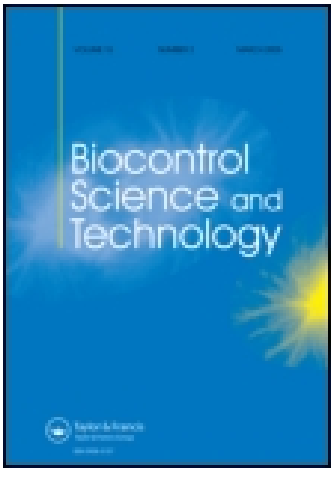

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Occurrence and distribution of entomophthoralean fungi infecting aphids in mainland China

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SHORT COMMUNICATION

Occurrence and distribution of entomophthoralean fungi infecting aphids in mainland China

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Abstract
Seventeen species of entomophthoralean fungi infecting 15 species of aphids have been reported from mainland China. They belong to seven genera: *Batkoa*, *Conidiobolus*, *Entomophthora*, *Neozygites*, *Pandora*, *Tarichium* and *Zoophthora*. *Conidiobolus thromboides*, *E. planchonian*a, *N. fresenii* and *P. neoaphidis* have the widest distributions covering five regions with the exception of the south-west. *Tarichium atrospermum* and *Z. canadensis* were only reported in the eastern region and *P. echinospora* only in the mid-southern region. *Pandora neoaphidis*, the most common species, occurred in many aphid populations. Species belonging to the genus *Conidiobolus* frequently appeared in the warm summer season, however, disease incidence was lower compared to the genus *Pandora*.

Keywords: *Entomophthorales, aphid, distribution, China*

Introduction

It is well known that some species of Entomophthorales are important aphid pathogens prevailing in host populations worldwide (Milner 1997; Pell et al. 2001). Since 1963, when Su and Hsin found that aphids on vegetables were heavily infected by *Entomophthora aphidis* Hoffman (*Pandora neoaphidis*) (Su & Hsin 1963), various studies were conducted on entomopathogenic fungi attacking aphids for the purpose of developing microbial insecticides in mainland China and there have been many reports in the literature on fungal pathogens and their occurrence, but there have been no reviews on this topic. In this paper we provide a review on the species and distributions of entomophthoralean fungi infecting aphids in mainland China.

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Fungal species, distributions and aphid hosts

Mainland China is usually divided into six regions: north (N), east (E), north-east (NE), north-west (NW), south-west (SW) and mid-south (MS) (Figure 1). We use these six regions to describe the distribution of the aphid pathogenic fungi. A fungus is considered to exist in a region if it had been reported at any one place within that region. In addition, the references covering records of the entomogenous fungi attacking aphids naturally in fields are only cited in the tables. All entomophthoralean species were identified based on the Humber (1989) classification system.

A total of 17 entomophthoralean fungi belonging to seven genera; *Batkoa*, *Conidiobolus*, *Entomophthora*, *Neozygites*, *Pandora*, *Tarichium* and *Zoophthora* were reported infecting 15 species of aphid hosts in mainland China (Table I). The four species, *C. thromboides*, *E. planchonian*a, *N. fresenii* and *P. neoaphidis* have the widest distributions covering five regions with the exception of the south-west. *Tarichium atrospermum* and *Z. canadensis* were only reported in the eastern region, and *P. echinospora* just in the mid-south region. The eastern region has the most entomophthoralean fungi distributed followed by the mid-south. No aphid pathogenic fungi were reported from the south-west so far. The distribution pattern may be mainly due to the difference of regional climatic characteristics. For instance, the eastern and mid-south regions experience a more moderate climate.

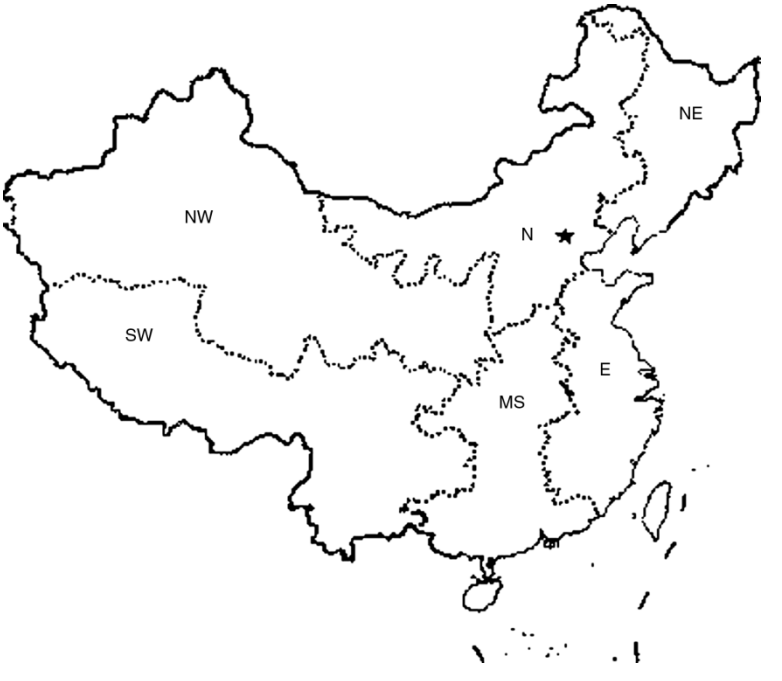

Figure 1. The six regions of mainland China (N, north; E, east; NE, north-east; NW, north-west; MS, mid-south; SW, south-west).

Table I. The entomophthoralean fungi infecting aphids in mainland China and their host aphids.

Fungal species	Host aphids	Distribution	References cited
Batkoa major (Thaxter) Humber	*Myzus persicae* (Sulzer), *Toxoptera citricidus* (Kirkaldy)	E, MS	Li (2000); Li et al. (1999)
Conidiobolus coronatus (Costantin) Batko	*Aphis craccivora* Koch, *Lipaphis erysimi* (Kaltenbach), *M. persicae*,	N, E, MS	Li et al. (2004); Li (2000); Li et al. (1999); Wu and Wang (1993)
C. obscurus (Hall & Dunn) Remaudière & Keller	*Aphis laburni* (Kaltenbach), *M. persicae*	N, E, NE, MS	Li (2000); Li et al. (1999); Sun et al. (2000); Wu and Wang (1993)
C. osmodes Drechsler	*Aphis glycines* (Matsumura)	N, NE	Cheng and Long (1987); Li (2000); Wu and Wang (1993)
C. pseudococci (Speare) Tyrrell & MacLeod	*T. citricidus*	E	Li (2000); Li et al. (1999)
C. thromboides Drechsler	*A. craccivora*, *Aphis gossypii* Glover, *Covariella salicicola* (Matsumura), *L. erysimi*, *M. persicae*, *Rhopalosiphum pseudobrassicae* (Davis), *Sitobion avenae* (Fabricius), *Tuberocephalus momomis* Matsumura	N, E, NE, NW, MS	Cheng and Ren (1984); Fan et al. (1990); Huang and Zheng (1990); Li et al. (2004); Li (2000); Li et al. (1999); Lu and Wang (1988); Lu et al. (1988); Wu and Wang (1984, 1993)
Entomophthora planchoniana Cornu	*A. gossypii*, *Brevicoryne brassicae* (L.), *L. erysimi*, *M. persicae*, *S. avenae*	N, E, NE, NW, MS	Chen and Feng (2002); Fan et al. (1990); Li and Kang (1989); Li et al. (2004); Li (2000); Li et al. (1999); Sun et al. (2000); Wu and Wang (1983)
Neozygites fresenii (Nowakowski) Remaudière & Keller	*A. gossypii*, *A. glycines*, *A. laburni*, *L. erysimi*, *M. persicae*, *Rhopalosiphum maidis* (Fitch), *Rhopalosiphum padi* (L.), *R. pseudobrassicae*	N, E, NE, NW, MS	Chen and Feng (2002); Fan et al. (1990); Han (2000); Huang and Zheng (1990); Li and Kang (1989); Li (1987); Li et al. (2004); Li (2000); Li et al. (1999); Lu and Wang (1988); Lu et al. (1988); Wu and Wang (1993); Zhang (1983)
Pandora echinospora (Thaxter) Humber	Unidentified species	MS	Huang et al. (2000); Li (2000)
P. kondoiensis (Milner) Humber	*B. brassicae*, *M. persicae*	E, NE	Huang et al. (2000); Li (2000); Li et al. (1999)
P. neoaphidis (Remaudière & Hennebert) Humber	Many species	N, E, NE, NW, MS	Chen and Feng (2002); Fan et al. (1990); Huang et al. (2000); Huang et al. (1990); Li and Kang (1989); Li et al. (2004); Li (2000); Li et al. (1999); Lu and Wang (1988); Lu et al. (1988); Song et al. (2001); Su and Hsin (1963); Sun et al. (2000); Wu and Wang (1983, 1993)

<?A3B2 tpfmt=Table I ([it]Continued[/it])>

Fungal species	Host aphids	Distribution	References cited
P. nouryi (Remaudière & Hennebert) Humber	*A. gossypii*, *C. salicicol*, *L. erysimi*, *M. persicae*, *S. avenae*	N, E, NE, MS	Huang (2000); Li and Kang (1989); Li et al. (2004); Li (2000); Li et al. (1999); Lu and Wang (1988); Lu et al. (1988); Wang et al. (1988); Wu and Wang (1993)
Tarichium atrospermum Petch	*L. erysimi*, *M. persicae*	E	Li (2000); Li et al. (1999); Wang et al. (1993)
Zoophthora anhuiensis (Li) Humber	*L. erysimi*, *M. persicae*	E, MS	Chen and Feng (2002); Huang and Zheng (1990); Li (2000); Li et al. (1999); Li (1986); Sun et al. (2000)
Z. aphidis (Hoffmann ex Fresenius) Batko	*L. erysimi*, *M. persicae*	E, NW	Li (1987); Li et al. (2004); Li (2000); Li et al. (1992, 1999)
Z. canadensis (MacLeod, Tyrrell & Soper) Remaudière & Hennebert	*Cinara pinitabulaeformis* Zhang & Zhang	E	Li (2000); Li et al. (1989, 1999)
Z. radicans (Brefeld) Batko	*L. erysimi*, *M. persicae*, *R. pseudobrassicae*, *S. avenae*	N, E, MS	Huang and Zheng (1990); Li (2000); Li et al. (1999); Wu and Wang (1983, 1993)

N, north; E, east; NE, north-east; NW, north-west; MS, mid-south; SW, south-west (showed in Figure 1).

Epizootiology

Difference in geography

The climates between south and north of China, which are separated by the Changjiang River, are very different. To the south it is warm and wet, but to the north it is usually dry and seasonally changeable. These differences in climate are most probably responsible for the remarkable differences in the prevalence of mycoses in the two areas. In the south, epizootics in aphids occur mostly from October to April. The epizootic season in Changsha starts from late autumn or the early period of winter, namely, from the last 10 days of October to the last 10 days of December. By and large, it is cool and rainy or heavy dew occurs during this period, the temperature ranges from 8 to 17°C, and these conditions are favorable for entomopathogenic fungi (Li & Kang 1989). In the south, *Pandora neoaphidis* infects various aphid hosts and is prevalent in aphid populations throughout the year, even in winter (Li 2000). In northern China, epizootics occur mostly in the autumn and spring as infections do not occur in the winter or summer because the entomogenous fungi are dormant at extreme temperatures (Lu & Wang 1988; Lu et al. 1988; Fan et al. 1990; Wang et al. 1993).

Pandora neoaphidis is frequently reported to cause epizootics in aphid populations in the south and the northern regions of mainland China (Lu et al. 1988; Fan et al. 1990; Li 2000). Wu and Wang (1983) reported that the fungus was the primary pathogen killing aphids in the autumn near Beijing, accounting for 74% mortality. Some pathogenic fungi are prevalent only in certain areas, occurring only rarely in other areas. For example, *Erynia* (*Zoophthora*) *anhuiensis* was only reported suppressing host populations in the provinces situated south of Huaihe River (Li 1986, 2000), and it was the primary pathogen of aphids in those areas. In Shandong province, populations of diseased aphids increased greatly in the field during the spring and autumn because of the prevalence of *Erynia* (*Pandora*) *nouryi* and *Erynia* (*Pandora*) *neoaphidis*, often occurring simultaneously. However, *E. nouryi* rarely causes epizootics in other areas (Lu & Wang 1988; Lu et al. 1988; Li et al. 2004). In suburban gardens of Urumchi, 30–50% of the aphids were killed in an epizootic of *Entomophthora planchoniana*, and the percentage of mortality reached 80% in some fields (Fan et al. 1990). However, the proportion of diseased aphids killed by this fungus was very low in many other areas.

Some of the entomophthoralean fungi isolated from other insect hosts rarely reduce aphid populations significantly, but they might exhibit high virulence to aphids by artificial augmentation. In the south, the main pathogen of *Nilaparvata lugens* Stal was *Pandora delphacis* which was infrequently found to infect aphids, however, a strain isolated from infected *Nilaparvata lugens* Stal showed high virulence against *Myzus persicae* Sulzer (Xu & Feng 2000). Huang et al. (1984) discovered for the first time *Conidiobolus coronatus* infecting imagoes of *Psychoda* sp., thereafter, there were many reports of this fungus in aphid populations (Wu & Wang 1993; Li 2000; Li et al. 2004).

Seasonal prevalence

It is well known that climate plays a critical role in an epizootic. In Shanghai, for example, many dead aphids infected by fungi are found during March and April

because it is rainy and cool and the epidemic ends in May (Su & Hsin 1963). Prevalence of *Erynia* (*Zoophthora*) *canadensis* in populations of *Cinara pinea* Mordv. in Anhui province peaked in mid-April, and destroyed the local aphid populations within the following few days with aphid mortality exceeding 99% in the last 10 days of April (Li et al. 1989). In summer, *Neozygites fresenii* was the dominant species, which prevailed in *Rhopalosiphum maidis* (Fitch) and *Aphis glycines* Matsumura populations in Shandong province. *Conidiobolus thromboides* infected 91.5% of the *R. maidis* and 8.5% of the *A. glycines populsations*. However, in spring and autumn, the main pathogens were *Erynia* (*Pandora*) *nouryi* and *Erynia* (*Pandora*) *neoaphidis*, *Conidiobolus thromboides* and two other unknown species followed (Lu & Wang 1988; Lu et al. 1988). Wu and Wang (1993) reported that some species of *Conidiobolus,* i.e. *C. thromboides*, *C. obscurus, C. coronatus* and *C. osmodes*, commonly occur in May and July when it is warmer in the northern and the north-east parts of China.

Conclusions and discussion

Except for *Erynia conica* (Nowakowski) Remaudière & Hennebert, *E. erinacea* (Ben-Ze'ev & Kenneth) Remaudière & Hennebert, *E. gracillis* (Thaxter) Remaudière & Hennebert, *Thaxterosporium turbinatum* (Kenneth) Kenneth & Ben- Ze'ev, entomophthoralean fungi listed in this paper were described in detailed by Li (2000) in his monograph *Flora Fungorum Sinicorum. Vol. 13. Entomophthorales*. However, *E. conica*, *E. erinacea*, *E. gracillis* and *T. turbinatum* were reported by Li and Kang (1989) without any morphological description. Therefore the accuracy of identification of these fungi is suspect.

Entomophthoralean fungi are among the most important natural resources in China. The deficiencies in classification limit their exploitation as a treasured natural enemy to control aphids. In fact, the distributions of some fungi are much more beyond what we know today, even worldwide (Milner 1997). Unfortunately, few investigations on these fungi have been done in China to date.

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