Bibliography on *Hydrellia griseola* Fallén (Diptera: Ephydridae) and review of its biology and pest status

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Abstract: A bibliography is presented on *Hydrellia griseola* (Fallén), a cosmopolitan species of shore fly that is an agricultural pest throughout much of its range. The literature review includes 195 references and spans 180 years: from 1813, when *H. griseola* was first described (as *Notophila griseola*), to 1993. My review updates and extends by 110 years a previous review of this species. The host plant associations, bionomics, distribution, pest status, and control of this species are reviewed. The known host plants of larval *H. griseola* are listed. My survey of the literature supports the hypothesis that *H. griseola* is increasing its range as a pest of rice. *H. griseola* can be controlled by cultural or chemical methods, but due to agronomic and environmental constraints on these methods, my review points out the need for more research on and use of the natural enemies of *H. griseola*.

Introduction

Hydrellia Robineau-Desvoidy (1830) (Diptera: Ephydridae: Notophilinae) is the most species rich genus of shore flies, and one of the most widely distributed genera in its family (Deonier, 1971; Zatwarnicki, 1988). *Hydrellia* contains about 11% of all species of shore flies and is recorded from all continents except Antarctica. Five species (*fascitibia* v. Roser, *griseola* [Fallén], *ischiaca* Loew, *tenebricosa* Collin, and *tibialis* Cresson) are Holarctic, and at least five (*griseola*, *ischiaca*, *philippina* Ferino, *prosternalis* Deeming, and *sasakii* Yuasa and Isitani) are economically important (Zatwarnicki, 1988). Also, *H. pakistanae* Deonier (from southern Asia) and *H. balciunasi* Bock (from Australia) have been introduced into the United States for biological weed control (Buckingham *et al.* 1989, 1991).

H. griseola (the smaller rice leafminer) is the most widely distributed and one of the most economically significant species (Joshi *et al.*, 1986; Zatwarnicki, 1988). The literature on *H. griseola* dates back to 1813, when Fallén originally described this species as *Notophila griseola*. Macquart (1835) later placed it in the genus *Hydrellia*. Since then, a considerable body of literature has accumulated on this species. Joshi *et al.* (1986) developed a bibliography limited to the years 1913-1983 on *Hydrellia* spp. that attack rice. Grigarick (1959a) and Deonier (1971) reviewed the biology of *H. griseola*.

However, an expanded and updated bibliography on *H. griseola* is needed. Ideally, this bibliography should cover the entire body of literature to date. Second, an updated review of the literature on *H. griseola* is also warranted.

Therefore, I present an expanded bibliography on *H. griseola*, including references from 1813 through early 1993. In addition to the bibliography, I summarize the literature, presenting a brief review of the distribution, host plant associations, bionomics, pest status, and control of this species. I discuss unresolved issues regarding the distribution of *H. griseola*, note the increasing recognition of this species as a pest of rice, and point out the need for more research on the natural enemies of *H. griseola*.

Distribution, host range, and bionomics

In the Palearctic, *H. griseola* occurs throughout Eurasia and insular regions of southeast Asia (Barrion and Litsinger, 1981; Zatwarnicki, 1988).

In the western hemisphere, *H. griseola* is found throughout the United States and Canada (Grigarick, 1959a; Deonier, 1971), and in Costa Rica (Cresson, 1918), Uruguay (Parker *et al.*, 1951-52), and Colombia (Weber *et al.*, 1988). The apparent discontinuous distribution in Latin America and South America may simply be due to incomplete information on the geographic distribution of *H. griseola*, or perhaps it may indicate introductions of this species at various sites.

The distribution of *H. griseola* in Africa and Australia is uncertain. Willcocks (1925) originally reported that *H. griseola* occurs in Egypt, but recent reports indicate that the species may actually be *H. prosternalis* (Ismail *et al.*, 1979; Isa, 1989). Halfpapp (1989) reported that *H. griseola* had been found in Queensland (Australia), but Bock (1990) asserted that specimens collected by Halfpapp represented a new sibling species (*i.e.*, *H. mareeba* Bock). More intensive surveys for *H. griseola* on these two continents is needed.

The wide distribution of *H. griseola* reflects its tolerance for a great range of habitats and environmental conditions. Adult activity and development of the immature instars occur at temperatures ranging from about 10° to 40°C (Grigarick, 1959a). Altitudinally, *H. griseola* has been collected from 87 m below sea level (Death Valley, USA) to 2950 m above (Mount Timpanogos, Utah, USA) (Deonier, 1971).

H. griseola occurs in various ephemeral habitats of aquatic, semi-aquatic, and terrestrial ecosystems (Grigarick, 1959a; Deonier, 1964b, 1971; Scheiring and Foote, 1973). This species occurs in natural settings as well as anthropogenic habitats (*e.g.*, rice paddies and other agroecosystems, canals, artificial ponds) (Grigarick, 1959a; Deonier, 1964b, 1971; Scheiring and Foote, 1973). Methods are described for sampling the different life stages of *H. griseola* in various habitats (see Grigarick, 1959a, b; Deonier, 1971; Deonier, 1972b).

H. griseola is a polyphagous plant-feeder in the larval stage (Grigarick, 1959a; Deonier, 1964b; 1971). The majority of larval host plants are members of the family Graminae (Table 1). Larvae are endophytophagous, burrowing into leaves and leaf sheaths (Grigarick, 1959a; Deonier, 1971; Manandhar and Grigarick, 1983). The larvae feed on leaf mesophyll, and this feeding creates mines between the epidermal layers of the leaf. Individual larvae may mine more than one leaf or sheath. Pupariation may occur within leaf mines or off of plants altogether (*e.g.*, at the bottom of ice-covered pools [Burghele, 1959a]). Often, development is completed on more than one plant species (Deonier, 1971). In Japan, Kuwayama (1955) found that both larval and puparial mines were present on monocotyledonous plants, whereas only puparial mines were found on dicotyledonous plants. Total developmental time ranges from 13 d at 32-35 °C to 94 d at 10 °C (Grigarick, 1959a). Up to 11 generations have been estimated to occur in a single year in California (Grigarick, 1959a).

Adults have a varied diet. They feed on, among other things, fungi, algae, diatoms, nectar, and leaf epidermis (Deonier, 1971; 1972a). They also prey and scavenge upon small insects such as small flies (including other *Hydrellia*), Psilidae, early instar Ephemeroptera and Odonata, Collembola, and Braconidae (Grigarick, 1959a; Deonier, 1971).

Under optimal conditions, adults may be quite long-lived. Grigarick (1959a) was able to maintain adult males for up to 130 d and females up to 139 d. He also found that adults mate as early as 3 d and as late as 70 d after emergence. Females can oviposit as early as 5 d and as late as 93 d after emergence (Grigarick, 1959a). Eggs of *H. griseola* are laid singly on the upper surfaces of leaves and require high humidity (80-100%) for hatching (Grigarick, 1959a).

The overwintering habits of *H. griseola* vary geographically. *H. griseola* overwinters primarily as adults in California (Grigarick, 1959a) and as adults in the Black Sea region of the former USSR (Kas'yanov, 1967). In Hungary, only parthenogenic females are known to overwinter (Szito, 1976). By contrast, *H. griseola* overwinters in puparia in the Maritime Province of the former USSR and in northern temperate regions of Japan (*i.e.*, Hokkaido district, Honshu) (Kuwuyama, 1956; Klimanova, 1971). In southern Japan (*i.e.*, south Ibaraki Prefecture), all life stages can be found during the winter months (Iwamoto, 1966).

Pest status

H. griseola is a pest of several crops, including rice (*Oryza sativa* L.), wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), oats (*Avena sativa* L.), timothy (*Phleum pratense* L.), and onions (*Allium* spp.) (see Grigarick, 1959a and references therein). Larvae develop also on maize (*Zea mays* L.) and wild rice (*Zizania aquatica* L.) (Grigarick, 1959a; Schmidt, 1962), but economically significant infestations of *H. griseola* have not been reported on these two crops. Injury to plants results from leaf- and stem-mining by the larvae. Their

Table 1: Principal host plants of *Hydrellia griseola* larvae, based on host plant records in Grigarick (1959a) and Deonier (1971).

Alismataceae	Graminae cont.	Graminae cont.
Alisma spp.	*Calamagrostis* sp.	*Polypogon* sp.
Damasonium sp.	*Catabrosa* sp.	*Scleropa* sp.
Sagittaria spp.	*Cynodon* sp.	*Secale cereale* L.
Caryophyllaceae	*Dactylis glomerata* L.	*Setaria* sp.
Lychnis sp.	*Digitaria* sp.	*Triticum sativum* L.
Stellaria media (L.)	*Echinochloa crusgalli* (L.) Beauv.	*Zea mays* L.
Chenopodiaceae	*Eleusine* sp.	*Zizania aquatica* L.
Kochia sp.	*Eragrostis* sp.	Hydrocharitaceae
Compositae	*Festuca pratensis* Huds.	*Hydrocharis morsus-ranae* L.
Bellis sp.	*Gaudinia* sp.	*Stratiotes aliodes*[1]
Cruciferae	*Glyceria* sp.	Labiatae
Nasturtium officinale R. Br.	*Hierochloe* sp.	*Lamium purpureum* L.
Cyperaceae	*Holcus lanatus* L.	Leguminosae
Carex sp.	*Hordeum vulgare* L.	*Trifolium* sp.
Cyperus sp.	*Lagarus* sp.	Lemnaceae
Scirpus sp.	*Lolium perene* L.	*Lemna minor* L.
Graminae	*Muhlenbergia* sp.	Liliaceae
Agropyron spp.	*Oryza sativa* L.	*Allium cepa* L., *A. porrum* L.
Agrostis sp.	*Panicum* sp.	Polygonaceae
Alopercurus sp.	*Paspalum* sp.	*Polygonum* sp.
Anthoxanthum odoratum L.	*Phalaris arundinacea* L.	Scrophulariaceae
Apera sp.	*Phleum pratense* L.	*Veronica* sp.
Avena sativa L.	*Phragmites* sp.	Typhaceae
Brachypodium sp.	*Poa annua* L., *P. pratensis* L., *P. trivialis* L.	*Typha latifolia* L.
Bromus sp.		

[1]Undetermined author.

feeding reduces photosynthesis, and causes leaf abscission and sometimes seedling death (Manandhar and Grigarick, 1983).

Early notoriety of *H. griseola* was due to its economic significance in small grain crops. Lilljeborg (1861) first reported *H. griseola* as a pest of barley, oats, and timothy in Sweden. Crop losses near 50% have been attributed to *H. griseola* in barley, oats, and wheat in Europe (Balachowsky and Mesnil, 1935).

During the 20th century, however, *H. griseola* has become increasingly recognized as a pest of rice. The first reports of *H. griseola* attacking rice came from California (de Ong, 1922). Later, Nepveu and D'Aguillar (1951) reported *H. griseola* as a pest of rice in France. Serious outbreaks of *H. griseola* in rice occurred in California in 1953 (Lange *et al.*, 1953) and in Japan in 1956 (Kuwayama, 1956). The 1953 outbreak in California resulted in a 10-20% crop loss worth $16 million (US); an additional $1.2 million were spent on insecticides for control (Jensen, 1954). The 1956 infestation in Japan caused a loss of 39,000 kl of rice over a 75,000-ha area (Kuwuyama, 1956).

The economic significance of *H. griseola* varies geographically depending on the crop. For instance, *H. griseola* is a pest of rice throughout most of its range. In contrast, its pest status on other crops is limited geographically to Europe and Asia, as the literature is devoid of any reference to serious infestations by *H. griseola* in North and South America in crops other than rice. Grigarick (1959a) did not find *H. griseola* infesting wheat and barley in California, but he was able to rear specimens from these two cereals, as well as oats, under laboratory conditions. Economically significant infestations of onions by *H. griseola* are apparently limited to European regions of the former USSR (Isaev, 1931).

Much of the recent literature on *H. griseola* is related to its occurrence on rice. Since 1980, 30 of the 38 reports about *H. griseola* have dealt exclusively with its economic significance in rice, and two additional reports addressed the pest status of *H. griseola* on rice and at least one other crop. Moreover, the geographic range in which *H. griseola* is recognized as a pest of rice has been increasing. Since 1980, several regions have reported their first accounts of economic loss in rice due to *H. griseola*, including The Philippines (Barrion and Litsinger, 1981), the southern US (Way *et al.*, 1983), India (Chakravarthy, 1987), Colombia (Weber *et al.*, 1988), and perhaps Australia (Halfpapp, 1989; but see Bock, 1990).

H. griseola is likely to receive increased attention as a pest, particularly in rice-growing regions of the US, because of changes in management practices. For instance, the practice of continuous, deep-water culture for weed control may become more prevalent in California rice production due to 1) increasing restrictions on herbicide use in rice fields (Williams *et al.*, 1990), and 2) the adoption of organic (*i.e.*, non-chemical) management practices by some rice growers (Altieri *et al.*, 1983; Hesler *et al.*, 1993). Deep-water culture causes the leaves of rice plants to lie prostrate on the water surface, favoring increased incidence and severity of attack by *H. griseola* (Lange *et al.*, 1953). Maintenance of a shallow water depth (*e.g.*, 7-10 cm) during the late seedling and early tillering stages reduces the potential for damage by *H. griseola* (Grigarick and Washino, 1983; Way *et al.*, 1983; see also Szilvassy and Petrasovits, 1960; Szito, 1985). However, shallow water levels can greatly increase the risk of weed problems (Williams *et al.*, 1990). Because weeds are a serious threat annually to rice production in California (whereas outbreaks of *H. griseola* occur sporadically), growers are likely to continue the use of deep-water culture despite an increased likelihood of problems with *H. griseola*. New means of managing *H. griseola* that are compatible with deep-water culture are clearly needed.

Control

Several means of preventing and controlling infestations of *H. griseola* are available. Many researchers have advocated the integration of cultural, chemical, and biological control methods (Buryi, 1980; Grigarick and Washino, 1983; Weber *et al.*, 1988).

Serious infestations of *H. griseola* can often be prevented by the attention to various cultural factors, such as planting date, field location, and water management (discussed above for rice). For instance, a delay in planting date that minimizes the time in which young plants are exposed to cool, humid weather can significantly reduce the extent of damage caused by *H. griseola* (Hering, 1951; Grigarick and Washino, 1983). In small grains, economically damaging infestations of *H. griseola* can also be prevented by avoiding plantings in low, damp areas near standing or running water (Hering, 1951). In Japan, damage to rice can be limited by avoiding synchrony between the transplanting of seedlings and the period of oviposition by *H. griseola* (Kuwuyama, 1955; Kidokoro *et al.*, 1982).

Insecticides can control infestations of *H. griseola*. These are usually targeted against the adults and newly hatched larvae (*e.g.*, Lange *et al.*, 1953; Kuwuyama, 1955; Grigarick, 1959a; Buryi, 1980), and applications, therefore, require proper timing.

The development of tolerant or resistant varieties of oats (Stavrakis, 1965), spring wheat (Zhu, 1981), and rice (Weber *et al.*, 1988) holds promise for limiting damage by *H. griseola*. Resistance in spring wheat was associated with dense fine hairs on the basal parts of leaves, a thick waxy cuticle, and leaf sheaths that were close to the stem (Zhu, 1981). Mechanisms of resistance in oats and rice were not specified.

Several kinds of natural enemies attack *H. griseola*. Many species of Hymenoptera are known to parasitize *H. griseola*, principally during the larval and pupal stages (for particular species, see Deonier, 1971; Kamijo, 1978; Halfpapp, 1989). In rice, the percentage parasitism in the first generation is usually low, but can approach 80% in later generations (Grigarick, 1959a; Buryi, 1980). A fungus, *Stigmatomyces hydrelliae* Thaxter (Ascomycetes: Laboulbeniales), also attacks *H. griseola* larvae and adults (see Rossi and Cesari Rossi, 1979). Wolf spiders (Araneae: Lycosidae) prey upon adult *H. griseola* in rice fields (Grigarick, 1959a). More research is needed to effectively use parasites and predators to prevent or control outbreaks of this pest, especially in light of the environmental and agronomic constraints with chemical and cultural methods that are discussed above.

Bibliography

The following bibliography contains 195 references on *H. griseola*. Because of the worldwide distribution of this pest, the bibliography collectively contains works written in more than 10 languages. References published in Chinese (C), Hungarian (H), Japanese (J), Korean (K), or Russian (R), and two in Italian (I), have been listed in English (actual language indicated by abbreviation in parentheses following reference). F = French. Lower case abbreviations are used to indicate the languages in which summaries (abstracts) are written: a = Arabic, e = English, g = German, p = Polish. Articles known to contain synonyms of *H. griseola* are indicated by listing the name(s) in brackets following the reference.

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