Description of a new species of *Orseolia* (Diptera: Cecidomyiidae) from *Paspalum* in West Africa, with notes on its parasitoids, ecology and relevance to natural biological control of the African rice gall midge, *O. oryzivora*

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Abstract

Field sampling of grasses growing in and near rice fields at 12 sites in Nigeria during April/May 1994 recorded the presence of galls on *Paspalum scrobiculatum* at densities of up to 10.9 galls per m^2. These galls were induced by *Orseolia bonzii* Harris, **sp. n.**, which is described. This species is morphologically close to, but distinct from, the African rice gall midge, *Orseolia oryzivora* Harris & Gagné, with which it has been confused in earlier studies of that pest species. In host-transfer experiments *O. bonzii* did not transfer to rice, *Oryza sativa*. Six hymenopterous parasitoids were reared from galls of *O. bonzii* and the most abundant of these were *Platygaster diplosisae* Risbec, *Aprostocetus* nr. *procerae* (Risbec) and *Neanastatus* nr. *cinctiventris* Girault. Host-transfer experiments with the *Platygaster* and *Aprostocetus* species from *O. bonzii* on *Paspalum* indicated that the *Platygaster* may not transfer onto *O. oryzivora* on rice whereas the *Aprostocetus* does. The overlap between the parasitoid faunas of the two species of *Orseolia* is potentially useful as it may be possible to enhance the natural biological control of *O. oryzivora* by manipulating parasitoid populations on *Paspalum*.

Introduction

The African rice gall midge, *Orseolia oryzivora* Harris & Gagné (Diptera: Cecidomyiidae), is an indigenous pest species that has caused serious damage to lowland rice crops in Burkina Faso since the late 1970s (Bonzi, 1980; Dakouo *et al.*, 1988) and in Nigeria since 1988 (Ukwungwu *et al.*, 1989; Ukwungwu & Joshi, 1992). It is now ranked as a major pest in both those countries and is causing concern in several others, including Zambia (Alam *et al.*, 1985), Sierra Leone (Taylor *et al.*, 1995), Mali (Hamadoun, personal communication) and Tanzania (E.A. Akinsola, M. Ukwungwu & E. Umeh, 1994. Unpublished report on a trip to Kapunga irrigated rice project, Tanzania, 9–18 April 1994). *Orseolia oryzivora* was not recognized as a distinct species until the early 1980s, when it was formally described by Harris & Gagné (1982) who separated it on morphological characters of larvae, pupae and adults from the similar Asian rice gall midge, *Orseolia oryzae* (Wood-Mason), which is a serious pest of rice in south and east Asia (Pathak & Dhaliwal, 1981;

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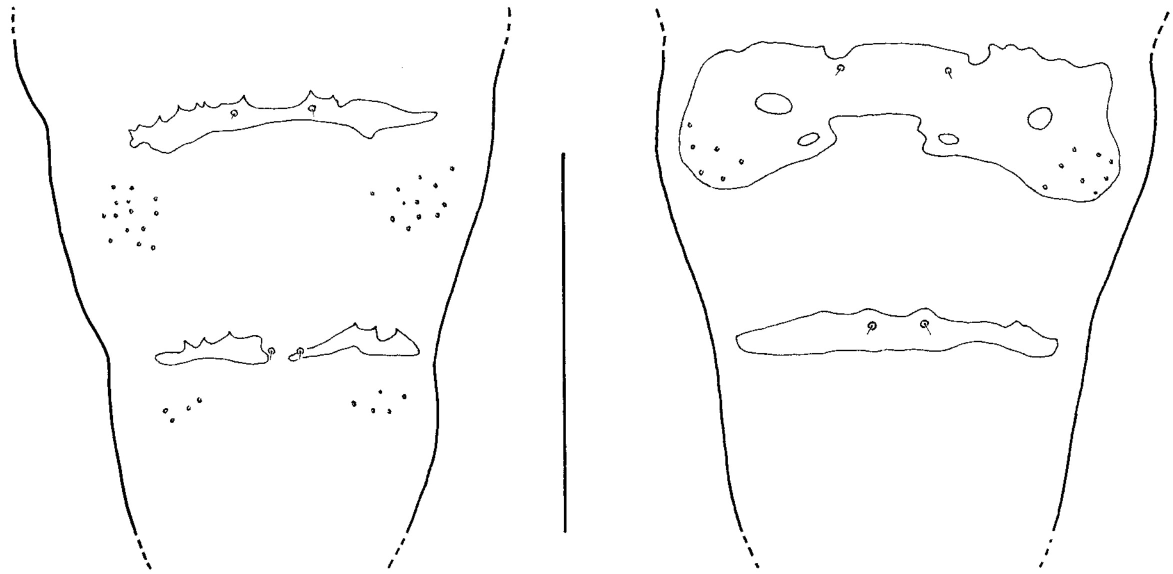

Fig. 1. Abdominal segments VII and VIII (dorsal) of male *Orseolia bonzii* **sp. n.** (right) and *O. oryzivora* (left). (Scale line = 0.5 mm.)

Waterhouse, 1993) but does not occur in Africa (Commonwealth Institute of Entomology, 1984).

During a field study on the host range of *O. oryzivora* in southwest Burkina Faso, Bonzi (1980) discovered tubular 'onion leaf' galls on the grass weeds *Paspalum scrobiculatum* and *P. polystachyum* (Poaceae), and concluded that *Paspalum* was an alternative host of *O. oryzivora*. However, Harris & Gagné (1982) examined available larvae and pupae from the galls on *Paspalum*, found morphological differences between them and those of *O. oryzivora*, and concluded that these specimens were probably of an undescribed species of *Orseolia*.

During recent studies on the host range, biology and ecology of *O. oryzivora* in West Africa much additional material of *Orseolia* from galls on *Paspalum* was collected in Nigeria. Examination of this material, combined with results of field surveys and host-transfer experiments, confirmed that it is morphologically and biologically distinguishable from *O. oryzivora*. In this paper the new species is described; new information on its ecology and that of its main hymenopterous parasitoids is presented and its potential use in the natural biological control of *O. oryzivora* is discussed.

Table 1. Numbers of sclerotized spines on pupal abdominal tergites II–VIII of *Orseolia bonzii* **sp. n.** and *O. oryzivora* Harris & Gagné.

Tergite	*O. bonzii*		*O. oryzivora*		
	Nigeria		Nigeria		Guinea
	Ikwo LGA Ebonyi State	Goga Niger State	Ekoi-Mbat Akwa Ibom State	Gadza Niger State	Boffa
II	17 ± 1	15 ± 2	31 ± 6	31 ± 6	26 ± 5
III	16 ± 2	14 ± 3	35 ± 4	34 ± 4	31 ± 4
IV	18 ± 4	14 ± 3	32 ± 3	33 ± 3	30 ± 5
V	14 ± 2	12 ± 3	30 ± 8	29 ± 5	30 ± 8
VI	11 ± 2	10 ± 2	28 ± 5	25 ± 5	23 ± 5
VII	11 ± 2	8 ± 1	18 ± 3	20 ± 3	15 ± 4
VIII	8 ± 1	7 ± 2	10 ± 2	15 ± 2	10 ± 3
n	4	11	8	6	5

Mean ± SE.

Orseolia bonzii Harris sp. n.

Description. Adults. Wing length *c*. 2.5–3.0 mm in males, *c*. 3.0–3.5 mm in females; venation as in other species of *Orseolia* with Sc weak, R1 about half wing length, R5 basally at a slight angle to M and curving in distal third to join C posterior to wing apex, Cu forked. Maxillary palps generally 3-segmented but occasionally 4-segmented; antennae with 12 flagellomeres (2 + 12), trifilar in males, with short circumfilar loops, and elongate-cylindrical in females, with short necks. Occiput without a post-vertical peak; eyes relatively large, eye bridge about 5–6 facets deep. Male abdominal tergites VII and VIII reduced but not to the same extent as in *O. oryzivora* and without the lateral groups of 2–6 setae on segment VIII (fig. 1); sternites VII and VIII relatively small and densely clothed in fine setae, as in other species of *Orseolia*. Male terminalia indistinguishable from *O. oryzivora*, with relatively broad hypoproct and gonocoxal apodeme and with gonostyle not markedly tapered in distal half. Female terminalia forming a short, non-retractile ovipositor, as in other species of *Orseolia*. Tarsal claws strong and simple, smoothly curved in distal half and as long as empodia.

Larvae. Morphologically very close to those of *O. oryzivora*, as described by Harris & Gagné (1982).

Pupae (fig. 2 and table 1). Length 4–6 mm (mean = 4.9, n = 14), male pupae generally smaller than female. Antennal horns tapering to apex, slightly flattened bilaterally; face with pair of inconspicuous anteromesal protuberances. Abdominal tergites with sclerotized recurved spines, larger and fewer than in *O. oryzivora*.

Gall (fig. 3). Fully developed galls tend to be shorter and slightly wider than those of *O. oryzivora* on *O. sativa*. A sample of 32 from a site near Uyo ranged from 21 to 108 mm long with a mean of 57 mm and a standard error of 3.7 mm. Galls from which adults had already emerged were of similar length to those containing pupae (means: 58 mm and 57 mm, respectively). Galls have pointed tips and are usually about 2–4 mm in width, often with a slight bulge in the distal

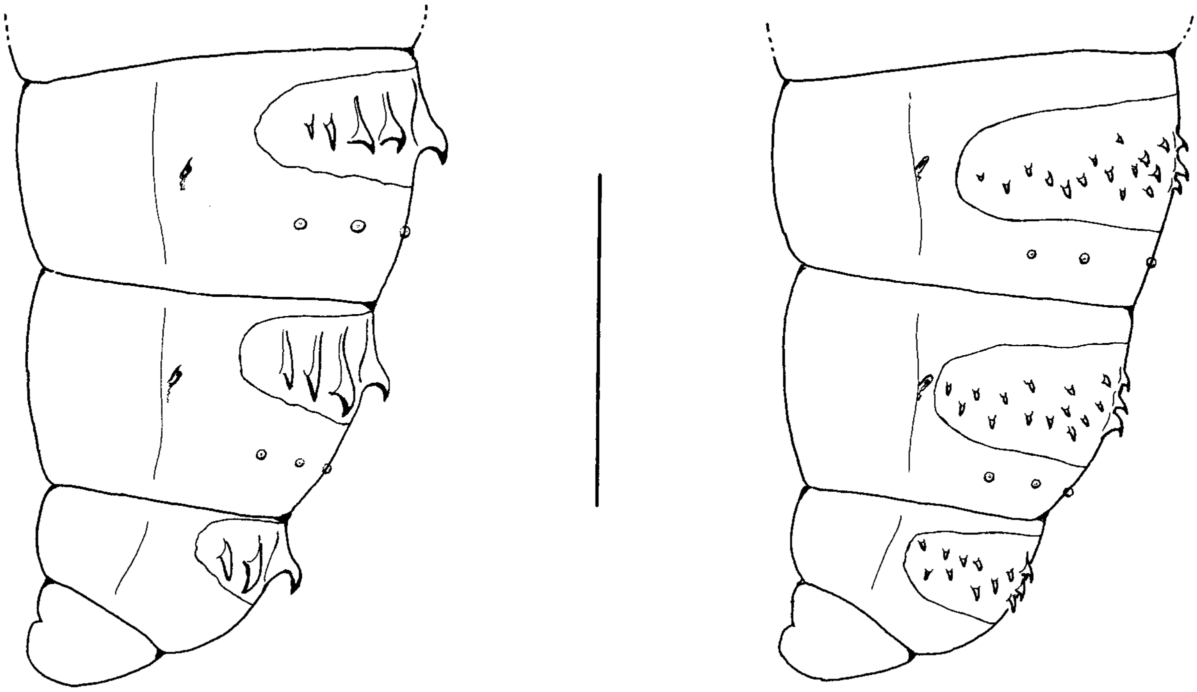

Fig. 2. Terminal pupal segments (lateral) of *Orseolia bonzii* **sp. n.** (left) and *O. oryzivora* (right). (Scale line = 0.5 mm.)

5 to 10 mm. Coloration varies from mainly pearly-whitish or pale green to almost entirely dark red. Both size and colour appear to vary with the condition of the host plant.

Material examined. Holotype ♂ (no. 19826), NIGERIA: Ikwo LGA, near Abakaliki, 5.vi.1995 (Williams & Okhidie no.2), ex *Paspalum scrobiculatum*. Paratypes: same data as holotype, 2♂ (nos. 19827–19828), 3♀ (nos. 19829–19831), 4 pupal skins (nos. 19832–19835), 2 larvae (nos. 19836–19837); Egunte, near Abakaliki, 23.v.1994 (Williams & Okhidie no.5), ex *Paspalum scrobiculatum*, 1♂ (no. 19825), 1♀ (no. 19824); Egunte, near Abakaliki, 23.v.1994 (Williams & Okhidie no.6), ex *Paspalum scrobiculatum*, 2 larvae (nos. 19822–19823); Goga, near Bida, 7.v.1994 (Williams & Okhidie no.3), ex *Paspalum scrobiculatum*, 2♂ (nos. 19840–19841), 2♀ (nos. 19842–19843), 4 pupal skins (nos. 19838–19839); Goga, near Bida, 7.v.1994 (Williams & Okhidie no. 4) ex *Paspalum scrobiculatum*, 6 pupal skins; Igwo LGA, 14.vi.1997 (Williams), ex *Paspalum scrobiculatum*, 4♂ (nos. 198858–19861), 1♀ (no. 19862), 5 larvae (nos. 19863–19865). BURKINA FASO [UPPER VOLTA]: Vallée du Kou, 6.v.1980, (Bonzi, CIE Coll. A.13749), ex *Paspalum scrobiculatum*, 14 larvae on slides, 3 pupal skins in vial; SENEGAL: Djibelor, 22.xi.1983, (Etienne SR 795, CIE Coll. A.15867), ex *Paspalum orbiculare*, 1♂ (no. 19821). The holotype and all paratypes have been deposited in the Cecidomyiidae slide collection of The Natural History Museum, London, UK. Additional specimens of pupae, pupal skins and adults stored in alcohol in tubes are not included in the type series.

Comments. Male and female specimens of this species are morphologically very close to *O. oryzivora* but good diagnostic characters in the pupae are easily observed as *O. bonzii* pupae have fewer and larger spines on the abdominal tergites. There are also diagnostic differences in tergites VII and VIII of male specimens. These differences, combined with the evidence of host-transfer experiments reported below, justify description of this new species which is named in recognition of the initial studies by S.M. Bonzi in Burkina Faso (Bonzi, 1980). The species is currently recorded only from Nigeria, Burkina Faso and Senegal but is likely to occur widely in West Africa, and possibly throughout sub-Saharan Africa. It is only the second species of *Orseolia* described from Africa. Intensive surveys of other potential grass host plants in Nigeria and Burkina Faso during the period 1994–1997 failed to discover any other undescribed species (C.T. Williams, unpublished observations).

An interesting parallel situation exists in south-east Asia where morphologically distinct species of *Orseolia* develop on *Oryza* and on *Paspalum* (Gagné, 1985). The Asian rice gall midge, *O. oryzae*, is the only species known to occur naturally on *Oryza* in the Oriental region (although there are many erroneous published records indicating a wider host range) and another species, *O. paspali* (Felt), which is morphologically similar, develops on *Paspalum scrobiculatum* and *P. conjugatum* in India and Indonesia. A second species, *O.* sp. nr. *monticola* (Felt) also occurs on these two species of *Paspalum* in both countries. There certainly seems to be much greater species diversity of *Orseolia* in the Oriental region as Gagné (1985) recorded 21 valid species.

Field sampling in Nigeria

During field sampling of *Orseolia* galls early in the wet season, between 21 April and 31 May 1994, the abundance of *Paspalum* species and of *Orseolia* galls on *Paspalum* were estimated at 12 sites in three African rice gall midge outbreak areas in central and southeast Nigeria: Bida, Niger State; Abakaliki, Ebonyi State; and Uyo, Akwa Ibom State. One of the sites near Uyo was irrigated and rice crops were grown year-round. At the others there was no irrigation, so rice was only grown in the wet season, with the first fields planted in June and July 1994, and the last harvested in December or January. *Paspalum scrobiculatum* and *P. conjugatum* were present at the sampled sites. The former is an extremely variable species, occurring in West Africa as two varieties, *P. scrobiculatum* var. *orbiculare* and *P. scrobiculatum* var. *polystachyum* (Johnson, 1997). These two varieties are very difficult to distinguish unless they are

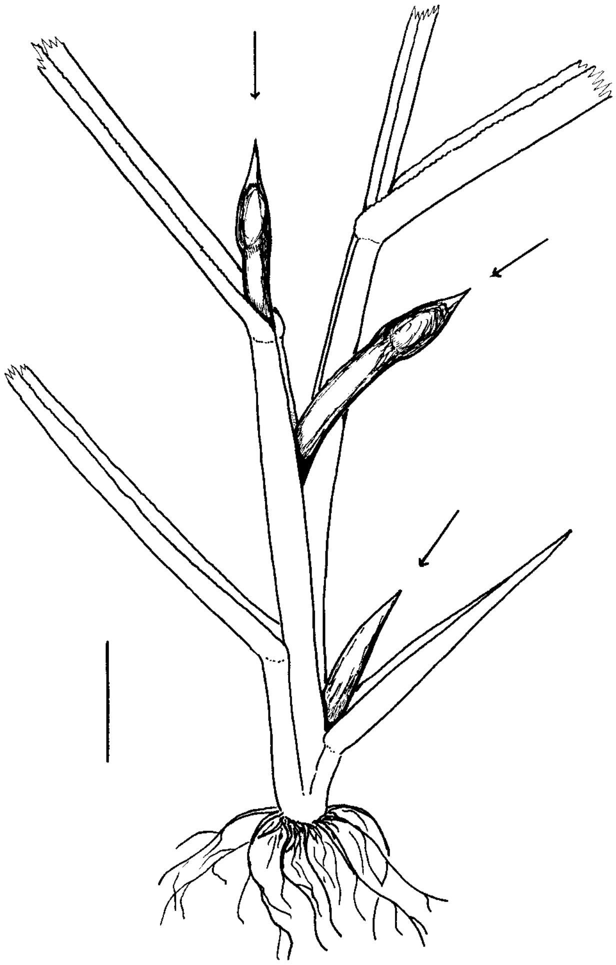

Fig. 3. Three galls of *Orseolia bonzii* **sp. n.** on young *Paspalum scrobiculatum* plant. (Scale line = 10 mm.)

flowering, and intermediate forms occur. Therefore they were not routinely separated in the present study but it was observed that var. *orbiculare* was generally more abundant than var. *polystachyum* at the sampled sites.

Sampling involved searching for galls on all the grasses present in 25 × 25 cm quadrats at predetermined intervals (normally 10 or 20 paces) along parallel transects through the main habitats at each site. Host plants and habitats on which galls were found and the abundance of each grass species were recorded. The main habitats at the sampled sites in April/May were: (i) fallow fields (rice fields left uncropped from one wet season to the next); (ii) dryland cropped fields (rice fields used to grow cassava or vegetables during the dry season); and (iii) permanent bunds and ditches. Galls found on *Paspalum* were dissected and the *Orseolia* larvae and pupae they contained were preserved in 80% alcohol. Some pupae were reared to adult in plastic beakers before preservation. Parasitoids found in the galls were reared to adult in glass vials and preserved in 80% alcohol.

Paspalum conjugatum was found at the two sites near Uyo but had no galls. *Paspalum scrobiculatum* was present at all 12 sites and occurred in at least 5% of transect quadrats at ten of them. Galls were found on this host plant at six sites: one of the four sampled near Bida, three of the six near Abakaliki and both sites near Uyo. *Paspalum scrobiculatum* was found in all three main habitats but was normally most abundant on dryland cropped fields (table 2a) which also held the highest numbers of *O. bonzii* galls per m^2 in the Abakaliki area (table 2b). Despite the fact that *P. scrobiculatum* was quite common in fallow fields, no galls were found on it in this habitat. Taking the relative area of each habitat into account, rough estimates of the average number of *O. bonzii* galls per m^2 were calculated for each site. The highest density was 10.9 galls per m^2 at one site near Abakaliki. The mean density for all 12 sites was 1.1 galls per m^2 (SE: 0.90). Galls were found on *P. scrobiculatum* var. *orbiculare* and on *P. scrobiculatum* var. *polystachyum*.

Quantitative sampling of *Paspalum* was not undertaken during the rice-cropping season but galls on *P. scrobiculatum* were generally much harder to find after rice crops had been planted, mainly because the large amounts of the host growing in the rice fields early in the wet season were destroyed when the fields were dug over in preparation for the rice crop. It therefore seems likely that *O. bonzii* population densities are highest in May and June, particularly at rainfed sites where wet season rice crops alternate with dryland crops, such as cassava and vegetables, grown in the dry season.

Table 2. Abundance of *Paspalum scrobiculatum* and numbers of galls of *Orseolia bonzii* **sp. n.** per m^2 in the main habitats at 12 sites in three *O. oryzivora* outbreak areas in Nigeria in late April/May 1994.

	Bida	Abakaliki	Uyo
Number of sites sampled	4	6	2
Agroecological zone	Moist Savannah	Transition	Humid Forest
a) Percent of quadrats with *P. scrobiculatum* (mean ± SE)			
Fallow fields	8.8 ± 4.87 (4)	22.7 ± 10.67 (5)	4.0 ± 0.4 (2)
Dryland cropped fields	17.4 ± 5.81 (3)	43.6 ± 16.30 (5)	29.2 (1)
Permanent bunds and ditches	25.2 ± 23.8 (2)	(0)	6.9 ± 5.20 (2)
b) Galls of *O. bonzii* per m^2 (mean ± SE)			
Fallow fields	0.0	0.0	0.0
Dryland cropped fields	0.0	2.93 ± 2.21	0.69
Permanent bunds and ditches	0.23 ± 0.23		0.14 ± 0.14

Figures in brackets show the number of sites at which each habitat was present.

Table 3. Parasitoids reared from galls of *Orseolia bonzii* **sp. n.** on *Paspalum scrobiculatum* and the occurrence of the same or congeneric species on *O. oryzivora*[1].

Parasitoids	Host species	
	O. bonzii	*O. oryzivora*[1]
Platygastridae		
Platygaster diplosisae Risbec	++	++
Eulophidae		
Aprostocetus nr. *procerae* (Risbec)	++	
Aprostocetus procerae (Risbec)		++
Neotrichoporoides sp.	+	
Eupelmidae		
Neanastatus nr. *cinctiventris* Girault	++	+
Eupelmus sp.	+	
Eurytomidae		
Eurytoma sp.	+	+

++, common; +, rare.
[1] Source: C.T. Williams (personal observations)

Table 4. Percentage parasitism in two collections of galls of *Orseolia bonzii* **sp. n.** on *Paspalum scrobiculatum* from Ikwo LGA, near Abakaliki, Ebonyi State, Nigeria.

	Time of collection	
	May 1994	June 1997
Number of galls	50	256
Parasitoids		
Platygaster diplosisae	24	9.4
Aprostocetus nr. *procerae*	6	6.6
Neanastatus nr. *cinctiventris*	22	4.3
Neanastatus sp. larva[1]	0	2.3
Eurytoma sp.	6	0.0
Unknown ectoparasitoid larva[1]	2	12.9

[1] *Aprostocetus* and *Eurytoma* were not separable unless reared to adult, but larvae of *Neanastatus* were distinguishable by their setae and thinner, more tapered shape.

The parasitoid fauna of *O. bonzii* sp. n.

Six hymenopterous parasitoid species were reared from galls of *O. bonzii*, three of which were morphologically identical to species reared from galls of *O. oryzivora* on *Oryza sativa* (table 3). In addition, the *Aprostocetus* species reared from *O. bonzii* was very similar to *A. procerae* (Risbec) (Hymenoptera: Eulophidae) from *O. oryzivora*. It differed mainly in having the antennal clubs whitish rather than black. The three commonest parasitoids on *O. bonzii* were *Platygaster diplosisae* Risbec (Platygastridae), *Aprostocetus* nr. *procerae* (Risbec) (Eulophidae) and *Neanastatus* nr. *cinctiventris* Girault (Eupelmidae) (tables 3 and 4).

Platygaster diplosisae and *A. procerae* are important natural biological control agents of *O. oryzivora* (Brenière, 1983; Dakouo *et al.*, 1988; Umeh & Joshi, 1993, Nacro, 1994). *Platygaster diplosisae* is a gregarious endoparasitoid which lays its eggs into the eggs or neonate larvae of *O. oryzivora* on the plant surface (Nacro, 1994). Thirty to over 50 *P. diplosisae* develop within a single host larva, kill it in its third instar and pupate inside before emerging as adults through very small circular emergence holes cut in the gall (Umeh & Joshi, 1993; Nacro, 1994). *Aprostocetus procerae*, previously known as *Aprostocetus* (=*Tetrastichus*) *pachydiplosisae* Risbec (LaSalle & Delvare, 1994), is a solitary ectoparasitoid. Feijen & Schulten (1983) found it attacking larvae and pupae of *O. oryzivora* in Malawi but in Nigeria and Burkina Faso it has only been recorded on pupae (Umeh & Joshi, 1993; Nacro, 1994).

Based on the gall dissections, five of the six parasitoids recorded from *O. bonzii* are solitary ectoparasitoids of the pupae. The exception is *P. diplosisae* which, as on *O. oryzivora*, is a gregarious endoparasitoid. *Neanastatus* nr. *cinctiventris* mainly parasitized *O. bonzii* pupae but may also attack larvae because in some dissected galls containing this parasitoid no host remains were found. Larvae and pupae of *N.* nr. *cinctiventris* were also occasionally found in galls containing the remains of *Platygaster* or *Aprostocetus*, so this species may be a facultative hyperparasitoid.

Experiment to determine whether *O. bonzii* sp. n. can develop on rice

To test whether *O. bonzii* **sp. n.** reared from galls on *Paspalum* could develop on *Oryza sativa*, the rice variety ITA 306 was sown on 30 May 1997 in two seed boxes kept in separate fine net cages, each containing about 160 plants. One cage was infested on 13 to 15 June with 197 female and 65 male *O. bonzii* less than 24 hours old and reared from galls on *P. scrobiculatum* collected near Abakaliki. The second cage was a control to determine whether any contamination with *O. oryzivora* had occurred. Both cages were kept in the shade out of doors and the plants were lightly sprayed with water every two to three hours during daylight from 15 to 22 June to maximize the survival of midge eggs and neonate larvae. All the plants were examined and dissected on 14 to 15 July to check for galls. None had any galls or *Orseolia* life-stages.

Experiments to determine whether *Platygaster* and *Aprostocetus* from galls of *O. bonzii* sp. n. can parasitize *O. oryzivora*

To test whether *P. diplosisae* and *A.* nr. *procerae* reared from galls of *O. bonzii* on *Paspalum* could parasitize *O. oryzivora*, seedboxes of rice plants (variety ITA 306) infested with *O. oryzivora* in a culture kept at the International Institute of Tropical Agriculture, Ibadan, Nigeria, were infested with one or other parasitoid species reared from galls on *P. scrobiculatum* collected near Abakaliki in June 1997. Other rice plants infested with *O. oryzivora* at the same time but not subsequently infested with the parasitoids were used as controls to check whether any accidental contamination with parasitoids had occurred. Test and control plants were kept in separate fine net cages throughout both experiments and were examined on the same dates. Seedboxes each containing 100–150 twelve-day-old rice plants were infested on 11 June with 17–30 female and three to five male *O. oryzivora* per box. They were then kept shaded and sprayed with water every two hours during daylight for the next four days to ensure high infestation. The two parasitoid species were introduced onto test plants on different dates because they attack different life-stages of *Orseolia*.

To test *Platygaster diplosisae*, which oviposits in the eggs or neonate larvae of its host, the parasitoids must be introduced onto rice plants as soon as possible after they have been infested with *O. oryzivora*. Over 300 *P. diplosisae* reared from galls on *P. scrobiculatum* were introduced into two cages of infested plants on the evenings of 13–15 June. The three-day delay was necessitated because adults of *O. oryzivora* and *P. diplosisae* are short-lived, so the plants had to be infested with *O. oryzivora* in Ibadan and then transported to Abakaliki where enough parasitized *O. bonzii* galls were available. On 17 July all the test plants were examined and dissected. They had 435 galls, none of which had been parasitized.

To test *Aprostocetus* nr. *procerae* from *O. bonzii*, which, like *A. procerae*, attacks the host pupa, 20 females and one male reared from galls on *P. scrobiculatum* were introduced into a cage of gall midge-infested rice plants on 27 June, by which time most of the *O. oryzivora* in the plants were pupae. The plants were dissected and examined for parasitoids on 21 July. They had 236 galls, of which 153 (65%) contained pupae or pupal skins of the parasitoid. In addition, many adult parasitoids were found in the cage. None of the galls on control plants were parasitized in either experiment.

Discussion

Orseolia bonzii is easily distinguished from *O. oryzivora* Harris & Gagné in the pupal stage or by examination of pupal skins, which often remain projecting from galls after the adults have emerged. Adult males of the two species are also morphologically distinguishable by microscope examination of abdominal tergites VII and VIII but separation of females on external morphological characters is not possible at present. Detailed studies of longer series of specimens may reveal differences and this possibility should be followed up because at present the inability to identify adult females if they are not associated with host plants or pupal skins limits the usefulness of light-trapping as a method for monitoring *O. oryzivora* early in the wet season. At this time of year, *O. bonzii* is likely to form a substantial proportion of the catch in some areas.

On present evidence, *O. bonzii* and *O. oryzivora* appear to have non-overlapping host plant ranges: C.T. Williams, (unpublished observations) found that *O. oryzivora* could not develop on *P. scrobiculatum*, while in the present study *O. bonzii* was unable to develop on *Oryza sativa*. More experiments are needed to check the negative result for *O. bonzii* because the test on that species did not include the experimental infestation of *P. scrobiculatum* plants to confirm that the adult *O. bonzii* used could reproduce under the test conditions. However, the infestation method employed in the test had been used successfully the previous year to infest screenhouse-grown *P. scrobiculatum* with *O. bonzii* and was routinely used to infest *O. sativa* with *O. oryzivora*. The observation that sites near Abakaliki with many galls on *P. scrobiculatum* in May still showed no or very few galls on well-grown rice crops two months later (C.T. Williams, unpublished observations) is further evidence that *O. oryzivora* and *O. bonzii* are distinct species and that the latter does not infest rice.

Paspalum scrobiculatum is a common grass in rice-growing areas in both Forest and Savannah agroecological zones (Johnson, 1997). *Orseolia bonzii* has now been collected from it at sites in Nigeria, Burkina Faso and Senegal and is probably present in many other areas. Averaged across the 12 sites sampled in the present study, galls of *O. bonzii* on *P. scrobiculatum* were more common in late April/May than those of *O. oryzivora* on wild *Oryza longistaminata* and cultivated rice. Though they reached very high levels on rice crops later in the wet season, the average density of *O. oryzivora* galls in May was only 0.4 per m^2 (C.T. Williams, unpublished observations) compared to 1.1 per m^2 for galls of *O. bonzii*. Considering only the 11 rainfed sites, where no dry season rice crops were grown, the difference was much more extreme: mean gall densities for *O. oryzivora* and *O. bonzii* at these sites were 0.006 and 1.2 per m^2 respectively. The difference in the abundance of the two species was greatest in the Abakaliki area, where no *O. oryzivora* galls were found in May 1994 and numbers in the same month were very low from 1995 to 1997 (C.T. Williams, unpublished observations). But near Bida, *O. oryzivora* galls were found at three of the four sites sampled in May and were more common on average than those of *O. bonzii*.

There appears to be considerable overlap between the parasitoid faunas of *O. bonzii* and *O. oryzivora*. Of particular importance is the finding that *Aprostocetus* nr. *procerae* reared from *O. bonzii* on *P. scrobiculatum* can readily attack and complete development on *O. oryzivora*. LaSalle & Delvare (1994) discussed what they thought to be an undescribed species near to *Aprostocetus procerae* from Benin. They observed that it differed from *A. procerae* mainly in having the antennal club mostly whitish rather than black, as well as having a couple of minor morphological differences. This agrees well with specimens treated in this paper as *A.* nr. *procerae*. In deciding whether this is actually a valid species, the evidence presented here is somewhat ambiguous. The fact that *A.* nr. *procerae* can develop on *O. oryzivora* does suggest that it may be merely a form of *A. procerae*, particularly as *A. procerae* shows considerable variation in colour (Feijen & Schulten, 1983; LaSalle & Delvare, 1994). However, the consistency of the club colour throughout individuals from different hosts could indicate that there are real differences between the forms. Further studies will be required to resolve this question.

In the test on *Platygaster diplosisae* from *O. bonzii*, none of the *O. oryzivora* galls became parasitized, suggesting that the parasitoids belong to a distinct host race which does not switch readily to *O. oryzivora*, or may even be a different species which cannot be distinguished morphologically. However, there is a possibility that the negative result was due to the three-day delay between infesting the plants with *O. oryzivora* and adding the parasitoids. Normally only one *O. oryzivora* larva can develop on the growing point of each rice tiller and at the infestation rate used there were probably many more midge eggs on the plants than there were tillers. *Orseolia oryzivora* eggs take only two to five days to hatch (Betbeder-Matibet, 1987; Bouchard *et al*., 1992). Therefore the three-day delay may have allowed all the available tillers to be infested by midge larvae which hatched early enough to avoid parasitism. If this was the case, no parasitized galls would show up at the end of the test even if some eggs had been parasitized. It is therefore worth re-testing *P. diplosisae* from *O. bonzii*, by introducing *O. oryzivora* and parasitoids onto the rice plants on the same day. An additional control treatment using *P. scrobiculatum* plants infested with *O. bonzii* should also be included, to check that the parasitoids can reproduce under the test conditions.

Platygaster diplosisae and *Aprostocetus procerae* are the two main natural biological control agents of *O. oryzivora* and can parasitize over 50% of galls on rice crops towards the end of the wet season, but they often increase too late to prevent economic damage (Dakouo *et al*., 1988; Umeh & Joshi, 1993). Given these facts and the apparent overlap in the parasitoid faunas of *O. oryzivora* and *O. bonzii*, it may be possible to use *O. bonzii* to increase *O. oryzivora* parasitoids early in the wet season and so enhance their effectiveness against the pest. The feasibility of this approach is increased by the fact that, even without any deliberate interventions to boost its numbers, *O. bonzii* appears to be much more common than *O. oryzivora* at this time of year, at least at rainfed sites in the Forest and Savannah/Forest Transition zones.

To improve the natural biological control of *O. oryzivora* in this way, methods are needed which ensure high populations of *P. scrobiculatum* and *O. bonzii* early in the wet season, and also increase the numbers of parasitoids which carry-over from *O. bonzii* to the first *O. oryzivora* galls on young rice crops. Sampling near Abakaliki suggests that improving carry-over is particularly important. In this area, parasitism levels on *O. oryzivora* were very low in October 1994 even at two sites which in May had high densities of *P. scrobiculatum* and *O. bonzii* galls with parasitoids (C.T. Williams, unpublished observations). This may have been because nearly all the *P. scrobiculatum* was on the fields themselves and so was destroyed during land preparation, well before *O. oryzivora* populations started to build up on the transplanted rice. Leaving narrow strips of land, a metre or two wide, undisturbed for a few weeks after the remaining area has been transplanted might allow enough parasitoids to persist on *O. bonzii* until *O. oryzivora* colonizes the first rice crops. At sites which have permanent bunds and ditches, it may also be possible to develop management practices which encourage more *P. scrobiculatum* to grow on them.

As human population density increases and good agricultural land becomes scarcer, more farmers are growing cassava and vegetables on their rice fields in the dry season, rather than leaving the fields fallow. This trend, which is particularly marked in the Abakaliki area, increases the feasibility of using *O. bonzii* for management of *O. oryzivora* because the dry season cultivation appears to favour *P. scrobiculatum*. Many seeds germinate on the almost bare soil after the first rains and produce a dense sward of young *P. scrobiculatum* plants in the next month or two, so that many vegetative tillers are available for *O. bonzii* to infest. On fallow fields, *P. scrobiculatum* is more thinly scattered among a denser sward of non-hosts and a greater proportion of the plants are older, with fewer vegetative tillers. This may explain why *O. bonzii* galls are less common in this habitat.

More work is needed on the ecology of *O. bonzii* and on the taxonomy and host ranges of its parasitoids, particularly *P. diplosisae*. If the results are promising, it will be worth carrying out field trials to develop practical methods for using *O. bonzii* to enhance the natural biological control of *O. oryzivora*. But to be adoptable by farmers these will have to demonstrate a clear economic benefit and take into account farmers' often severe labour, capital and land constraints.

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