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Estimation of Rice Yield Losses Due to the African Rice Gall Midge, *Orseolia oryzivora* Harris and Gagne

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Abstract

The African rice gall midge, *Orseolia oryzivora* Harris and Gagne (Diptera: Cecidomyiidae), is an important pest of rice, *Oryza sativa*, in Burkina Faso as well as other countries in West and East Africa. In spite of its importance, little is known regarding the relationship between gall midge populations and grain yield losses. To determine yield losses, the gall midge was reared in cages, and adult midges were placed on caged plants of the rice variety ITA 123 at different population levels. The seven treatments consisted of different numbers of insects infested on the plants: 0 insect pairs (noninfested check), and 1, 5, 10, 15, 20, or 25 midge pairs/cage. The loss in yield in relation to the noninfested control was highly positively correlated ($R^2 = 0.81$) with the percentage of gall midge damaged tillers. The infestation by the insect on the plants resulted in the compensatory production of tillers which developed in response to the gall midge damage, but the compensation was not sufficient to make up for the loss of yield due to the damaged tillers. Yield loss ranged from 0% in the control to 65.3% in the treatment with 25 pairs of adults. One percent of tillers damaged resulted in 2% grain yield loss.

Keywords: African rice gall midge, Burkina Faso, plant compensation, *Orseolia oryzivora*, *Oryza sativa*, rice, rice insect pest, yield loss, West Africa

1. Introduction

The African rice gall midge, *Orseolia oryzivora* Harris and Gagne, is distributed throughout West Africa (Dale, 1994) and is also found in other African countries (Anonymous, 1984). There is evidence that gall midge damage is increasing in West Africa, and serious damage has been reported in Nigeria (Ukwungwu et al., 1989) and in Tanzania (personal communication). In Burkina Faso this insect causes damage annually in all rice agroecosystems: upland, rainfed lowland, and irrigated lowland fields—but is generally most serious in lowland ecologies. Attack occurs in the vegetative stage when plants are actively tillering. The African rice gall midge produces a distinctly characteristic plant damage symptom, which is a gall that resembles an onion leaf (Dale, 1994). Size of the gall varies but is usually ca. 3 mm wide and ca. 30 cm in length. Larval feeding suppresses leaf primordial differentiation at the growing tip, which results in the elongation of the leaf sheath (Perera and Fernando, 1968). Galls appear within a week after the larvae reach the growing point. As a result of the damage, the central shoot is transformed into a gall instead of a grain-producing panicle.

In spite of the reports of damage by the gall midge in African countries, the yield losses caused by this pest are not well documented. The estimation of losses due to pests is necessary to justify research efforts for developing pest management strategies (Breniere, 1982). In Africa there have been few studies conducted on yield loss caused by insects in rice, and many reports are estimates from field studies where several insects attack simultaneously and various abiotic and other biotic constraints operate. Consequently, reports on yield loss caused by a specific pest are not always reliable (Agyen-Sampong, 1988). This paper reports on a simple method for evaluating grain yield losses due to *Orseolia oryzivora* which minimize many of the variables that occur under field conditions. The method involves the submission of one rice variety to several insect population densities under semicontrolled conditions.

2. Materials and methods

The rice variety utilized for the test was ITA 123, which has a growth cycle of seed emergence to harvest of 120 days. ITA 123 is the most commonly grown rice variety in irrigated lowland fields in the west and southwest region of Burkina Faso. The test insects used to infest the rice plants were mass-reared in wood cages outdoors using the method described by Bouchard et al. (1992).

The experimental units consisted of 28 cages measuring 110 cm in length, 90 cm in width, and 110 cm in height. A metal container measuring 96 cm in length, 56 cm in width, and 28 cm in depth was placed in each cage. The container was filled with lowland irrigated rice soil up to 18 cm depth. Rice seeds were sown in small holes in the soil at the rate of 5 seeds per hole and covered with a thin layer of soil. In each container 35 holes (hills) of seed were planted at a spacing of 10 × 10 cm (= 106 hills per hectare). Two weeks after sowing the rice hills were thinned to two seedlings per hill and fertilizer applied at the rate of 42g of N, P, K (14–23–14) per cage(= 300 kg, N, P, K/ha). Three weeks after sowing, plants in the cages were infested with newly emerged gall midge adults. The seven treatments consisted of 0 insects (check), and 1, 5, 10, 15, 20, and 25 pairs (1 male and 1 female) per cage.

All of the cages were infested with gall midge adults on the same day. Two weeks after infestation, 10 g of 46% nitrogen fertilizer was applied to each cage. The first evidence of developing galls caused by *O. oryzivora* occurred between the 25th and 30th day after infestation. The adults that emerged from the galls were collected and removed daily, until the 40th day after infestation, to prevent reinfestation of the plants and the number of galls was then counted. Tiller number and plant height was recorded at 40 days after infestation. At plant maturity, rice panicles were removed and grains harvested and cleaned. Grains were then weighed and weight corrected to a moisture content of 14%. Yield loss due to gall midge attack was determined according to the following formula of Walker (1987).

$$P(\%) = \frac{r_{\mathrm{m}} - y_{\mathrm{i}}}{r_{\mathrm{m}}} \times 100$$

where

p = grain loss or % of yield production
r_m = maximum yield potential in the absence of the pest (control)
y_i = yield of the *i*th treatment

Treatment means for all experiments were separated using the LSD of Fisher (1935).

3. Results

3. 1. Tiller number and plant height

Table 1 reports the mean number of tillers and mean plant height of the plants. The mean number of tillers varied from 21.6 ± 0.54 in the 1 pair per cage treatment to 32.49 ± 2.67 in the 25 pairs per cage treatment. The 7 treatments can be classified into two groups. The first group consists of those treatments where the mean number of tillers is less than 28.69 ± 1.99 and the second group, which consists of the last 4 treatments, produced a mean number of tillers significantly greater than the first group. Thus the treatments with the higher numbers of gall midge adults per cage also produced the most tillers.

Plant height varied little with only the 25 pair per cage treatment being significantly less than the other treatments.

Table 1. Mean number of tillers and height of rice plants (cm) as affected by the number of gall midge adult pairs (♂ and ♀) per cage[a]

Treatments	√ Tillers ± s.e.m.	√ Height (cm) ± s.e.m.
C0 = 0 pair (control)	22.06 ± 0.23 (a)	8.09 ± 0.05 (a)
C1 = 1 pair	21.56 ± 0.54 (a)	8.08 ± 0.05 (a)
C5 = 5 pair	21.94 ± 1.36 (a)	8.04 ± 0.01 (a)
C10 = 10 pair	28.69 ± 1.99 (b)	6.25 ± 0.06 (a)
C15 = 15 pair	29.91 ± 1.26 (b)	8.10 ± 0.05 (a)
C20 = 20 pair	29.26 ± 1.08 (b)	8.26 ± 0.01 (a)
C25 = 25 pair	32.49 ± 2.67 (b)	6.05 ± 0.23 (b)
F(6,27) = 3.56	9.02	61.31
Probability	0.0001	0.0001

a. Mean comparisons were made according to the least significant difference method of Fisher (1935). Means followed by a common letter are not significantly different at the probability level indicated.

3.2. Damaged tillers and undamaged, panicle-bearing tillers

Percentage of gall-infested tillers ranged from 0% in the uninfested control to 45.6% with 25 pairs of adults per cage (Table 2). The percentage of infested tillers increased in proportion to the level of insect infestation. One pair of adults per cage caused 12.6% damaged tillers whereas 10 pairs caused 32.5% damage, the increase being 3-fold. The relationship between the square root of the number of tillers produced and the number of galls counted indicated a linear-type relationship between the two variables ($R = 0.80$) (Figure 1(A)). The highly significant correlation indicated that the number of tillers produced is proportional to that of the gall midge–damaged tillers.

Table 2. Percentage (± s.e.m.) of gall-infested tillers and undamaged tillers bearing panicles as affected by the number of gall midge adult pairs (♂ and ♀) per cage[a]

Treatments	Arcsin √(% galls) ± s.e.m.	Arcsin √(% panicles) ± s.e.m.
C0 = 0 pair (control)	0 (a)	51.81 ± 0.68 (a)
C1 = 1 pair	12.64 ± 1.14 (b)	49.47 ± 2.30 (a)
C5 = 5 pair	31.93 ± 2.24 (c)	47.87 ± 6.69 (a)
C10 = 10 pair	32.52 ± 2.67 (c)	35.89 ± 4.67 (b)
C15 = 15 pair	35.77 ± 1.61 (cd)	33.64 ± 2.75 (b)
C20 = 20 pair	39.41 ± 1.73 (d)	27.38 ± 0.54 (b)
C25 = 25 pair	45.36 ± 2.52 (e)	14.39 ± 0.94 (c)
F(6,27) = 3.56	70.94	15.93
Probability	0.0001	0.0001

a. Mean comparisons were made according to the least significant difference method of Fisher (1935). Means followed by a common letter are not significantly different at the probability level indicated.

The percent of tillers bearing panicles expresses the rate of tillers which escaped damage by the gall midge (Table 2). These figures describe proportionally the level of gall midge infestation with the control registering 52% tillers bearing panicles and the 25 pair of adults treatment having only 14% panicle-bearing tillers. This relationship is illustrated in Figure 1(B) where the percent of tillers bearing panicles is significantly and negatively correlated with the percentage of gall-infested tillers ($R = 0.77$).

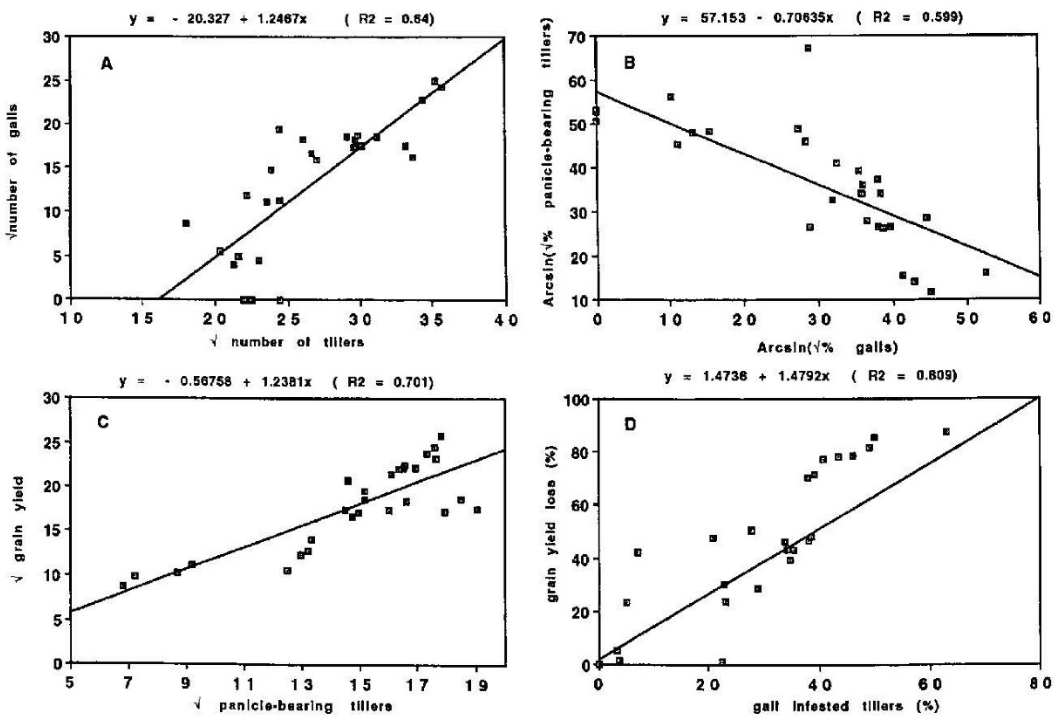

Figure 1. (A) Regression of the number of galls (y) on the number of tillers (x), (B) regression of the percent of panicle-bearing tillers (y) on the percent of gall-infested tillers (x), (C) regression of the rice grain yield (y) on the number of panicle-bearing tillers (x), (D) regression of the percent rice grain yield loss (y) on the percent of gall-infested tillers (x).

3.3. Grain yield and yield loss

Grain yield was positively correlated ($R = 0.83$) with the number of tillers bearing panicles (Figure 1(C)). Grain yields varied from 24 in the check to 10 g in the treatment with 25 pairs of adult midges per cage (Table 3). There were no statistically significant differences in the check and 1 pair, 1 and 5 pair, 5 and 10 pair, and the 10, 15, and 20 pair treatments.

Table 3. Rice grain yield and percent grain yield loss of rice plants as affected by the number of gall midge adult pairs (♂ and ♀) per cage[a]

Treatments	√(yield) ± s.e.m.	Arcsin √(% loss)
C0 = 0 pair (control)	24.10 ± 0.74 (a)	0 (a)
C1 = 1 pair	21.59 ± 0.74 (ab)	22.44 ± 7.55 (b)
C5 = 5 pair	20.70 ± 1.15 (bc)	27.57 ± 7.86 (bc)
C10 = 10 pair	18.22 ± 0.35 (cd)	40.50 ± 2.44 (bc)
C15 = 15 pair	16.10 ± 1.25 (d)	47.07 ± 4.95 (c)
C20 = 20 pair	13.52 ± 1.30 (d)	55.07 ± 4.97 (cd)
C25 = 25 pair	10.01 ± 0.51 (e)	65.31 ± 1.77 (d)
F(6,27) = 3.56	27.62	19.19
Probability	0.0001	0.0001

a. Mean comparisons were made according to the least significant difference method of Fisher (1935). Means followed by a common letter are not significantly different at the probability level indicated.

There was a linear relation ($R = 0.90$) between the percent yield loss and percent of gall midge–damaged tillers (Figure 1(D)). Yield loss ranged from 22% in the one pair treatment to 65% in the 25 pair treatment (Table 3). In comparing the 1 and 5 pair treatment a 5-fold increase in number of pairs of gall midge adults only increased yield loss by 6%, from 22 to 28%, and a 25-fold increase in number of midge pairs increased yield loss by 3 times (22 to 65%).

4. Discussion and conclusions

The presence of the gall midge larva in the rice plant results in increased tillering of the plants. In this study the observations on tiller and gall numbers were made at 40 days after infestation of the adults, which is when the gall midge had completed its life cycle in the plant. It can thus be concluded that the production of the compensatory tillers occurs during the time that the insect is still in the gall. These results are in agreement with those reported on the Asian rice gall midge, *Orseolia oryzae* (Wood-Mason) (Hidaka, 1974a, 1974b). Our results also show that only a severe larval infestation or high density of midge adults causes a reduction in plant height.

Grain yield was not significantly reduced until the population of gall midge pairs per cage reached 5. Only one pair of adults per cage resulted in 13% of the tillers having galls and a yield loss of 22% or 1% galls causing a 2% loss. However, at higher midge populations, the relationship between % galls and% yield loss was less than a 1:2 ratio varying from 1:0.9 in the 5 pairs treatment to 1:1.4 in the 20 and 25 pairs treatments. Based on the regression line in Figure 1(C) it can be predicted that a 77% tiller infestation will cause a yield loss of 100%. The difference between the percentage of gall-infested tillers and the yield loss can be explained by the fact that the compensatory tillers produced in reaction to the gall midge infestation often do not produce grain-bearing panicles. Ukwungwu et al. (1989) reported similar results in studies conducted in farmers' fields where an 80%

level of gall midge–infested tillers caused a yield loss of 100%. Calling et al. (1987), however, reported that in deepwater rice in Bangladesh, for every 2% tillers damaged by the lepidopterous stem-borer, *Scirpophaga incertulas* (Walker), only a 1% yield loss occurred. It is evident that the nature and importance of the yield loss is dependent on a complex of reactions between the plant and the pest. Thus, the physiological state of the plant, its phenological stage at time of attack, the part of the plant attacked, soil fertility, the presence of other biotic and abiotic stresses (Heinrichs, 1988) and the species of the pest insect all can be factors determining the yield loss caused by the pest.

In spite of the fact that this study was conducted under cage conditions, the relationship between percent tiller attack and percent yield loss is similar to that reported in field studies by Ukwungwu et al. (1989). Gall midge infestation in lowland rice in Burkina Faso often exceeds 20% infested tillers (Dakouo et al., 1988). Based on the results of this study, such infestation levels result in economic yield losses which resource-poor farmers can ill afford. However field studies should be conducted in Burkina Faso to verify the relationship between number of gall midge adults per unit area, percent tiller attack, and percent yield loss.

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