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Twenty-one rice cultivars were evaluated to determine the difference between populations of Sogatodes oryzicola (Muir) (Homoptera: Delphacidae) in Costa Rica and Colombia. Survival, mortality and population development of S. oryzicola on five selected cultivars was used to determine levels of plant resistance. The importance and potential of the parasitoid-predator Haplogonatopus sp. (Hymenoptera: Dryinidae) on S. oryzicola also was studied.

Minor differences were observed among cultivars: Inti, CICA 4 and IR 8, which were resistant in Colombia were intermediate in Costa Rica. Cultivars rated intermediate in Colombia, were rated the same in Costa Rica, except CR-1113 which was susceptible in two Costa Rica colonies. Susceptible ratings in cultivars coincided in both countries, except Tadukan which was resistant to the Northern Atlantic colony and intermediate in the overall rating in Costa Rica. Seedling mortality in

intermediate and resistant cultivars was higher in Colombia. The results indicated that there were no biotypes of S. oryzicola within or between populations in Costa Rica and Colombia. Results suggest that CICA 4 has an antibiotic effect on S. oryzicola : more nymphs died, fewer nymphs were produced and fewer adults developed than on the other cultivars. Longevity of S. oryzicola adults was shorter when they fed on CICA 4, IR 8, CR-1113 or Ciwini than on the susceptible check Bluebonnet 50. Low levels of resistance could explain why rice fields planted with CR-1113 often become infested with S. oryzicola.

Haplogonatopus sp. was a parasitoid and predator on S. oryzicola . Percent parasitism ranged from 1.7 to 12.2 in unsprayed plots, and from 1.4 to 5.0 in the sprayed plot. In the laboratory, dryinid females produced ca. 118 offspring. The complete life-cycle of the dryinid was 26.7 $\pm$ 0.7 days at a mean of 27 C. No dryinid males were found, and females lived 6.8 $\pm$ 0.8 days. The initial satiation capacity of females was ca. six to seven nymphs with a daily consumption of 15.4 $\pm$ 0.5 nymphs. S. oryzicola adults were not parasitized or preyed-upon. Second and third instar nymphs were preferred. Winged adults of S. oryzicola (parasitized as fourth and fifth instar nymphs) bearing the parasitoid could be the way this dryinid disperses.

Studies on Resistance of Rice to *Sogatodes oryzicola* (Muir) and a Parasitoid, *Haplogonatopus* sp., in Costa Rica.

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Studies on Resistance of Rice to *Sogatodes oryzicola* (Muir) and a Parasitoid, *Haplogonatopus* sp., in Costa Rica.

INTRODUCTION

Rice is a staple food in Costa Rica with a mean annual consumption of ca. 48 Kg per capita. In Costa Rica, nearly 85,000 ha of rice are grown mainly in the low lands which are influenced by the Pacific and Atlantic Oceans. Rice is planted at different times depending on the region. About 85 percent of the fields are planted with the cultivar CR-1113 which has been grown commmercially in Costa Rica for ten years.

Pesticides are the major method of controlling weeds, diseases, and insects, despite the efforts to select cultivars that tolerate certain pests. Changes in pathogen races, such as rice blast disease, *Pyricularia oryzae* (Cav.), frequently reduce plant resistance to diseases. There also exists the possibility that physiological changes in insect populations could lower the tolerance of plant cultivars to insect damage. The use of pesticides not only causes detrimental effects to the environment but also increases the price of the commodity to the consumer, and since pesticides are imported, their cost contributes to Costa Rica's unbalanced economy.

The planthopper, *Sogatodes oryzicola* (Muir), is an

important insect pest of rice (Oryza sativa L.) in the Latin American countries that border the Caribbean Sea. It caused appreciable losses in rice production from 1956 until 1968, both as a vector of hoja blanca virus (HBV) and through direct feeding injury. Losses were largely eliminated after 1968 with the release of the semi-dwarf rice cultivars from the Philippines and the CICA cultivars from Colombia which replaced the susceptible cultivars from the United States of America. Thus, resistant or tolerant cultivars have been the most effective method for preventing insect feeding injury and the spread of HBV. Resistant and tolerant cultivars are compatible with other control tactics such as biocontrol and chemical control (Panda and Heinrichs 1983). Natural enemies interact with tolerant or resistant cultivars to reduce S. oryzicola populations, thus minimizing the probabilities of pest outbreaks and/or HBV epiphytotics.

Isolated reports from Cuba, Costa Rica, Panama and Colombia indicate that population densities of S. oryzicola may be again reaching the pest status on rice. These reports suggest that physiological changes or specialization of the planthopper is developing in these countries.

My study was designed to compare the damage caused by four geographically different colonies of S. oryzicola to 21 rice cultivars with known damage reactions caused by this insect in Colombia. The major objective was to

determine whether the populations of S. oryzicola in Costa Rica were the same or were distinct biotypes, and different from the populations in Colombia. Survival, mortality and development of S. oryzicola on selected cultivars, including CR-1113, were studied to more accurately determine levels of plant resistance and to determine if insect population increase on farms was the result of inadequate cultivar resistance.

A second objective of the study was to evaluate the importance and the potential of the parasitoid-predator Haplogonatopus sp., in regulating population densities of S. oryzicola.

LITERATURE REVIEW

Sogatodes oryzicola is known as the rice delphacid and the rice planthopper (Ling 1972), but several other regional common names are used in the Latin American countries. In general, this species is found in the Caribbean Islands, Central America, Mexico, North and Central South America and occasionally in the United States of America (Pathak 1968, Grist and Lever 1969, Everett 1969). Oryza sativa L. is the major host plant, but S. oryzicola may survive for short periods on certain wild grasses, particularly in the genus Echinochloa and Sacchiolepsis (Renteria 1960, Cordero and Newsom 1962, Grist and Lever 1969).

S. oryzicola has distinct macropterous and brachypterous forms; the latter are commonly females. Infestations in the field start with macropterous immigrants. The nymphs and females feed on the basal parts of the plant, whereas the males remain in the upper portions (Everett 1969).

The females lacerate the midrib of the leaf blade and lay egg-masses in the parenchyma tissues (Rentería 1960, Grist and Lever 1969). The number of eggs in each cluster varies, but is usually in multiples of seven because of the fourteen ovarioles in each of the two ovaries of the female (McGuire et al. 1960, McMillian 1963). Mated females begin ovipositing on the third to fifth day after reaching

maturity, and lay an average of ten eggs per day with an average total production of 161 eggs (McMillian 1963). Virgin females do not deposit eggs for about one week and then do so in an erratic pattern (Everett 1969). Rentería (1960) reported an average incubation period of 9.4 days under greenhouse conditions, and McGuire et al. (1960) found an average incubation period of eight days at 26.7 C.

S. oryzicola has five nymphal instars. Each stadium lasts for three to seven days (Everett 1969) depending on the temperature and humidity. McGuire et al. (1960) found that the average duration of each instar was three days at 26.7 C. The development threshold and the thermal constant for the nymphal stages were 8.2 C and 257.6 heat units, respectively (McGuire et al. 1960). A morphological description of each of the nymphal stages was reported by Everett (1969).

Males and females of S. oryzicola differ in their life span. Rentería (1960) determined a life span of 13.8 days for males and 43.9 days for virgin females. Elias et al. (1962) found a life span of 20 to 40 days for females during the summer. Beltrán (1967) reported an adult stadium of 14 days for males and 40 days for females. Jennings and Pineda (1970b) determined a mean range for female longevity of 13.4 to 14.3 days on the cultivar Bluebonnet 50.

S. oryzicola damages rice by direct feeding, and as a vector of hoja blanca virus (HBV). Affected plants show an

initial withering of the leaves and stems. The presence of "hopperburn" is common in maturing rice fields and yield losses in susceptible cultivars can be devastating. Honeydew excreted by the insect encourages sooty molds which grow copiously, often covering the entire plant. Severely affected plants eventually die (DeLong 1965, Jennings and Pineda 1971a). From personal observations, the insect also accounts for high levels of floret-sterility and spotted grain when infestations occur close to or during the heading period even when populations are not high enough to cause characteristic leaf-injury symptoms.

Slight to nearly complete grain losses in rice fields infected with HBV have been observed in some South American countries (Jennings 1963). Hoja blanca virus has been reported in all the American countries where its vectors, S. oryzicola and Sogatodes cubanus (Craw.), are present (Atkins 1974). The symptoms and injury from the disease were described by Atkins and Adair (1957), and reviewed by Lobatón and Martínez (1976). Gálvez (1969) placed the symptoms of hoja blanca intc the yellow-type group.

Cultivar resistance to hoja blanca virus was reported before resistance to its vector, S. oryzicola (Cralley 1957, Atkins and Adair 1957). Virus transmission and virus-vector-host relationships have been studied by Rentería (1960), Hendrick et al. (1965), Gálvez (1968 and 1969), Jennings and Pineda (1971b), and Lobatón and

Martínez (1976). Beachell and Jennings (1961) indicated that resistance to HBV was conditioned by a single dominant gene, but minor genes could influence resistance when certain cultivar combinations occurred. Resistance to HBV was not associated with resistance to the vector (Jennings and Pineda 1970a).

Rice plants resistant to S. oryzicola affect all stages of the life cycle of the insect; they reduce the number of eggs deposited and the number of nymphs which hatch, lower nymphal survival, prolong the nymphal development, and reduce adult longevity (Jennings and Pineda 1970b). The specific mechanism(s) of resistance to S. oryzicola have not been determined. Jennings and Pineda (1970b) observed that about equal numbers of caged insects fed on susceptible and resistant cultivars, suggesting that nonpreference is not important. The mechanisms of resistance to the brown planthopper, Nilaparvata lugens (Stäl.), and the whitebacked planthopper, Sogatella furcifera (Hovarth) have been studied in detail at the International Rice Research Institute (IRRI) 1975 to 1978), Sögawa and Pathak 1970). They reported that both nonpreference and antibiosis mechanisms are involved, acting together or separately depending on the source(s) of resistance. Resistance to the brown planthopper seems to be primarily of a biochemical nature, and it is monogenic in most of the cultivars studied (IRRI 1978). Resistance to S. oryzicola in cultivar IR 8 was found to be controlled

by a single recessive gene, whereas a dominant gene was found to control resistance in cultivar H-5 (CIAT 1978). However, observations from segregating populations suggest that a combination of major and minor genes might be involved (Dr. P. R. Jennings 1980, personal communication).

Fifteen-day old rice seedlings caged with a large number of virus-free S. oryzicola are used in the screening program at Centro Internacional de Agricultura Tropical (CIAT). The cultivars Mudgo and Bluebonnet 50 serve as resistant and susceptible checks, respectively. In a survey of 534 rice cultivars randomly selected from the World Collection from IRRI, Jennings and Pineda (1970a) found that no cultivars were more resistant or susceptible than Mudgo and Bluebonnet 50. The new CICA cultivars were nearly as resistant as Mudgo. The condition of either resistance or susceptibility was maitained in the plants through all their growing stages; the only noticeable difference was that S. oryzicola required more time to kill older plants of the susceptible cultivars. The International Collaborative Project on Brown Planthopper Resistance (IRRI 1982), when evaluating for resistance to the brown planthopper, found that some cultivars were susceptible in the greenhouse during the seedling stage but were resistant as older plants in the field. Of the greenhouse methods used to test the degree of field resistance to the brown planthopper, population growth was the most reliable.

Thus far, the brown planthopper and the green rice leafhopper, Nephotettix virescens (Distant), are the only confirmed rice-attacking homopterans that have developed biotypes in response to pressure from resistant rice cultivars. Cultivar IR 26, a brown planthopper resistant cultivar named by IRRI in 1973, was reported to be resistant in the Philippines but susceptible in India during the same period. Three years later, IR 26 also became susceptible in the Philippines because of the development of a brown planthopper biotype. The same sequence of biotype development occurred in Indonesia and Vietnam (Seshu and Kauffman 1980). Different ratings of some cultivars tested for the International Rice Brown Planthopper Nursery in India indicated the existence of different biotypes; the population at Pantnagar and nearby areas was geographically distinct from the population in Southern India. The Pantnagar biotype destroyed all cultivars with known resistance genes (Verma et al. 1979, Pathak and Verma 1980). Reddy and Kalode (1981) concluded that the susceptible reaction in masscreening tests of resistant cultivars to different biotypes and donors, such as cultivars Mudgo and ASD 7, further confirmed the likelihood that different biotypes occurred in the Hyderabad (India) area. Seshu and Kauffman (1980) pointed out that, although there was a major distinction between brown planthopper populations in East and Southeast Asia and those in South Asia, biotypic differences of a lower

order existed among the common insect populations in different countries within East and Southeast Asia. Wu et al. (1981) found only brown planthopper biotype 1 when they evaluated twelve rice cultivars with different resistance genes to brown planthoppers collected from ten provinces in China.

Several observations suggest the possibility of physiological specialization of S. oryzicola . In 1974, there were two reports of problems with cultivar IR 8 in Colombia (CIAT 1975). In one report, severe damage by HBV and direct feeding of S. oryzicola was observed. None of the insects collected were found to be from a new biotype when they were tested among cultivars of known resistance ratings. It was suspected that the damaged field was planted with a susceptible reselection of cultivar IR 8.

In Cuba, there have been recent reports of susceptibility in rice cultivars known to be resistant to S. oryzicola in Colombia. These reports were from tests with caged S. oryzicola populations where a new biotype may have developed (Dr. G. Gálvez and Dr. P. R. Jennings 1979, personal communication). In Colombia, colonies of S. oryzicola in cages have been observed to change their feeding severity as evidenced by injury reactions on tested cultivars. For this reason, caged colonies are renewed annually with field collected insects.

Several contradictions of S. oryzicola resistance in rice cultivars have been observed in Costa Rica. Field

evaluations of promising rice cultivars carried out in 1973 by the Entomology Department, Ministry of Agriculture and Husbandry (1974) indicated that the cultivars CR-1113 and CICA 4 had comparatively fewer S. oryzicola in the Dry Pacific and Southern Atlantic areas. However, cultivar CICA 4 had a higher population of S. oryzicola than CR-1113 in the South Pacific. In some commercial fields of CICA 4 located in the South Pacific, high populations of S. oryzicola were observed, but whether or not the populations would have caused damage was not determined because the fields were sprayed with insecticide. After 1975, S. oryzicola gradually became a problem on CR-1113 and later on CR-5272; both cultivars showed intermediate reactions in standard screening tests in Colombia. Cultivar CR-1113 presently occupies about 85 to 90% of the rice grown in Costa Rica, and even though high populations of S. oryzicola occur in some areas in some seasons HBV is rarely observed.

In the Boyano area of Panama, high populations of S. oryzicola were observed on the resistant cultivar CICA 7 and on the less resistant cultivars Damaris, Nilo 2 and CR-1113 (Dr. R. Lasso 1980, written communication). In some cases, about 600 insects per sweep-net sample were collected, and losses of 83% were estimated in those fields where chemical control failed. No symptoms of HBV were observed. Specimens from the Boyano area were identified as S. oryzicola and S. cubanus ; however, the proportion of

each species in the sample was not determined. It is known that S. cubanus does not survive well on rice, but prefers and thrives on species of Echinochloa which are common weeds in rice fields (Gálvez et al. 1961). The population of S. cubanus was estimated by Gálvez (1967) to be about ten percent in rice and about 96 percent in Echinochloa , when compared to the abundance of S. oryzicola .

The natural enemies and their relationships with S. oryzicola have not been well-studied. There are isolated reports of several parasitoids and predators that might be important in regulating populations of this pest. McGuire et al. (1960) found two species of coccinelids, Coleomegilla maculata cubensis Csy. and Cycloneda sanguinea limbifer Csy. in rice fields in Cuba. A mirid, Tytthus sp., a species of Mymaridae, Anagrus sp. and two species of Dryinidae also were found in Cuba. In Costa Rica, C. maculata and C. sanguinea have been recorded (files of the Ministerio de Agricultura y Ganadería, Costa Rica). Elias et al. (1962) reported a species of Strepsiptera, Sogatelenchus mexicanus Pierce, predatory mites (Leptus sp.: Erythracidae), Empidae flies and predatory spiders, associated with S. oryzicola in rice fields in Mexico. Species of Dryinidae parasitizing S. oryzicola have been reported from Mexico (Elias et al. 1962), Panama (Gordon 1981), Cuba (McGuire et al. 1960, and Colombia (Castaño and Pineda 1982).

The importance of the family Dryinidae as

parasitoids/predators on populations of S. oryzicola has not been well-studied. The only report was by Gordon (1981) who found an average of 5.98% parasitism of S. oryzicola in a rice field in Panama.

The percentage of parasitism by Dryinidae on the brown planthopper (N. lugens) has been found to be rather low. Manjuntah (1979) found an average of 7.8% parasitism by H orientalis Roh. in India. Rao et al. (1981) found that parasitism of N. lugens by a species of Haplogonatopus ranged from 1 to 5 percent. They concluded that because of such low parasitism they would not consider this parasitoid as an effective natural enemy of N. lugens , but it could supplement other parasitoids. DeBach (1974) reported similar conclusions for Haplogonatopus vitiensis Perkins and Pseudogonatopus hospes Perkins in connection with biological control of the sugar cane leafhopper, Perkinsiella saccharicida Kirkaldy, in Hawaii. In discussing the value of some dryinids in reducing pest populations, Clausen (1940) reported that reduction by parasitism is greatly enhanced by the predaceous habits of adult dryinids and suggested that greater mortality occurs by adult predation than by parasitism. Barrion et al. (1981) found four species of Dryinidae in the Philippines and reported that adult dryinid predation needs more study.

Studies on the taxonomy of Dryinidae have been reported by Perkins (1905, 1907, 1912), Richards (1953), Freytag (1977) and Olmi (1979). The general biology and

habits of the Dryinidae have been reported by Clausen (1940), Waloff (1974) and Panomarenko (1975).

MATERIALS AND METHODS

Evaluation of Rice Resistance to Leaf-feeding Injury

Studies were conducted in Costa Rica at the Experimental Station "Enrique Jiménez Núñez" located in Guanacaste Province at a latitude of 10° 20' North and a longitude 85° 09' West. The climate features a dry period from December through April and a rainy season from May through November. The mean temperature is about 27 C during the rainy season and 28 C during the dry period. The relative humidity ranges from about 72% to 90% during the dry and the rainy seasons, respectively.

In Costa Rica, rice is grown under upland conditions during the rainy season. Ecological conditions throughout the country permit rice cultivation in four distinct areas: Dry Pacific (including Guanacaste), South Pacific (including Middle Pacific), Northern Atlantic (Upala), and Southern Atlantic. Three hundred or more S. oryzicola nymphs and adults were collected from each geographic area and brought to the experiment station inside transfer cages. Each cage was a 5 cm x 45 cm cylindrical tube made of cellulose butyrate. One susceptible Bluebonnet 50 rice plant was grown in each cage in a 10 cm diameter pot. One end was covered with nylon mesh fastened with rubber bands. After proper identification, insects collected from each

geographic area were transferred to rearing/evaluation cages and separated into four colonies. The rearing/evaluation cage was a wooden frame 1.8 m long, 1.3 m wide and 1.0 m high. The top and lateral sides were covered with nylon cloth. The front and back sides each had a 70 cm glass door in the middle, and the remaining area was covered with transparent plastic. The four cages were placed in a cement enclosure 20 cm deep and watered from below. Cages were protected from rainfall and direct sun by placing a roof made of transparent plastic painted light green. Insects inside the cages were provided with one-month old Bluebonnet 50 plants grown in 15.5 cm diameter and 12 cm high pots. Withered plants were replaced periodically.

To compare damage on rice cultivars grown in Costa Rica with those grown in Colombia, a set of 21 rice cultivars was tested in 1979 with the S. oryzicola colony kept at CIAT, Colombia. Table 1 shows the cultivars that were evaluated, the corresponding insect leaf damage ratings and the percent dead plants obtained after three experiments at CIAT. The cultivars evaluated included commercial cultivars as well as lines used in crosses in the CIAT breeding program.

In my study, seeds of the same cultivars were planted in 10 cm diameter and 14 cm high pots, and thinned to ten plants per pot five days after germination. Fifteen days after planting, seedlings were introduced into the

rearing/evaluation cage, previously emptied of the plants used to maintain the S. oryzicola colony. A colony was ready for testing when there was at least fifteen nymphs per seedling to be evaluated. Nine pots containing ten seedlings of each of the 21 cultivars were challenged with each of the four S. oryzicola colonies. Each pot represented one replicate. Three replicates of each cultivar were evaluated to give nine replications on the following dates:

Colony	Entering date	Evaluation date
Dry Pacific	06-30-1981	07-08-1981
	06-30-1981	07-08-1981
	10-28-1982	11-08-1982
Southern Pacific	05-07-1982	05-17-1982
	07-09-1982	07-18-1982
	08-13-1982	08-23-1982
Northern Atlantic	09-02-1982	09-10-1982
	10-01-1982	10-10-1982
	11-23-1982	12-02-1982
Southern Atlantic	03-11-1982	03-19-1982
	03-19-1982	03-29-1982
	04-15-1982	04-25-1982

Reactions of cultivars to S. oryzicola feeding were rated when susceptible Bluebonnet 50 seedlings were 90 to 100 percent dead, and not over 12 days after introducing the cultivars into the rearing/evaluation cage. Surviving plants of each cultivar were rated using a 5-unit scale (Jennings and Pineda 1970a):

1) No visible damage or a faint discoloration of the leaf tips.
2) Slight orange color on the leaf borders and tips.
3) The majority of the leaves heavily discolored. Seedlings slightly stunted with initial symptoms of wilting.
4) All leaves totally discolored, many dry leaves and pronounced plant stunting.
5) Plants near death.

Ratings of 1.0 to 2.0 indicated resistance; 2.5 to 3.5 indicated an intermediate reaction; and ratings of 4.0 to 5.0 indicated susceptibility. The number of dead plants also was recorded to complement the ratings.

Analysis of variance of data was used to determine differences among cultivars, regions and evaluation dates.

Population Development on Selected Cultivars

The cultivars, selected for these studies included: IR 8 and CICA 4 rated as resistant, CR-1113 and Ciwini rated intermediate, and Bluebonnet 50 rated susceptible (resistance rating based on evaluations at CIAT). The five cultivars evaluated were commercial cultivars grown in Costa Rica.

First trial (June-July, 1981)

Four pairs of newly emerged adults, one from each colony, were caged on a one-month old plant of each of the selected cultivars planted in pots 19.5 cm diameter and 21 cm high. Cages were made from screen wrapped with transparent plastic cloth. To allow air circulation, three 10 cm^2 holes were cut in the cage and covered with fine-mesh nylon cloth. Caged plants were placed in trays provided with water and held at a mean temperature of 28 C. Fifteen days after infestation, the nymphs were shaken off the plants onto a black screen and counted. Each treatment was replicated five times. Analysis of variance and mean separation by Duncan's Multiple Range Test were used to analyze the data.

Second trial (March-April, 1982)

Two pairs of newly emerged adults from each colony were separately caged on a 22-day old plant of each selected cultivar planted in a pot 14 cm diameter and 18 cm high. Cages were made of rigid cellophane 9 cm diameter and 38 cm high. The tops of the cages were covered with fine-mesh nylon cloth fastened with rubber bands. Cages were held at a mean temperature of 28 C. As soon as nymphs appeared, adults were removed from the cages with an aspirator, and plants were beaten gently so nymphs would

fall onto a black screen where they were counted and then discarded. After counting the nymphs, the cages were set up again and the surviving adults were reintroduced. Counts were made periodically until no more nymphs appeared. Analysis of variance and mean separation by Duncan's Multiple Range Test were conducted to analyze differences among cultivars and regions.

Adult survival was checked 2,4,8,14,18,20 and 25 days after caging, and the cumulative percent mortality on each cultivar was recorded.

Nymph mortality and adult development

One colony of S. oryzicola was initiated with adults from each of the four geographic regions. One hundred second instar nymphs were caged on 25-day old plants (20 nymphs per cage) of the selected cultivars. Dead nymphs were discarded from the experiment during the first 24 hours, as were plants that withered during the experiment. Some of the adults that emerged were placed on new plants of the same cultivars to obtain another generation which was used to initiate a second experiment. Nymphal death and adult emergence was recorded from each experiment.

Statistical tests (X^2 test, the Wilcoxon Rank Sum test, F-test for equal population variances, analysis of variance, and Z-test) were conducted to analyze data from each experiment and between experiments.

Studies on the Dryinid Parasitoid-predator

Samples of adult dryinid females and S. oryzicola nymphs and adults showing symptoms of parasitism were sent to Oregon State University. The parasitoid was identified to belong to the genus Haplogonatopus (Hymenoptera: Dryinidae) (Dr. R. Berry 1981, personal communication). Specimens of the parasitoid were also sent to Italy where it was identified as a new species in the genus Haplogonatopus by Dr. Massimo Olmi (1983), Universita Degli Studi Della Tuscia, Istituto Di Difesa Delle Plante, Viterbo (written commmunication). A description and name for the new species has not been published.

Host-dryinid abundance

One insecticide free rice plot located in the Dry Pacific area and two plots located in the Northern Atlantic (Upala) area, one of which was sprayed with methamidophos (O, S-Dimethyl phosphoramidothioate) insecticide, were used to study the percent parasitism by Haplogonatopus sp. on S. oryzicola . Abundance of S. oryzicola was determined by taking eighteen 4 sweep-net (38 cm diameter) samples at random on three different dates from the Northern Atlantic sprayed plot, and on five different dates from the Dry Pacific untreated plot. Seven, 4 sweep-net samples were

taken at random from the Northern Atlantic untreated plot on six different dates. In order to determine the percentage of parasitism, live adults and nymphs of S. oryzicola were captured, caged and maintained in the laboratory to allow parasite development (Chandra 1980). Ten days after collection, insects were killed and the total number of parasitized and nonparasitized individuals was counted. Insects were maintained in the laboratory in plastic cylindrical cages 16 cm diameter and 20 cm high (Figure 1). Three 2.5 cm diameter holes were cut in the cage and covered with fine-mesh nylon cloth for air circulation. An additional 3.5 cm diameter hole was made in the cage for inserting an aspirator. This hole was plugged with cotton. The center of the lid was cut out and replaced with a piece of nylon cloth. A 3 cm diameter hole was cut out of the bottom of the cage so it could be placed over a pot (18 cm diameter, 20 cm high) containing three to four young rice plants. The bottom of the cage was covered with moistened filter paper to maintain adequate humidity inside the cage.

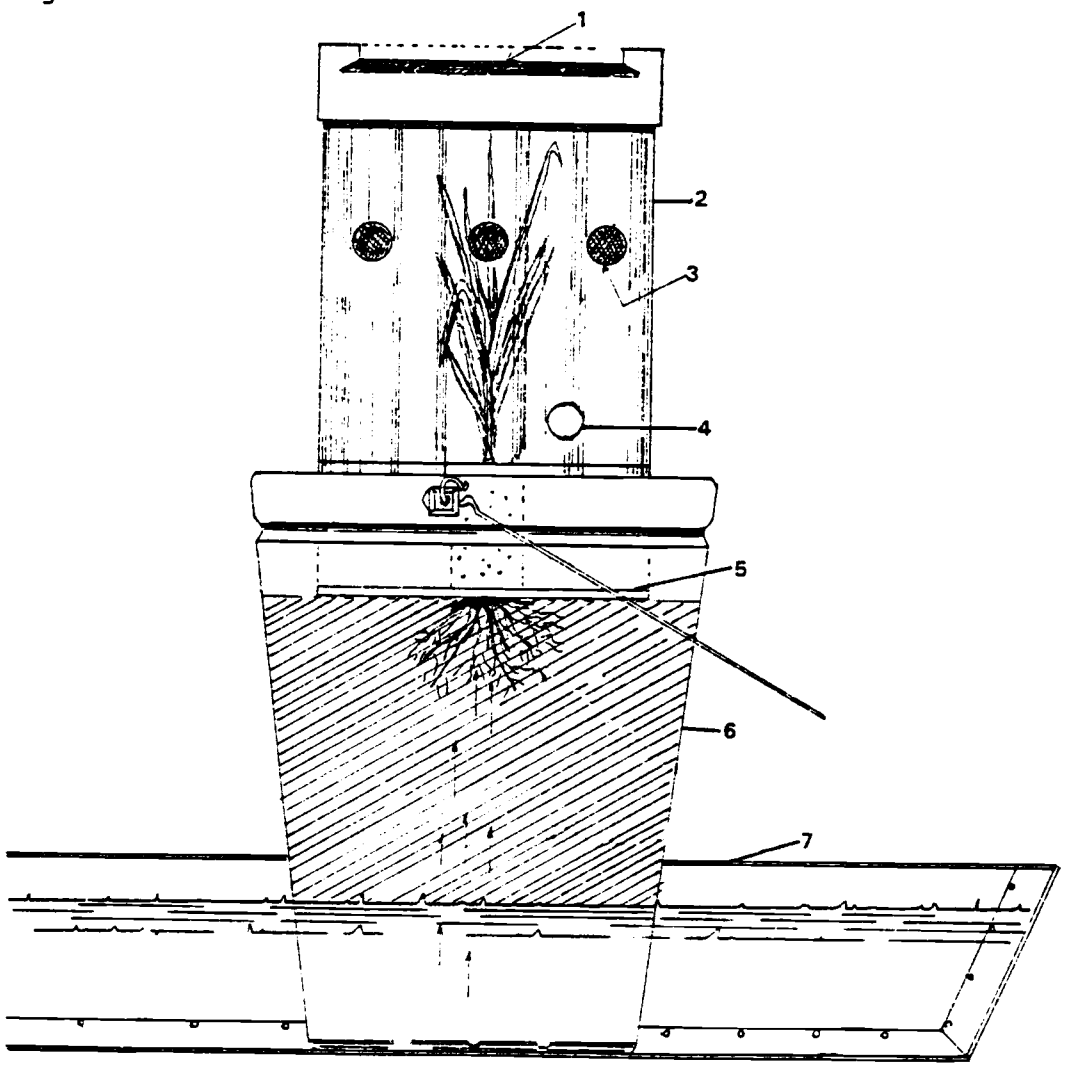
Description of plots sampled

A. Northern Atlantic insecticide-sprayed plot (NAISP).

A plot ca. 4000 m^2 heavily infested with S. oryzicola was selected in a farmer's rice field (cv. CR-1113). One

Figure 1. Cage used for rearing Haplogonatopus sp. in the laboratory. 1. Center of the lid covered with fine-mesh nylon cloth. 2. Plastic cage (16 cm diameter, 20 cm high). 3. Holes for aereation (2.5 cm diameter) covered with fine-mesh nylon. 4. Hole for inserting aspirator and covered with a cotton plug when not in use. 5. Filter paper on bottom of cage to keep humidity high. 6. Plastic pot (18 cm diameter, 20 cm high). 7. Galvanized-iron tray with water and nutrients.

Figure 1.



sample was taken weekly starting September 9, 1981 when the rice plants were 76 days old. This field had been sprayed with methamidophos insecticide for Spodoptera frugiperda (Smith), Mocis sp. and S. oryzicola four weeks before the first sample was taken. The field was sprayed again on September 15 for S. oryzicola . Rice plants began heading a week after the last sample was taken on September 24.

B. Northern Atlantic untreated plot (NAUP).

A plot ca. 1500 m^2 was planted with CR-1113 rice for this study on September 26, 1981. Three weekly samples were taken starting October 15, and three additional samples, one every two weeks, were taken starting November 11.

C. Dry Pacific untreated plot (DPUP).

A rice plot ca. 7000 m^2 of rice was selected for this study at the Enrique Jiménez Núñez Experimental Station. The field was planted on July 10. Four samples, one every week, were taken starting September 18 and ending October 15.

Dryinid Biology

A modified cage (Chandra 1980) was designed which

permitted close examination of insects through a dissecting microscope and manipulation in the laboratory (Figure 2). The cage was made from a transparent cellulose butyrate tube (2.5 cm diameter, 26 cm high) open at both ends. Nylon mesh was attached with a rubber band to the upper end of the tube for air circulation. A PVC pipe-reducer (from 38 mm to 12.5 mm) was fitted to one end of the tube. The wider end of the PVC reducer was used as the base of the cage. One end of the reducer was plugged with a cylindrical piece of polyurethane foam cut radially to hold the stem of a small rice plant. The polyurethane plug was covered with a piece of moistened filter paper to provide adequate humidity inside the cage. The base of the cage was set on a flat wooden rack and placed in a tray containing water and nutrients. Insects were removed from the cage by inserting an aspirator through the upper end. When needed, a rice plant was replaced in the cage by fitting another PVC reducer together with the new plant in the upper end of the tube.

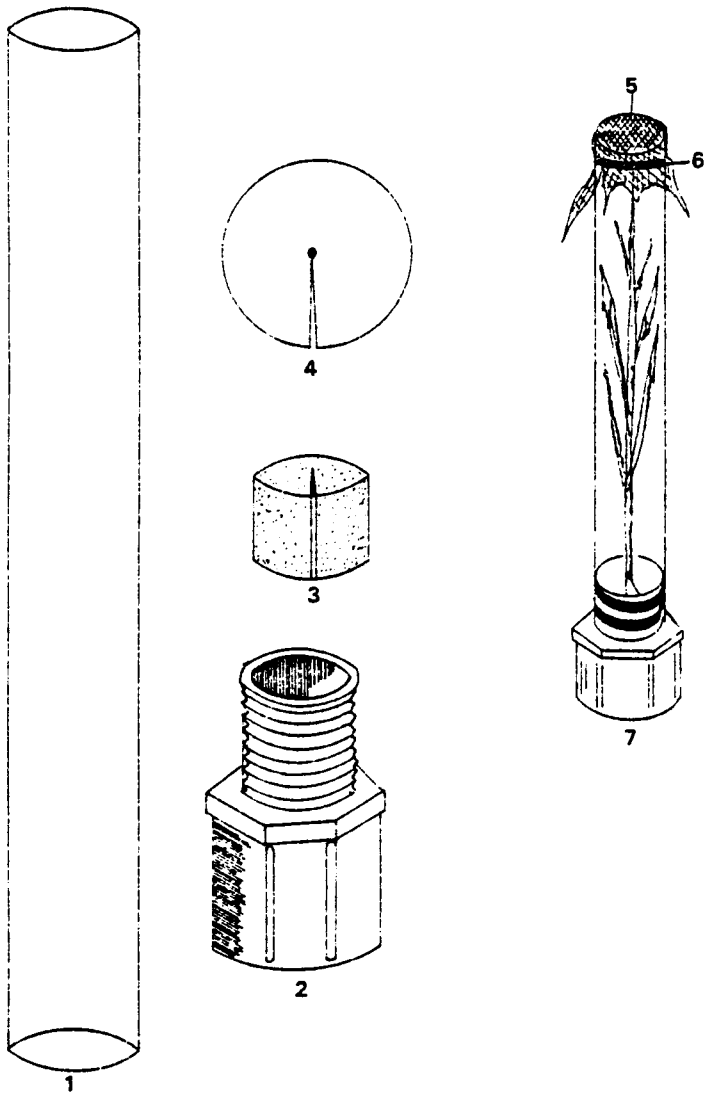
Insects were shaken off the old plant which was then removed together with the base of the cage. The end of the tube was then covered with the nylon mesh and became the new upper end of the cage.

Stage of the host preyed-upon

One newly emerged dryinid female was placed in each of

Figure 2. Cage used for Haplogonatopus sp. studies in the laboratory. 1. Cellulose butyrate tube (2.5 cm diameter, 26 cm high). 2. PVC pipe-reducer (from 38 mm to 12.5 mm). 3. Polyurethane foam cut radially inserted in one end of the reducer to hold the stem of a rice plant. 4. Filter paper cut radially to cover the polyurethane foam and to provide high humidity. 5. Fine mesh-nylon cloth attached with a rubber band. 7. Assembled cage.

Figure 2.



six cages together with first to fifth instar nymphs and adults of S. oryzicola . Observations of the dryinid behavior were started immediately after the insects were caged.

Satiation studies

Three newly emerged dryinid females were placed in 20cc vials together with second and third instar S. oryzicola nymphs. Continuous observations of each dryinid female were made until the female stopped feeding. Additionally, two out of the three females were subjected to starvation periods to observe their behavior when exposed again to S. oryzicola nymphs.

Consumption studies

Parasitized S. oryzicola nymphs were placed in cages and fed until dryinid pupae appeared. Pupae were observed three to four times a day to determine when adults emerged. Sixteen newly emerged dryinid females were put individually in cages together with ten to twenty second to third instar S. oryzicola nymphs. Dryinids were supplied with ten to twelve more nymphs four times a day, and were fed until death. Consumption was assessed by counting the uneaten nymphs (live or death) every time new nymphs were added.

Stage of the host parasitized

Satiated dryinid females were each put in 20cc vials together with S. oryzicola first to fifth instar nymphs and adults. Observation of the dryinid behavior was started immediately after placing the female dryinids in the vials. Parasitized S. oryzicola were caged to observe parasite development. Additional information was obtained by observing the rearing/evaluation cages infested with S. oryzicola and dryinids.

Dryinid reproductive capacity

Eleven cages, containing Bluebonnet 50 plants seeded in two-liter pots, were each infested with two pairs of S. oryzicola . Two parasitized nymphs (parasitoid nearing pupation) were added one to each of two cages. After ten days in the laboratory, cages were moved to a clean rearing/evaluation cage. The pots were clustered together in the center of the cage. Counts and removal of parasitized nymphs, adults and dryinid pupae were started thirteen days later. Counts were stopped when no further parasitism was observed.

Life-cycle studies

S. oryzicola nymphs of different instars were placed

in 40cc vials with a satiated dryinid female. The parasitized nymphs were each moved with an aspirator to cages. Observations were made twice daily to determine: 1) when the parasitoid larval sac-like protuberance appeared on the S. oryzicola nymphs, 2) the number of days from dryinid oviposition to pupation, 3) days from pupa to adult and 4) the number of days from dryinid oviposition to adult emergence. Results of these experiments were based on 34 observations made on different dates. Data on adult longevity were obtained from the consumption experiments.

RESULTS

Reaction of Rice Cultivars to *Sogatodes oryzicola*

Evaluation times were chosen based on mortality (more than 90%) of Bluebonnet 50 seedlings which served as susceptible checks. The length of time cultivars were exposed to a colony of *S. oryzicola* in a rearing/evaluation cage, ranged from seven to eleven days depending on the number of nymphs and adults present in the cage at the time of exposure. After about ten days, most of the colony were adults which moved to the walls and roof of the cage and died.

Analysis of variance of data for different rice cultivar ratings and leaf-feeding damage showed highly significant differences ($P=0.01$) among cultivars and among the different regions where *S. oryzicola* were collected. There were no statistical differences among dates of evaluation. Table 2 shows the mean rating of leaf-feeding damage caused by the four different colonies of *S. oryzicola* on the 21 cultivars tested. Table 2 also shows an average rating from all the four regions. Rice cultivars Mudgo, H-5, L.d. 125, Bg 90-2 and Linea 13 were consistently resistant when exposed to the colonies collected from the four different regions. The same trend resulted when the overall average leaf damage was analyzed.

Table 1. Rice cultivars and their reaction to leaf-feeding damage caused by S. oryzicola in Colombia.

Cultivars	Replications I D/P [1]	I R [2]	II D/P	II R	III D/P	III R	Average %D	Average R
Resistant								
Inti	0/10	2	0/10	2	0/10	2	0	2.00
CICA 4	4/10	2	0/10	2	5/10	2	30.00	2.00
IR 8	0/10	2	0/10	3	0/10	2	0	2.33
Linea 13	1/10	2	0/10	1	0/10	2	3.33	1.66
Mudgo	0/10	1	0/10	1	0/11	1	3.22	1.00
Bg 90-2	0/10	2	0/10	1	1/10	2	3.33	1.66
H-5	0/10	1	0/10	1	0/10	1	0	1.00
L.d.-125	0/10	1	0/10	1	2/10	2	6.66	1.33
Intermediate								
IR 442	8/10	3	0/10	2	7/10	2	50.00	2.66
CR-1113	11/20	3	3/10	3	0/10	3	35.00	3.00
Ciwini	0/10	3	1/10	3	6/10	3	23.33	3.00
Tapochooz	2/10	3	0/10	3	0/10	3	6.00	3.00
IR 1416-131-5-10-2	3/10	3	1/10	3	2/10	3	20.00	3.00
Bg 66-1	3/10	3	1/10	3	2/10	3	20.00	3.00
Susceptible								
ICA 10	10/10	5	10/10	5	8/8	5	100.00	5.00
Bluebonnet 50	10/10	5	10/10	5	10/10	5	100.00	5.00
Moroberekan	10/10	5	10.10	5	9/10	5	96.66	4.66
IRAT 10	10/10	5	10/10	5	10/10	5	100.00	5.00
Azucena	10/10	5	10/10	5	10/10	5	100.00	5.00
Tadukan	10/10	5	3/10	4	2/10	4	50.00	4.33
R-67	9/10	5	9/10	4	10/10	5	93,33	4.66

1/ Dead plants/tested plants.
2/ Damage rating: 1) No visible damage or a faint discoloration of leaf tips. 2) Slight orange color of the leaf borders and tips. 3) The majority of the leaves heavily discolored. Seedlings slightly stunted with initial symptoms of wilting. 4) All leaves totally discolored, many dry leaves, pronounced plant stunting. 5) Plants near death.

Table 2. Reactions of different rice cultivars to leaf-feeding damage caused by colonies of *S. oryzicola* collected from different regions in Costa Rica.

Cultivar	$\bar{X}$ ± SD Rating of Leaf-feeding Injury 1/					
	Dry Pacific	Southern Pacific	Southern Atlantic	Northern Atlantic	Overall Mean	Rating
Mudgo	1.8 ± 0.4a 2/	1.2 ± 0.4a	1.8 ± 0.4a	2.0 ± 0.0ab	1.7 ± 0.5a	R
L.d 125	1.9 ± 0.3ab	1.2 ± 0.4a	2.2 ± 0.4b	2.0 ± 0.0ab	1.8 ± 0.5a	R
H-5	1.6 ± 0.5a	1.8 ± 0.4b	2.3 ± 0.5bc	1.7 ± 0.5a	1.8 ± 0.5a	R
Bg 90-2	2.2 ± 0.4bc	2.1 ± 0.3bc	2.4 ± 0.4bc	2.4 ± 0.5bcd	2.3 ± 0.5b	R
Linea 13	2.6 ± 0.5cd	2.2 ± 0.4cd	2.4 ± 0.5bc	2.7 ± 0.5cde	2.5 ± 0.5bc	R
Inti	2.7 ± 0.5de	2.6 ± 0.5de	2.8 ± 0.4cde	2.7 ± 0.5cde	2.7 ± 0.5cd	I
Tadukan	3.0 ± 0.5de	2.7 ± 0.5e	3.1 ± 0.3de	2.3 ± 0.5bc	2.8 ± 0.5de	I
CICA 4	3.0 ± 0.0de	2.7 ± 0.5e	2.8 ± 0.4cde	2.8 ± 0.4cde	2.8 ± 0.4def	I
IR 442	3.1 ± 0.3ef	2.9 ± 0.3ef	2.7 ± 0.5bcd	3.0 ± 0.0e	2.9 ± 0.3ef	I
Tapochooz	3.1 ± 0.3ef	3.0 ± 0.0ef	3.0 ± 0.3de	3.0 ± 0.0e	3.0 ± 0.2ef	I
Bg 66-1	3.1 ± 0.3ef	2.8 ± 0.4e	3.2 ± 0.4ef	3.0 ± 0.0e	3.0 ± 0.4ef	I
Ciwini	3.1 ± 0.3ef	2.9 ± 0.3ef	3.0 ± 0.0de	3.0 ± 0.0e	3.0 ± 0.3ef	I
IR 8	2.9 ± 0.6de	2.9 ± 0.3ef	3.1 ± 0.3de	3.0 ± 0.0e	3.0 ± 0.4ef	I
IR 1416-131-5-10-2	3.1 ± 0.3ef	3.0 ± 0.0ef	3.0 ± 0.0de	2.9 ± 0.3de	3.0 ± 0.2ef	I
CR-1113	3.6 ± 0.5fg	3.3 ± 0.5fg	3.7 ± 0.5g	3.1 ± 0.3e	3.4 ± 0.5g	I
R-67	3.7 ± 0.7g	4.1 ± 0.6h	3.6 ± 0.5fg	4.2 ± 0.8fg	3.9 ± 0.7h	S
Moroberekan	3.8 ± 0.8g	3.7 ± 0.5g	4.3 ± 0.5h	4.2 ± 0.8fg	4.4 ± 0.7h	S
ICA 10	4.6 ± 0.5h	4.6 ± 0.5i	4.8 ± 0.4i	4.6 ± 0.5gh	4.6 ± 0.5i	S
Azucena	4.8 ± 0.4h	4.8 ± 0.4i	4.8 ± 0.4i	4.1 ± 0.3f	4.6 ± 0.5i	S
Bluebonnet 50	4.8 ± 0.4h	4.8 ± 0.4i	4.7 ± 0.5hi	4.7 ± 0.5hi	4.7 ± 0.5i	S
IRAT 10	5.0 ± 0.0h	5.0 ± 0.0i	5.0 ± 0.0i	5.0 ± 0.0i	5.0 ± 0.0j	S
Overall Mean	3.20bc	3.05a	3.27c	3.16b		

1/ Damage rating: 1) No visible damage or a faint discoloration of the leaf tips. 2) Slight orange color of the leaf borders and tips. 3) The majority of the leaves heavily discolored. Seedlings slightly stunted with initial symptoms of wilting. 4) All leaves totally discolored, many dry leaves, pronounce plant stunting. 5) Plants near death.

2/ Means followed by the same letter are not significant different (P=0.05, DMRT) (error's variance=0.1916, 166 degrees of freedom).

The cultivar Tadukan was rated resistant when exposed to the Northern Atlantic colony; but was rated intermediate when exposed to the other colonies. Tadukan was rated susceptible when evaluated at CIAT, Colombia (Table 1). Cultivars IRAT 10, Bluebonnet 50, Azucena, ICA 10, Moroberekan and R-67 were consistently the most susceptible within and among regions (Table 2). The cultivar CR-1113 was susceptible when exposed to colonies collected in the Dry Pacific and Southern Atlantic areas. The remaining cultivars were rated as intermediate (Table 2).

The total average ratings to leaf-feeding damage in each region, including all the cultivars, were: Southern Pacific, 3.05; Northern Atlantic, 3.16; Dry Pacific, 3.20; and Southern Atlantic, 3.27. The average damage rating from the Southern Pacific region was statistically different from the other regions (P=0.05) (Table 2).

Table 3 shows the mean number of dead seedlings of each cultivar after exposure to S. oryzicola collected from different regions and the total average seedling mortality for each cultivar. Analysis of variance indicated a highly significant difference among cultivars and regions (P=0.01), but no statistical difference among dates of evaluation. These data show that the cultivars IRAT 10, Azucena, Bluebonnet 50, ICA 10, Moroberekan and R-67 had the highest seedling mortality and the most severe feeding damage. Mortality of these cultivars averaged 70 to 100%.

The cultivar CR-1113 had 2.2 dead seedlings (22%) in the overall average and was significanly different (P=0.05) from the other cultivars evaluated.

The cultivar IRAT 10 was the most susceptible cultivar evaluated. Seedling mortality reached 100% four days after exposure to S. oryzicola in all the experiments. In general, there were no consistent statistical differences in seedling mortality between cultivars that were rated as resistant and those rated as intermediate.

The total average number of dead seedlings exposed to S. oryzicola from different regions were: Northern Atlantic, 2.47; Southern Pacific, 2.84; Southern Atlantic, 3.07 and Dry Pacific, 3.20. The number of dead seedlings exposed to S. oryzicola from the Northern Atlantic region was significantly lower than the other regions (P=0.05) (Table 3).

Mortality and Population Development on Selected Cultivars

Nymph mortality and adult development

Table 4 shows the cummulative numbers of adults produced and the nymph mortality of S. oryzicola on selected cultivars for the first and the second trials. Table 4 also includes the mean proportion of adults that developed on the cultivars. A X^2 test run separately for both trials gave sufficient statistical evidence (P=0.01)

Table 3. Mean number of dead seedlings of each cultivar exposed to different colonies of S. oryzicola collected in Costa Rica.

Cultivar	$\bar{X}$ ± SD Dead Seedlings 1/				
	Dry Pacific	Southern Pacific	Southern Atlantic	Northern Atlantic	Overall Mean
Mudgo	0.0 ± 0.0a 2/	0.0 ± 0.0a	0.4 ± 0.7a	0.0 ± 0.0a	0.1 ± 0.0a
L. d 125	0.1 ± 0.3a	0.0 ± 0.0a	0.2 ± 0.4a	0.0 ± 0.0a	0.1 ± 0.3a
Bg 90-2	0.0 ± 0.0a	0.1 ± 0.3a	0.3 ± 0.7a	0.0 ± 0.0a	0.1 ± 0.4a
Linea 13	0.3 ± 0.1ab	0.0 ± 0.0a	0.0 ± 0.0a	0.1 ± 0.3a	0.1 ± 0.5a
H-5	0.3 ± 0.1ab	0.0 ± 0.0a	0.6 ± 0.7a	0.0 ± 0.0a	0.2 ± 0.6ab
CICA 4	0.9 ± 1.7ab	0.0 ± 0.0a	0.1 ± 0.3a	0.2 ± 0.4a	0.3 ± 0.7abc
Tapochooz	0.5 ± 0.5ab	0.9 ± 0.8ab	0.2 ± 0.7a	0.1 ± 0.3a	0.4 ± 0.6abc
IR 442	0.9 ± 1.4ab	0.3 ± 0.5a	0.1 ± 0.3a	0.3 ± 0.7a	0.4 ± 0.8abc
Inti	1.2 ± 1.5ab	0.0 ± 0.0a	0.2 ± 0.7a	0.2 ± 0.7a	0.4 ± 1.0abc
Tadukan	0.8 ± 0.8ab	0.4 ± 0.7a	0.7 ± 1.0ab	0.2 ± 0.4a	0.5 ± 0.8abc
IR 8	1.6 ± 1.8b	0.0 ± 0.0a	1.9 ± 1.7bcd	0.0 ± 0.0a	0.9 ± 1.5bcd
Bg 66-1	0.8 ± 1.4ab	0.1 ± 0.3a	2.4 ± 2.2cd	0.1 ± 0.3a	0.9 ± 1.6bcd
Ciwini	1.6 ± 1.9b	1.2 ± 1.3ab	0.1 ± 0.3a	1.0 ± 0.5a	1.0 ± 1.2cd
IR 1416-131-5-10-2	2.9 ± 1.5c	0.7 ± 1.3ab	1.3 ± 1.4abc	0.8 ± 0.8a	1.4 ± 1.6d
CR-1113	3.1 ± 2.7c	1.9 ± 1.2b	3.1 ± 1.2d	0.7 ± 0.7a	2.2 ± 1.9e
R-67	6.8 ± 2.4d	8.3 ± 1.3cd	5.7 ± 1.9e	7.3 ± 2.1b	7.0 ± 2.1f
Moroberekan	8.0 ± 2.3e	7.4 ± 1.3c	9.0 ± 0.9f	6.4 ± 2.1b	7.7 ± 1.9g
ICA 10	8.9 ± 1.4ef	9.2 ± 0.8de	9.3 ± 1.4f	7.7 ± 1.9b	8.8 ± 1.5h
Bluebonnet 50	9.1 ± 1.2ef	9.6 ± 0.7de	9.2 ± 1.0f	9.1 ± 0.8c	9.3 ± 0.9h
Azucena	9.4 ± 0.7f	9.4 ± 1.1de	9.6 ± 0.7f	7.6 ± 1.2b	9.0 ± 1.3h
IRAT 10	10.0 ± 0.0f	10.0 ± 0.0e	10.0 ± 0.0f	10.0 ± 0.0c	10.0 ± 0.0i
Overall Mean	3.20c	2.84b	3.07bc	2.47a	

1/ Mean from nine pots each containing ten seedlings.
2/ Means followed by the same letter are not significant different (P=0.05, DMRT) (error's variance=1.5835, 166 degrees of freedom).

to support the hypothesis that cultivars had an effect on the proportion of nymphs that reached the adult stage (X^2= 13.4 and X^2=23.5 for the first and the second trials, respectively). The Wilcoxon rank sum test (McClave and Dietrich 1979) showed statistical evidence (TA=20) to support the hypothesis that the proportion of adults that developed in both trials were equally distributed. An F-test for equal population variances for both trials showed that there was no significant difference between variances (P=0.05). Analysis of variance showed that there was a significant difference (P=0.05) among the mean proportions of adults developing on selected cultivars. The proportion of adults on CICA 4 (0.55) was significantly lower (P=0.05) than the proportions on CR-1113 (0.94), Ciwini (0.83), IR 8 (0.87), and Bluebonnet 50 (0.97), which were not statistically different. The Z-test (McClave and Dietrich 1979), used to compare the proportions of adults developing on CICA 4 in the first and the second trials (0.68 and 0.42 adults respectively), showed that the proportion of adults developing on CICA 4 significantly decreased (Z=3.29) (P=0.05) from one generation to another. Results showed that nymph mortality was higher and fewer adults developed on CICA 4 than on IR 8, CR-1113, Ciwini and Bluebonnet 50 in both trials (Table 4).

Table 4. Adult development and nymph mortality of *S. oryzicola* on selected cultivars.

	Cultivars									
	CICA 4		IR 8		CR-1113		Ciwini		Bluebonnet 50 [2]	
	First Trial									
	n=100 [1]		n=93		n=92		n=96			
DAC [3]	No. Adults	Nymph mort.	No. Adults	Nymph mort.	No. Adults	Nymph mort.	No. Adults	Nymph mort.	No. Adults	Nymph mort.
10	65	24	72	05	85	03	72	08		
14	68	29	76	07	85	07	83	08		
18	68	30	81	08	86	07	83	08		
21	68	32	82	08	86	07	84	08		
Prop.	0.68	0.32	0.88	0.09	0.93	0.07	0.88	0.08		
	Second trial [4]									
	n=60		n=65		n=53		n=50		n=103	
09	00		08		04		10		08	
14	14	26	50	08	47	03	37	08	93	03
17	20	29	55	08	48	03	40	08	97	03
24	25	35	56	09	50	03	41	09	100	03
Prop.	0.42	0.58	0.86	0.14	0.94	0.06	0.82	0.18	0.97	0.03
Mean Prop.	0.55b [5]		0.87a		0.94a		0.83a		0.97a	

1/ n=number of nymphs at the beginning of experiment.
2/ Nymphs on Bluebonnet 50 were discarded because plants withered in the first trial.
3/ Days after caging.
4/ Nymphs for second trial were the offspring of adults from the first trial.
5/ Proportions followed by the same letter are not statistically different (P=0.05, DMRT).

Adult mortality

Table 5 shows the cumulative mortality of S. oryzicola adults on selected rice cultivars. In general, adults had a higher mortality when fed on CICA 4; mortality reached 100% after 14 days. Adults fed on Bluebonnet 50 had the lowest mortality (25%), while those fed on IR 8, CR-1113 and Ciwini had about 50% mortality during the same period. Mortality was similar on all cultivars after 18 days.

Population development

Analysis of variance of population development indicated that there was a significant difference among the selected cultivars in the first (P=0.05) and second (P=0.01) trials. However, there was no statistical difference in population development among S. oryzicola females collected from the four different regions. As can be noted from Table 6, which includes the mean number of nymphs produced on selected cultivars in the two experiments, there was a substantial decrease in the number of nymphs produced on CICA 4. Table 7 shows the mean number of nymphs produced on cultivars by females collected from the four regions (experiment two). Females from all the regions produced significantly fewer (P=0.05) nymphs on CICA 4 than on IR 8, Bluebonnet 50, CR-1113 and Ciwini (Table 7). The number of nymphs produced by females from

Table 5. Cumulative mortality of adult S. oryzicola on selected cultivars. 1/

DAC 2/	Cultivars				
	CICA 4	IR 8	CR-1113	Ciwini	Bluebonnet 50
2	5	0	0	0	0
4	5	0	0	0	0
8	7	1	1	2	0
14	16	8	9	10	4
18	16	14	14	13	11
20	16	15	14	14	14
22	16	15	15	14	14
25	16	15	16	15	14

1/ Observations from 8 males and 8 females on each cultivar. Two pairs collected from four different regions.
2/ Days after caging.

Table 6. Mean number of nymphs produced on selected cultivars. 1/

Cultivar	1st. trial 2/	2nd. trial 3/
Bluebonnet 50	343.2 b 4/	228.4 b
IR 8	342.8 b	198.9 b
CR-1113	320.2 b	185.5 b
Ciwini	204.6 ab	171.6 b
CICA 4	177.8 a	41.0 a

1/ Data transformed to $\sqrt{x}$ for analysis.
2/ Mean number of nymphs produced by four females up to 15 days after caging.
3/ Mean number of nymphs produced per female through life.
4/ Values followed by the same letters are not significantly different (P=0.05, DMRT).

Table 7. Mean number of S. oryzicola nymphs produced on selected cultivars by females collected from different regions. 1/ 2/

	colony 3/			
Cultivars	DP	SP	SA	NA
IR 8	270.0a 4/	183.5b	120.0a	222.0a
Bluebonnet 50	202.0ab	341.0a	211.5a	159.0a
CR-1113	146.5b	269.5ab	159.0a	167.0a
Ciwini	126.0bc	266.0ab	144.0a	150.5a
CICA 4	58.5c	17.0c	39.0b	49.5b

1/ n=2 females /region/cultivar.
2/ Data transformed to $\sqrt{x}$ for analysis.
3/ DP: Dry Pacific. SP: Southern Pacific. SA: Southern Atlantic. NA: Northern Atlantic.
4/ Values followed by the same letters are not significantly different (P=0.05, DMRT).

the Southern and Northern Atlantic regions on cultivars IR 8, Bluebonnet 50, CR-1113 and Ciwini was not significantly different (P=0.05, DMRT). The same trend occurred with females collected from the Dry and Southern Pacific regions (Table 7).

Studies on the Dryinid Parasitoid-predator

Host-dryinid abundance

Table 8 shows the number of adult male and female S. oryzicola in 4-sweep net samples and the respective percent parasitism by Haplogonatopus sp. in each of three sampled plots: Northern Atlantic insecticide-sprayed plot (NAISP), Northern Atlantic untreated plot (NAUP), and Dry Pacific untreated plot (DPUP). The abundance of S. oryzicola was generally low, except for NAISP (Table 8a) which reached a mean density of 71.3 adults per 4-sweeps on September 9. Adult abundance significantly decreased in this plot on September 17 after being sprayed on September 15. However, adult abundance began increasing nine days after spraying. On the untreated plot (NAUP, Table 8b), S. oryzicola showed a uniform abundance throughout the sampling period except on the last two sampling dates when the population decreased. In this plot, the number of adults caught in 4-sweep samples reached mean values equivalent to one-fourth of the action or treatment level, i.e., an

average of 80 adults in 4-sweep samples for cultivar CR-1113.

The density of S. oryzicola adults was low throughout the sampling period in the untreated plot in the Dry Pacific region (DPUP, Table 8c), with values ranging from 2.9 to 4.9 adults in 4-sweep samples.

Figure 3 derived from Table 8 summarizes the relative abundance of S. oryzicola and the percent parasitism by Haplogonatopus sp. observed on females and nymphs in the three plots sampled. The percentage of parasitized males was very low in all three plots. Parasitized females were more abundant at the beginning of the sampling period when nymph populations were still low, but decreased through time as nymph populations and nymph percent parasitism increased. Parasitized females were not observerd in the last samples (Figure 3a and c). Figure 3c also shows that, in general, percent parasitism increased or decreased according to the density of S. oryzicola .

Effective percent parasitism (considering only S. oryzicola females and nymphs) calculated from Table 8 ranged from 1.7 to 11.1, and from 7.9 to 12.2 percent in an increasing pattern through time in the NAUP and DPUP plots, respectively. In the NASP plot, effective parasitism ranged from 1.4 to 5.0 percent in a decreasing pattern.

Table 8. Relative abundance of S. oryzicola and Haplogonatopus sp. collected from three different study plots in Costa Rica.

a- Northern Atlantic Insecticide-sprayed Plot (NAISP)[1/]

DATE	♂	♀	Mean[2/]	SD[3/]	#/♂ Par.	% Par.	#/♀ Par.	% Par.	# Nymph Par.	% Par.
9- IX-81	30.9	40.4	71.3	14.9	133/1	0.8	150/7	4.7	31/2	6.5
17- IX-81	2.3	3.2	5.5	2.1	42/0	0.0	34/0	0.0	12/1	8.3
24- IX-81	4.6	7.7	12.3	13.2	42/0	0.0	18/0	0.0	55/1	1.8

b- Northern Atlantic Untreated plot (NAUP)

15- IX-81	10.3	9.1	19.4	9.1	55/0	0.0	53/1	1.9	5/0	0/0
22- X-81	12.7	8.1	20.8	9.7	23/0	0.0	36/1	8.3	4/0	0.0
29- X-81	19.6	15.9	35.5	18.8	46/0	0.0	43/5	11.6	2/0	0/0
11- XI-81	15.0	10.4	25.4	10.0	44/1	2.3	37/3	8.1	26/1	3.8
26- XI-81	8.0	3.6	11.6	1.6	25/0	0.0	23/1	4.4	22/1	4.6
10-XII-81	2.6	2.4	5.0	2.0	15/0	0.0	12/0	0.0	21/1	4.8

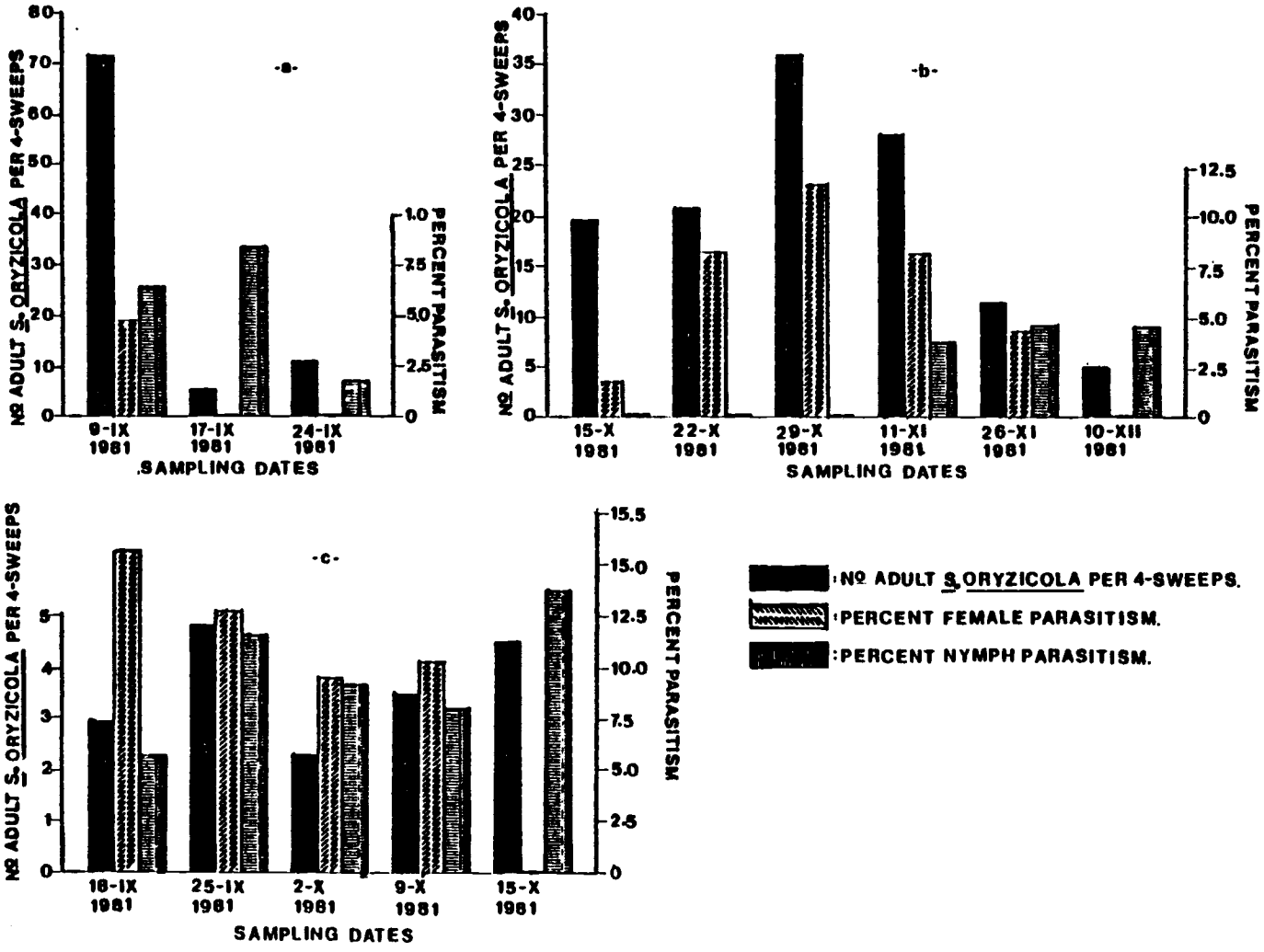
c- Dry Pacific Untreated Plot (DPUP)

18- IX-81	1.5	1.4	2.9	1.5	31/0	0.0	32/5	15.6	17/1	5.9
25- IX-81	2.9	1.9	4.8	2.4	27/0	0.0	40/5	12.5	35/4	11.4
2- X-81	1.6	0.7	2.3	1.6	34/0	0.0	21/2	9.5	43/4	9.3
9- X-81	2.5	1.0	3.5	2.7	28/0	0.0	29/3	10.3	39/3	7.7
15- X-81	3.4	1.0	4.4	2.7	40/0	0.0	26/0	0.0	37/5	13.5

1/ Insecticide methamidophos was sprayed on August 5 and September 15, 1981.
2/ Mean number of adult S. oryzicola per 4-sweeps.
3/ NAISP, n=18; NAUP, n=7; DPUP, n=18.

Figure 3. Relative abundance of adult S. oryzicola and percent parasitism by Haplogonatopus sp. in the three plots sampled. a. Northern Atlantic insecticide-sprayed plot (NAISP). Insecticide methamidophos was sprayed on August 5 and September 15, 1981. b. Northern Atlantic unsprayed plot (NAUP). c. Dry Pacific unsprayed plot (DPUP).

Figure 3.


-a-
Nº ADULT S. ORYZICOLA PER 4-SWEEPS
PERCENT PARASITISM
9-IX 1981
17-IX 1981
24-IX 1981
SAMPLING DATES
-b-
15-X 1981
22-X 1981
29-X 1981
11-XI 1981
26-XI 1981
10-XII 1981
-c-
16-IX 1981
25-IX 1981
2-X 1981
9-X 1981
15-X 1981
: Nº ADULT S. ORYZICOLA PER 4-SWEEPS.
: PERCENT FEMALE PARASITISM.
: PERCENT NYMPH PARASITISM.

Stage of the host preyed-upon

Newly emerged Haplogonatopus sp. preyed on first to fourth instar nymphs of S. oryzicola . First instar nymphs were capture only when the dryinid contacted them with its antennae. Second to fourth instars were easily captured because they were probably "more apparent" as they moved nervously when the parasitoid-predator approached them. Fifth instar nymphs were also capture, however, their strength made it difficult for the dryinid to hold them. S. oryzicola adults (alate or brachypterous forms) were not normally captured. Under forced conditions, brachypterous adults were capture but they jumped together with the dryinid and subsequently dislodged the dryinid.

Satiation studies

Female 1. Once together with S. oryzicola nymphs, the newly emerged dryinid female readily started to feed. After eating six nymphs, the female dryinid went into a resting period for about 12 minutes then ate another nymph before starting to parasitize the nymphs. After a four hour starvation period, this female ate three more nymphs before parasitizing additional nymphs.

Female 2. This dryinid female consumed seven nymphs before an 11 minute resting period. She then ate another nymph before beginning parasitism. After parasitizing some

nymphs she was left alone for five hours. She then preyed on four more nymphs before starting parasitism again. This female was left together with nymphs for eighteen hours, then she was given a six hour starvation period after which she ate three nymphs.

Female 3. This female fed on five nymphs before a 13 minute resting period, after which she parasitized two nymphs, ate another nymph and continued parasitism.

Results showed that initial satiation occurred after dryinid females had eaten from five to seven nymphs before starting parasitism. After a starvation period of 4 to 6 hours, females once again preyed on nymphs but were satiated after consuming only three to four nymphs. Whether longer starvation periods would induce dryinid females to eat more prey was not determined.

Haplogonatopus sp. consumption studies

Table 9 shows the total number of S. oryzicola nymphs consumed and the mean daily consumption by female Haplogonatopus sp.. Table 9 also shows the dryinid female life span. The mean number of nymphs consumed per female was 102.9 $\pm$ 12.1, ranging from 51 to 204 nymphs. The mean number of nymphs consumed per day was 15.5 $\pm$ 0.5, ranging from 11.4 to 18.6. Figure 4 shows that 43.7% and 31.5% of the females consumed 41 to 80 and 81 to 120 nymphs, respectively. The remaining 25% of the females consumed from 121 to 241 nymphs.

Stage of S. oryzicola parasitized

First instar nymphs of S. oryzicola were not visibly parasitized even under forced conditions. First instar nymphs may have been parasitized but they never showed the sac-like protuberance typical of dryinids. In some instances, when first instar nymphs were captured they were preyed upon or just killed by the dryinid. Second and third instar nymphs were the most commonly parasitized stage. When parasitism occurred on these instars the protuberance appeared on the fourth and fifth instars and less commonly on the adult stage. Fourth and fifth instar nymphs also were parasitized and the protuberance appeared in the adult stage in all instances. Alate and brachypterous adults were not parasitized under forced conditions.

Observations on S. oryzicola nymphs and adults in rearing/evaluation cages, infested with Haplogonatopus sp., showed that the majority of individuals with symptoms of parasitism were fourth and fifth instar nymphs. Adult S. oryzicola females with the protuberance also were common, but very few males had the protuberance. When rearing the parasitoid-predator for some of these studies, it was observed that out of 32 parasitized S. oryzicola nymphs, 23 developed into females.

Table 9. Mean number of S. oryzicola nymphs consumed and average daily consumption by Haplogonatopus sp.

	X ± SE (n=16)	Range
Life Span in days	6.8 ± 0.8	2.8--13.8
# of Nymphs consumed	102.9 ± 12.1	51.0-204.0
Average daily consumption	15.4 ± 0.5	11.4--18.6

Table 10. Life cycle of Haplogonatopus sp. from oviposition in S. oryzicola to adult emergence.

	X ± SE(n=34)	Range
Days to protuberance	10.9 ± 0.4	7-17
Days to pupa	16.9 ± 0.7	12-24
Days from pupa to adult	9.9 ± 0.2	6-12
Days to adult	26.7 ± 0.7	20-35

Dryinid reproductive capacity

The presence of empty pupa cases indicated that the dryinid adults had emerged normally inside the rearing/evaluation cage. A total of 236 parasitized S. oryzicola nymphs and adults and dryinid pupal cases were counted. Double parasitized individuals were counted twice. Results showed that there was a mean of 118 parasitoids produced per dryinid female.

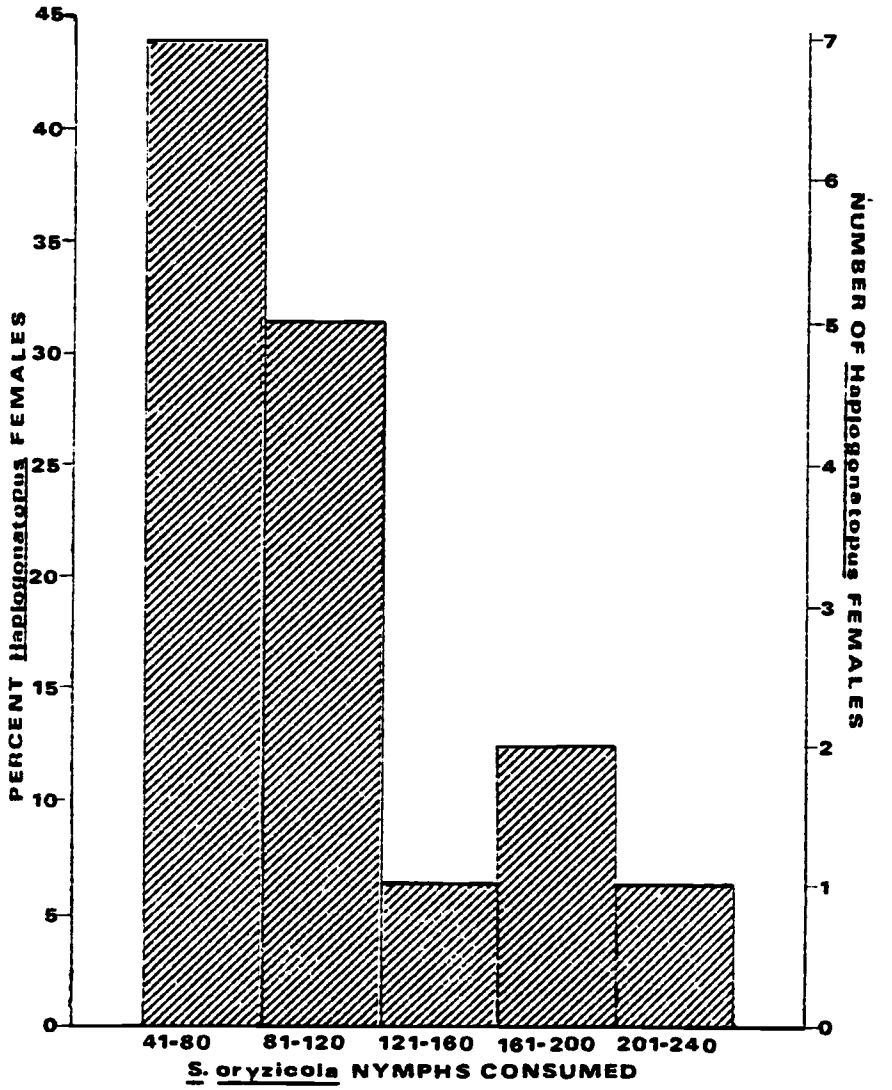
Life cycle studies

The mean number of days from oviposition to the appearance of the sac-like protuberance was 10.9 ± 0.4 (range 7-17), the mean number of days to the pupa stage was 16.9 ± 0.7 (range 12-24), the mean number of days from pupa to adult was 9,9 ± 0.2 (range 6-12), and the mean number of days from oviposition to adult emergence was 26.7 ± 0.7 (range 20-35) (Table 10). Adult dryinids lived an averaged of 6.8 ± 0.8 days (range 2.8-13.8) (Table 9).

No linear correlation was found between days to appearance of the protuberance and days to adult emergence ($r=0.095$), between days from pupa to adult ($r=0.1397$), or between days from pupa to adult and days to adult emergence ($r=0.3993$). A positive linear correlation was found between days to pupa and days to adult ($r=0.9413$) ($y=9.1848 + 1.0416x$) and between days to appearance of the protuberance and days to pupa ($r=0.7986$) ($y=2.6285+1.3025x$).

Figure 4. Histogram of the number of S. oryzicola nymphs consumed by Haplogonatopus sp. females. The mean number of nymphs consumed was 102.9 ± 12.1 (range 51-204).

Figure 4.


PERCENT Haplognathopus FEMALES
NUMBER OF Haplognathopus FEMALES
45
40
35
30
25
20
15
10
5
0
7
6
5
4
3
2
1
0
41-80
81-120
121-160
161-200
201-240
S. oryzicola NYMPHS CONSUMED

Additional observations of parasitoid-predator behavior

The searching, capturing and prey-holding behavior of Haplogonatopus sp. was similar to that described by Clausen (1940). When in the base of the plant, the dryinid climbed up in a spiral-like pattern until reaching a leaf. It then walked up on one side of the leaf blade, returned down on the other side, and moved to another leaf. The captured S. oryzicola nymph was held with the chelate tarsi of the forelegs which folded in so that the ventral part of the nymph faced the mouth of the dryinid. The dryinid started chewing on the ventral part of the nymph's abdomen and used the tip of its own abdomen to push the prey into its mouth. When nymphs were small (first and second instars) the dryinid consumed the entire insect except the exoskeleton which in some instances remained in the mouth of the parasitoid-predator. When larger nymphs were eaten, part of the thorax and head was left.

Dryinid females could capture nymphs more than once for oviposition, but when this occurred only single and/or double-parasitized nymphs were observed.

Visual contact seemed to be needed for Haplogonatopus sp. to capture S. oryzicola nymphs. The dryinid was observed in a resting position in the dark.

The resting period was characterized by a cessation of adult activity, a constant stretching of the hindlegs and an intermitently moving of the antennae and the forelegs.

After a few minutes, the dryinid started a "push-up-like" movement and then took an immobile crouched position. The end of the resting period was signaled by movements of the antennae, first slowly then faster and accompanied by stretching of the forelegs. The dryinid then renewed its searching behavior.

After emerging, adult dryinid females apparently require food since they did not live more than 32 hours without prey (observation of five females). The presence of free water was necessary during starvation periods.

When there was no food available, both newly emerged and old females drank water from any wet surface. During dry conditions, females became slugish after five to six hours and died within seven hours. It was observed that when dryinids were "weary" and water was supplied, they regained their normal activity.

Variation in size of females was observed, and progeny from the smaller and/or larger females also exhibited size differences.

Males and/or alate forms of Haplogonatopus sp. were not found after rearing and examining a few hundred individual dryinids in the laboratory.

DISCUSSION

Exposing the different rice cultivars to a colony of S. oryzicola for less than twelve days and allowing 90 or more percent mortality of Bluebonnet 50 seedlings was adequate to evaluate leaf damage in this research. The position of cultivars inside the evaluation cages did not affect results. Wiseman et al. (1980) found that the position of cultivars in cages was not as important as rating time when evaluating plants for insect resistance. The lack of statistical difference among evaluation times in my study confirms the reliability of the technique developed by Jennings and Pineda (1970a).

Comparing the results from CIAT-Colombia (Table 1) with those obtained in my experiments in Costa Rica (Table 2), it was found that cultivar ratings in both countries were similar although some differences were observed. Cultivar Tadukan which was susceptible to S. oryzicola in Colombia had an intermediate resistance reaction in Costa Rica. However, the percentage of dead Tadukan seedlings was relatively low in two out of the three evaluations in Colombia (20 and 30%) (Table 1). The cultivars rated as resistant in Colombia, Inti, CICA 4 and IR 8, showed more hopperburn in Costa Rica and were rated intermediate in my study (Tables 1 and 2). The cultivars rated as intermediate in Colombia gave the same reaction in Costa

Rica, except CR-1113 which tended to be more susceptible when challenged with S. oryzicola colonies from the Dry Pacific and Southern Atlantic regions (Tables 1 and 2). Except for the cultivar Tadukan, cultivars rated as susceptible in Colombia were rated the same way in my experiments. However, in my study the cultivar IRAT 10 was the most susceptible. Mortality of IRAT 10 seedlings reached 100 percent within the first five days after exposing plants to any of the four different colonies. Jennings and Pineda (1970a), after evaluating 534 rice cultivars from the World Collection, found that none was more susceptible than Bluebonnet 50. However, because of its high susceptibility, cultivar IRAT 10 must not be used as a comparative susceptible check in mass screening selections for resistance to S. oryzicola .

In general, S. oryzicola colonies from Costa Rica caused lower seedling mortality than the colony used in CIAT-Colombia, especially for those cultivars rated as intermediate and susceptible. Apart from the differences noted, the results from my study do not indicate that the S. oryzicola population in Costa Rica is different from the population in Colombia. Identification of biotypes occurring in Costa Rica and Colombia will require additional research. "Biotypic differences of a lower order" are more likely to exist between isolated populations. Seshu and Kauffman (1980) referred to such "biotype differences of a lower order" to explain

differences in reaction of rice cultivars to N. lugens among the common insect populations within East and Southeast Asia.

Evidence of S. oryzicola biotypes from different regions in Costa Rica was not determined in my research. Although statistical differences were found among regions in the overall analysis of variance of the cultivars for reaction to leaf-feeding damage and seedling mortality (Tables 2 and 3). The damage rating of each cultivar was consistent across regions (Table 2). Deviations from this general trend occurred in cultivars in which damage ratings were near one resistance category or another; namely Linea 13, Tadukan and CR-1113. These deviations also may be related to "biotypic differences of a lower order", which also could explain the changes in the "virulence" of caged colonies mentioned by Dr. G. Gálvez and Dr. P. R. Jennings (personal communication 1979).

Results from experiments on the effect of selected cultivars on S. oryzicola demonstrated that fewer adults developed (57%) and more nymphs died on CICA 4 than on Bluebonnet 50, IR 8, CR-1113 and Ciwini. A decrease in adult development on CICA 4 from one generation to another suggested an antibiotic effect of this cultivar on S. oryzicola (Table 4). Nonpreference to feeding appears to be less important as evidenced by the intermediate reaction of CICA 4 to S. oryzicola (Table 2). This observation agrees with that of Jennings and Pineda (1970b), although

it would be difficult to detect nonpreference under the insect pressure to which seedlings were exposed in the evaluation cages in my studies. Dr. P. R. Jennings at the "V Conference of the International Rice Testing Program for Latin America, 1983" presented data that showed a nonpreference mechanism to oviposition in CICA 4 that conferred resistance to S. oryzicola .

Results indicated that some cultivars showed some degree of resistance in mass screening evaluations in the greenhouse, but they could lose resistance in the field. For example, as many nymphs were produced on the cultivars IR 8, Ciwini, and CR-1113 (rated intermediate in my experiment) as on the susceptible check Bluebonnet 50. However, on CICA 4 (also rated intermediate) from 70 to 95 percent fewer nymphs were produced in one of the experiments (Table 6). My results support the IRRI (1982) finding that "population growth" is the most reliable method to measure field resistance. The trend of fewer nymphs produced on CICA 4 and more on the other selected cultivars was consistent with S. oryzicola females collected from the four different regions evaluated (Table 7). Thus, my results suggest that IR 8, CICA 4, Ciwini, CR-1113 and Bluebonnet 50 would have similar levels of resistance in the four regions.

When comparing the results from my research with those from similar studies on the cultivar Mudgo (Jennings and Pineda 1870b), CICA 4 differed only in that it permitted

slightly higher numbers of developing adults and more nymphs per female than on Mudgo. Thus, CICA 4 can be categorized as a resistant cultivar in terms of survival and population development of S. oryzicola . The intermediate rating of leaf-feeding damage observed on CICA 4 could be explained by the fact that this cultivar does not prevent S. oryzicola from feeding on it and is considered intrinsically susceptible to feeding injury. The isolated occasions (Entomology Department, Costa Rica 1974, Dr. R. Lasso 1980, written communication) when CICA 4 and other CICA 4 cultivars were observed infested with S. oryzicola might be attributed to first generation S. oryzicola immigrating from adjacent fields.

Even though my results indicated that cultivar IR 8 allowed a population increase of S. oryzicola statistically similar to Bluebonnet 50; the fact is that the population of S. oryzicola was substantially reduced during the two years IR 8 was grown in Costa Rica. The mechanism of resistance in IR 8 that prevents S. oryzicola outbreaks in the field is unknown. My results, together with field observations where reselections of IR 8 (Dr. P. R. Jennings 1980, personal communication) became infested in two rice fields in Colombia (CIAT 1975), suggest that genes exist in IR 8 that confer a nonpreference mechanism of resistance to S. oryzicola . Such genes could change their action in improved derivative materials, as has been observed when evaluating rice germplasm for brown planthopper resistance

(Seshu and Kauffman 1980). Certain degree of nonpreference also may exist in cultivar CR-1113 because it has been shown to be less susceptible than Bluebonnet 50 in the field (personal observation).

Cultivars CR-1113, IR 8 and Ciwini had levels of resistance similar to the susceptible Bluebonnet 50 in the number of nymphs surviving, adults developing and population development. However, there was a different trend in the adult survival experiment; adult mortality was about 50% lower on Bluebonnet 50 than on the other cultivars in the first fourteen days after caging (Table 5). Thus, longevity of adult S. oryzicola was shortened when it fed on IR 8, CR-1113 or Ciwini. Similar results were reported by Sögawa and Pathak (1970) when studying resistance to brown planthopper in Mudgo (resistant), IR 8 (tolerant) and Taichung 1 (susceptible).

Gallun (1972) suggested that monogenic insect resistant cultivars would likely be broken down by the resurgence of different physiological forms of the insect. The results of my research do not diminish the possibility of the occurrence of "biotype differences of a lower order" within S. oryzicola populations, which, under certain environment conditions, decrease the resistance of cultivars like CR-1113 which have been planted continously for up to ten years. However, there is no substantiated evidence to indicate that resistance to S. oryzicola has broken down in Latin America. Cultivar CR-1113, which was

derived from a backcross to IR 8, could have inherited some of the IR 8 resistance to S. oryzicola . The crosses that originated both cultivars were developed in IRRI where S. oryzicola does not exist. Allopatric resistance is often a polygenic type of resistance (Harris 1975) where several minor genes provide low to moderate levels of resistance. The low level of resistance in cultivar CR-1113 to S. oryzicola shown in my research could help explain why rice fields planted with CR-1113 very often become infested with S. oryzicola even though CR-1113 is tolerant to leaf-feeding damage in the greenhouse in Costa Rica and Colombia. Panda and Heinrichs (1983) concluded that high levels of tolerance contributed to the moderate resistance of cultivar Utri Rajapan to the brown planthopper, whereas other moderately resistant cultivars had varying levels of both tolerance and antibiosis.

Even though CR-1113 was rated intermediate to moderately susceptible to S. oryzicola , there are fields of this cultivar in which population densities never reach levels high enough to require insecticide treatments. This is especially true in fields that do not become infested with worms (Spodoptera frugiperda or Mocis sp.) forty or fifty days after planting (personal observation). This suggests that natural enemies and/or low levels of resistance in CR-1113 is preventing large populations of S. oryzicola in those fields.

Haplogonatopus sp. were commonly observed in rice

fields in Costa Rica and in other Latin American countries (McGuire et al. 1960, Elias et al. 1962, Gordon 1981, Castano and Pineda 1982). Previous personal observations showed that parasitism by Haplogonatopus sp., reached about 90% after two or three generations S. oryzicola inside rearing cages.

The adaptability of Haplogonatopus sp. to different environment conditions was not studied, except that I observed that Haplogonatopus sp. required host food or free water to survive for more than one day after emergence or after a starvation period. This could be a constraint to the effectiveness of this species during drought periods or from one growing season to another when S. oryzicola is very scarse and no free water is available, especially in the upland rice production system.

Haplogonatopus sp. had a high reproductive potential on S. oryzicola under laboratory conditions. The female progeny produced by each dryinid female (ca. 118) surpassed the reproductive potential of S. oryzicola which had an oviposition capacity of 161 eggs per female (McMilliam 1963). S. oryzicola has a 1:1 sex ratio (Elias et al. 1962). The predacious behavior of Haplogonatopus sp. adds to the efficiency of this parasitoid-predator; an average of 102.9 S. oryzicola nymphs were consumed per adult dryinid (Table 9) which represented ca. 63.9% of one S. oryzicola female's offspring.

The number of parasitized and/or individuals preyed

upon is related to the searching capacity, host or prey availability, satiation capacity (Huffaker et al. 1971), and the life span of the natural enemy. Based on the life span of adult dryinids, their consumption capacity (Table 9, Figure 4) and satiation studies, predation by Haplogonatopus sp. in the field could be lower than in the laboratory, especially if low populations of S. oryzicola exist.

Haplogonatopus sp. required an average of 26.7 days from oviposition in the host to emergence of new adults which is well-synchronized with the life-cycle of S. oryzicola which is ca. 25 days under similar temperature conditions (McGuire et al. 1960). An irregular life-cycle in Haplogonatopus sp. is indicated by the range of days from parasitism to emergence of new adult dryinid (20 to 35 days), and by the positive linear correlations between days from parasitism to the appearance of the protuberance on S. oryzicola and days to dryinid pupation as well as days to dryinid pupation and adult emergence. This irregular life-cycle is suitable for this parasitoid-predator to coincide with the availability of S. oryzicola nymphs.

In relation to host specificity, I never found Haplogonatopus sp. parasitizing any host other than S. oryzicola in the field. Other parasitized homopterans were rarely found and they were parasitized by different species of dryinids (species not determined) which did not accept S. oryzicola nymphs as a host or prey. This observation

disagrees with Olmi (1979) who concluded that any species of dryinid in the same genus would attack any host species in the same family. However, more specific research is required to determine more accurately the host range of Haplogonatopus sp.

Alate forms of Haplogonatopus sp. were never found so migration of parasitized S. oryzicola adults could be how this species of dryinid disperses. The number of parasitized adults decreased as the number of parasitized nymphs increased (Table 8, Figure 3) which suggests that Haplogonatopus sp. has an ineffective dispersal capacity. When parasitized by the dryinid second and third instar S. oryzicola nymphs rarely reached the adult stage, in my experiments. Parasitized fourth and fifth instar nymphs commonly reached the adult stage but were less preferred by the dryinid.

The large standard deviations observed for the relative abundance of S. oryzicola in the plots evaluated (Table 8) indicated that this pest has a contagious distribution (Southwood 1966). This suggests that for a cultivar like CR-1113 a failure of the natural enemies of S. oryzicola in spots in the field could result in pest outbreaks. In rice fields in Costa Rica, S. oryzicola outbreaks start in isolated spots even though the insect is present all over the field in colonies of different densities. Adkinsson and Dyck (1980) reported that cultivars with a moderate level of resistance have value in

an intergrated control system, but their success depends on their use in management systems which include other control measures. In my research, the results indicated that in the plots planted with CR-1113 which were undisturbed by insecticides, S. oryzicola abundance oscilated up and down through the sampling period, but never reached densities high enough to damage the rice plants. However, in greenhouse studies, CR-1113 permitted a population increase similar to that on the susceptible check Bluebonnet 50.

The frequency of parasitized S. oryzicola tended to be similar whether the pest density was relatively low or high which suggests a weak natural enemy-host numerical response relationship. This fact, together with the low percent parasitism (1.7 to 11.11%) found in this research, indicates that Haplogonatopus sp. is ineffective by itself in preventing a pest outbreak. However, Haplogonatopus sp. could be a good supplement to the activity of other natural enemies of S. oryzicola .

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