Variability in the Biology of the Yellow Stem Borer *Scirpophaga incertulas* from the Philippines

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Abstract

Six local strains of the yellow stem borer, Scirpophaga incertulas, *were collected from the field and reared in the susceptible variety IR62 at the same conditions in the greenhouse. Development time of the larvae from hatching to emergence was noted in the first to third generations (F_1-F_3). Sex ratios were recorded from the first three and twelfth generations. Significant difference in development among populations was observed although this varied from generation to generation presumably due to temperature effects in the greenhouse. However, no differences in development time between the two sexes, and no sex by population interaction were observed in all three generations in culture. It was concluded that sex was not a factor attributable to variations between populations. Primary sex ratios among the populations did not deviate from 1:1 although succeeding generations showed some minor variations.*

When five populations were allowed to develop in nine rice hosts, variation in pupal weights and development between the populations among different rice hosts was observed. Variation between the two sexes was not observed for pupal weights and developmental period. The host was observed to be a major factor for the differences in development among populations.

Key Words: *Scirpophaga incertulas*, sex ratio, Stem borer

Introduction

The yellow stem borer *Scirpophaga incertulas* Walker is one of the most important stem borers attacking rice (Miyashita, 1971). The adults show sexual dimorphism and are often mistaken for being two separate species. They mate early in the evening and deposit their eggmasses usually under the surface of the leaf (Van der Goot1948, personal observations). Upon hatching, the larvae bore to the stem. Usually a single larva completes its entire development inside one stem (Nickel, 1964, personal observations).

Agricultural practices influence the size of yellow stem borer populations (Saha and Saharia, 1970). It was argued that differences in agricultural practices also affect the evolution of *S. incertulas* populations. Studies conducted by Loehvinson (1989) in three fields in Central Luzon showed the importance of agricultural change in the dynamics of yellow stem borer populations, especially on the synchrony with which the crops were planted. His

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study demonstrated that areas with asynchronous planting of rice had been characterized by differences in the quality of populations that inhabit them as expressed by the variations in life history indices studied. Furthermore, his study suggests a genetic divergence in life history traits between areas separated by less than 13 kilometers of continuous rice land, thus indicating a relatively restricted dispersal of the species. We examined this hypothesis by studying the life history of yellow stem borer that originated from sites separated by short and long distances and which had different cultural practices.

Materials and Methods

Insect collection and maintenance. Colonies of yellow stem borers were collected in April 1991 from IRRI and Calauan in Laguna, Lian in Batangas, Zaragosa in Nueva Ecija, Banaue in Ifugao, and Ballesteros in Cagayan either by light trap, lights near houses, or were caught on leaves of rice plants where the moths often rest.

At IRRI, moths were collected from four light traps. The area in IRRI where the moths were collected is characterized by plots where different varieties of rice are planted throughout the year. IRRI has its own irrigation system to facilitate continuous supply of water throughout the season. Cultivation of rice in other fields in the vicinity of IRRI was, however, asynchronous. In this area, one can possibly find rice at all developmental stages at any time of the year.

In Calauan, the collection site was 10 kilometers away from IRRI. The fields characterizing the area were irrigated and the planting was asynchronous. The adjacent fields were observed to be planted with different rice varieties at different stages of development. Moths were collected from leaves of rice stubble in a newly harvested field and were placed in test tubes. In the evening, a light trap was set with a black cloth placed behind the light bulb. Moths found clinging to the cloth were collected using test tubes, brought to the greenhouse and allowed to lay eggs overnight on the leaves of TN1 rice variety.

The collection site in Batangas ricefields was bounded by mountains and was near the seashore and the ricefields were non-irrigated. Asynchrony of transplanting dates and a mixture of varieties were observed in the area. The moths were collected from light posts of houses.

The planting in the collection site in Zaragosa was asynchronous, with fields planted with different varieties at various phenological stages. Moths were collected from light posts and were allowed to oviposit on rice plants. The eggmasses were transported to IRRI and were allowed to hatch.

The Banaue site was situated in the mountain province. Traditional rice varieties were planted in rice terraces several kilometers above sea level. The area was colder and was characterized by synchronous planting. Moths were collected by light trap and from leaves of the growing rice plants.

The site in Cagayan was situated in the Northern tip of the Philippines. The rice fields in this area were non-irrigated and the stunted rice could be due to inadequate supply of water. Moths were collected during the day by looking at the base of the rice plants where the moths stay to protect themselves from the intense heat of the sun.

All hatched larvae were infested on susceptible IR62 rice cultivar. To facilitate moth emergence, the plants were cut at least 8 inches above the soil after 30 days. Emerging moths were monitored daily, sexed, and the development time of each was recorded. The monitoring of development of the populations was done up to three generations. Analysis of variance was conducted with generation, population and sex as main effects. F_1, F_2, F_3, and F_{12} generations of the insects in culture were monitored for sex ratios.

The first generation develoment time was observed in summer (late April to June, mean temp. = 28.83°C, rel. hum. = 79.67), second generation in rainy season (late June to August, mean temp. = 27.6°C, rel. hum. = 84.67), and the colder months of September-November for the third generation progenies (mean temp = 26.1°C, rel. hum. = 85.0) (IRRI Agrometeorological Station Report, unpubl.).

Experiment on developmental period of different rice cultivars/species. Five populations of the stemborer were allowed to feed and undergo development on nine selected rice cultivars/species utilizing nine thousand insects (4,500 for pupation and 4,500 for adult emergence). To minimize inter-individual variation, neonates from individual eggmasses were equally allocated to all nine rice hosts. Nine-hundred neonates were infested on rice tillers per population (100 neonates/host, 1 larva tiller) and were allowed to develop up to thirty days in time when the insects have already pupated. The pupae were dissected and immediately weighed. Pupal weight was one of the parameters used for developmental study because adult longevity and fecundity in insects is often correlated with size (Engelmann, 1970).

The other 4,500 insects were tested for emergence. The insects were allowed to emerge from the plants and the time of emergence of each was recorded. Analysis of variance was conducted with population and host as main effects.

Results and Discussion

Effect of generation time. Table 1 illustrates the differences among YSB populations in development times from neonate to adult emergence for three generations in culture. Analysis of variance of the data set indicates a major significant effect of population and generation time (Table 1). However, there was no effect of sex of the pest and population by sex, but strong interaction effect was observed on population by generation time.

Separate analyses within each generation have shown that sex was never a factor for differences in populations as there was no sex and sex by population interaction effects. This was also true when each population was analyzed for differences in development time from generation to generation (Table 1). This result indicates that the differences observed between populations was never due to variation in development of the two sexes.

The development time observed for each generation among populations differed. The first generation development time had shorter duration compared to the second and third generation (Table 1). It seems that temperature decrease and increasing relative humidity have affected the development time of the insects. Colder temperatures with high relative humidity have relatively increased the mean development time of the insects. Studies conducted by Korat and Patel (1988) have shown the importance of temperature in the development of the yellow stem borer. They have observed that insects allowed to develop at lower temperature had longer development time than those which were observed at higher temperatures. The differences observed among populations as shown in this study were affected by differences in temperature. The extent of the effects however differ from popula-

Table 1. Development time of selected strains of *S. incertulas*.

COLONY	GENERATION	MALE			FEMALE			MEAN* COMPARISON (HSD)**
		Range	Mean	N	Range	Mean	N	
IRRI.								
Laguna	First	37-48	42.30	387	37-48	42.26	424	B
	Second	33-43	36.84	37	33-43	37.67	64	C
	Third	40-60	49.38	155	39-61	48.86	195	A
Lian								
Batangas	First	37-44	40.42	34	39-44	40.31	38	C
	Second	35-47	41.38	37	34-48	42.03	46	B
	Third	39-56	49.00	66	38-56	48.65	94	A
Banaue.								
Ifugao	First	32-40	35.17	59	32-41	34.794	82	C
	Second	28-46	37.10	172	28-47	36.82	164	B
	Third	36-52	41.15	116	33-53	42.59	107	A
Ballesteros.								
Cagayan	First	30-40	33.54	12	28-40	33.33	16	A
	Second	36-45	39.17	23	36-43	39.56	16	A
	Third	30-48	38.51	128	30-51	39.74	123	A
Calauan.								
Laguna	First	31-40	35.07	79	31-40	34.73	102	C
	Second	36-44	39.66	113	36-44	39.33	60	B
	Third	31-43	37.81	21	31-44	36.91	23	A
Zaragosa.								
N. Ecija	First	34-42	37.38	93	34-45	38.61	104	B
	Second	41-44	42.00	11	39-44	42.00	25	A
	Third	36-50	41.84	85	36-49	41.77	87	A

ANOVA

Source	DF	MS	F	Pr > F
Generation	2	5174.257	466.56	0.0001
Population	5	2715.872	244.89	0.0001
Sex	1	12.741	1.15	0.2839
Population x sex	10	1046.084	94.32	0.0001
Population x generation	5	20.333	1.83	0.1029

* Includes both sexes

** Within each population

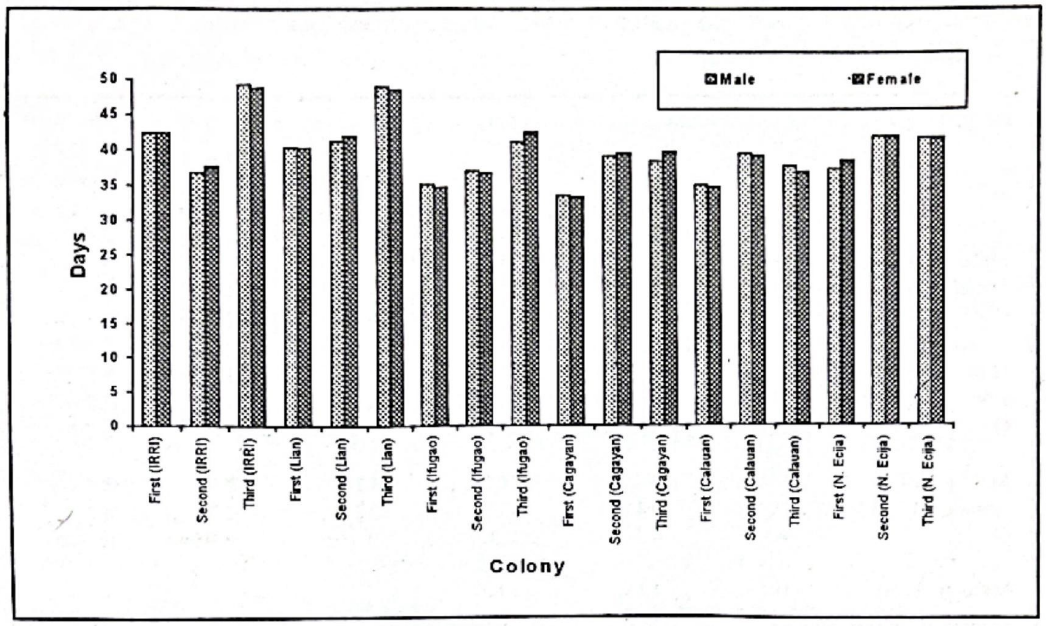

Figure 1. Development time of selected strains of *S. incertulas.*

tion to population and this could be inherent in the population itself. The increase in development time was observed to vary from 3-11 days (Table 1).

Comparison of means shows that the Batangas and IRRI strains have the longest development time (mean = 44.521, 43.726), followed by Cagayan (mean = 39.269) and Zaragosa (mean = 38. 491) which have shorter development time, while Calauan and Banaue have the shortest development time (mean 37.194, 37.698). There was no significant difference in development time of YSB from Calauan and Banaue which are hundreds of kilometers apart but not between YSB from Calauan and IRRI which are only approximately 5 kilometers apart. This result indicates that geographical distance is not a factor for differences observed between populations but could be genetic in nature.

Variation in emergence times observed in this study is generally dependent on geographical location. This is in conformity with several studies conducted on the pest collected from different areas in Asia (Sung Hui-Ying et al., 1968; Murthy and Perraju, 1969; Keizo et. al., 1956; Calora and Reyes, 1971; Shiraki, 1917; Rowan, 1923; Otanes and Sison, 1952; Puttarudriah, 1946; Banerjee and Pramanik, 1967; Korat and Patel, 1988).

Sex ratio. Qualitative inspection of the data shows that except for Cagayan and Calauan populations, there seems to be more females than males in the stem borer populations investigated. When statistically analyzed, however, only one population (Lian, Batangas) deviated from the 1:1 sex ratio where there seemed to be a selection in favor of the females as being continued to be reared in IR62 up to 12 generations (Table 2). The pooled G is significant indicating that populations deviated in the same direction favoring the female sex. Because the pooled frequencies were based on a large sample size, a high significant

Table 2. Sex ratios of selected strains of *S. incertulas.*

GENERATION	POPULATION					
	IRRI, Laguna	Lian, Batangas	Banaue, Ifugao	Ballesteros, Cagayan	Calauan, Laguna	Zaragosa, N. Ecija
Male (first)	387	34	59	12	79	93
Female (first)	424	38	82	16	102	104
G	1.68ns	0.22ns	3.77ns	0.57ns	2.93ns	0.61ns
Male (second)	37	37	172	23	113	11
Female (second)	64	46	149	16	60	25
G	7.31*	0.97ns	1.64ns	1.26ns	16.50*	5.58*
Male (third)	155	66	107	128	21	85
Female (third)	195	94	116	123	23	87
G	4.58*	4.93*	0.36ns	0.10ns	0.09ns	0.02ns
Male (twefth)	106	138	119			
Female (twelfth)	91	187	139			
G	1.44ns	7.42*	1.16ns			
Male (pooled)	685	275	457	163	213	189
Female (pooled)	774	365	486	155	185	216
G	1.43ns	12.69*	0.89ns	0.20ns	1.97ns	1.80ns

	POPULATION				
	First	Second	Third	Twelfth	Pooled
Total G	9.79ns(df=6)	1.40ns(df=6)	4.81ns(df=6)	3.37ns(df=3)	17.23(df=6)
Pooled G	7.29*(df=1)	33.3*(df=1)	10.08*(df=1)	9.72*(df=1)	9.51*(df=1)
Heterogeneity	2.50ns(df=5)	31.9*(df=5)	5.26ns(df=5)	5.98ns(df=2)	7.7ns(df=5)

*significant
ns- not significant
G- G-statistics

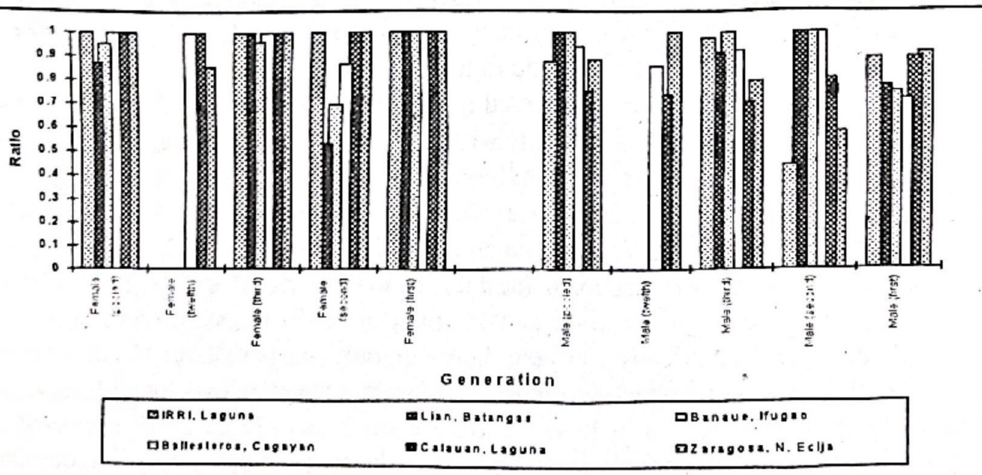

Figure 2. Sex ratios of selected strains of *S. incertulas.*

Table 3. Comparison of development time (days) of five selected strains of *S. incertulas* reared on different rice types.

		POPULATION					
HOST	Sex	Calauan Laguna	Banaue Ifugao	Zaragosa Nueva Ecija	Lian Batangas	IRRI Laguna	Average all strains
O. nivara	male	42.42±2.9	45.00±1.5	39.87±0.9	39.14±1.3	41.32±1.3	41.55±2.3
	female	46.33±3.2	50.50±5.5	40.20±1.3	40.78±1.4	46.17±1.2	43.17±3.7
O. Officinalis	male	41.21±0.9	44.50±2.1	38.36±0.1	40.08±1.2	43.83±0.9	41.60±2.6
	female	44.75±1.7	45.00±1.5	42.00±0.8	41.83±1.9	42.18±1.2	43.15±1.6
O. barthii	male	42.00±2.7	45.33±1.4	38.91±0.5	39.82±1.5	43.74±1.1	41.96±2.7
	female	44.80±1.3	ns	37.67±0.9	42.78±1.8	49.29±1.5	43.64±4.8
IR40	male	39.88±1.3	41.50±3.5	39.70±0.5	37.80±0.8	47.91±2.3	41.36±3.9
	female	39.71±1.1	44.67±3.3	42.00±0.4	39.25±1.1	50.86±2.3	43.18±4.5
IR56	male	43.92±1.6	43.33±3.2	40.23±1.1	40.08±1.0	46.78±1.1	42.87±2.8
	female	37.60±1.2	ns	41.25±1.3	40.61±1.2	46.71±1.4	41.54±3.8
IR62	male	45.67±1.4	45.33±1.2	41.33±2.3	44.25±1.8	48.50±2.0	45.02±2.6
	female	44.00±0.9	ns	47.00±0.0	42.60±1.7	53.63±2.6	46.81±4.9
WI253	male	42.60±3.2	ns	39.50±1.6	44.25±2.6	41.25±0.6	41.90±2.0
	female	43.67±1.9	42.33±0.9	39.25±1.5	47.67±1.5	45.25±1.6	43.63±3.2
C018	male	44.33±1.8	47.40±2.0	38.44±0.7	42.00±1.3	43.80±0.8	43.91±3.1
	female	47.67±4.1	ns	41.20±1.4	43.33±2.8	45.18±2.4	44.35±2.7
Rexoro	male	40.50±0.8	47.80±3.6	37.78±0.8	37.25±0.9	45.78±1.7	41.82±4.7
	female	44.43±1.4	46.00±3.5	39.00±3.0	37.50±0.7	48.18±1.5	43.02±4.6
Average for all hosts	male	42.50±1.8	45.02±2.0	59.35±1.1	40.52±2.5	44.77±2.6	
	female	43.66±3.1	45.70±3.0	41.06±2.7	41.82±2.9	47.49±3.4	

ns = no survivors

Figure 3. Development time of selected strains of *S. incertulas* on different rice types.

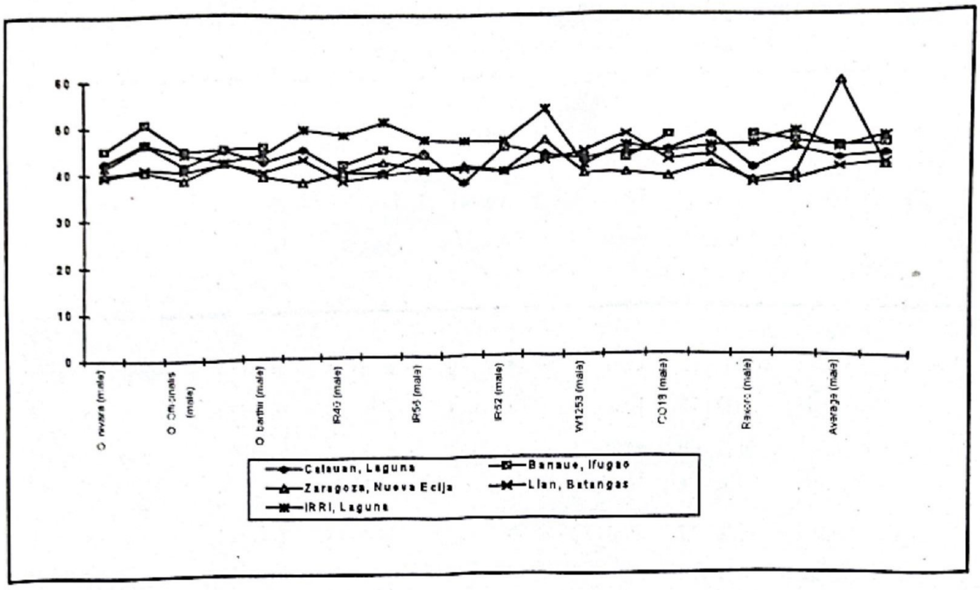

Table 4. Analysis of variance of total development time of five strain of *S. incertulas* reared on nine rice types.

SOURCE	DF	MS	F	Pr>F
Population	4	884.829	37.06	0.0001
host	8	49.885	2.09	0.0348
Sex	1	426.830	17.88	0.0001
Host x sex	8	28.903	1.21	0.2899
Population x host	32	58.227	2.44	0.0001

value was observed. When heterogeneity among populations was tested by subtracting the pooled G value from the total G value, no significance was observed indicating that the colonies did not differ in sex ratio.

Effect of rice cultivars/species on development time and sex ratios. Means and standard errors of development time of different populations of yellow stem borer on different rice cultivars/species are given in Table 3. Analysis of variance of development times shows significant population, host, and sex effects (Table 4). However, no significant sex x host interaction effect was observed indicating that within a population, both sexes develop similarly on each host. The strong sex effects observed in this study is an indication that between populations, the two sexes differ in performance resulting in differences in development time of the populations. The strong host x population effects indicate that the rice host was a major factor for the differences in development observed between populations.

Table 5. Comparison of sex ratios of five strains of *S. incertulas* reared on nine rice types.

POPULATION	SEX		SEX RATIO	N		DF	G	P
	Male	Female	Male: Female					
Banaue, Ifugao	34	14	0.708:0.292	48		1	8.592	<0.001
Calauan, Laguna	75	46	0.620:0.380	121		1	7.021	<0.001
IRRI, Laguna	150	120	0.555:0.444	270		1	3.034	ns
Lian, Laguna	81	74	0.523:0.477	155		1	0.316	ns
Zaragosa, N. Ecija	86	36	0.705:0.295	122		1	21.109	<0.001
	426	290	0.595:0.405	716	Total	5	10.378	<0.001
					Pooled	1	25.992	<0.001
					Heterogeneity	3	14.386	<0.001
Among hosts:								
O. nivara	45	25	0.643:0.357	70		1	5.838	<0.025
O. officinalis	76	46	0.623:0.377	122		1	6.855	<0.001
O. barthii	60	31	0.659:0.341	91		1	9.408	<0.01
IR	47	40	0.540:0.460	87		1	0.664	ns
IR56	59	48	0.551:0.449	107		1	1.134	ns
IR62	21	16	0.568:0.432	37		1	0.676	ns
W1253	18	27	0.400:0.600	45		1	1.814	ns
CO18	58	22	0.725:0.275	80		1	16.798	0.001
Rexoro	42	35	0.545:0.455	77		1	0.636	ns
	426	290	0.595:0.405	716	Total	9	49.284	<0.001
					Pooled	1	29.562	<0.001
					Heterogeneity	8	19.722	>0.025

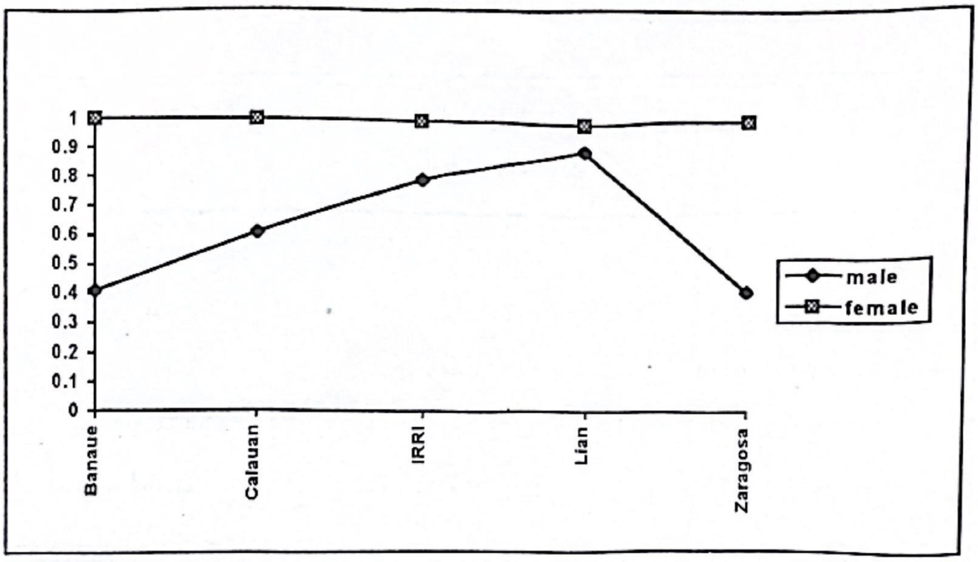

Figure 4. Sex ratios of nine populations of S. incertulas across all rice types.

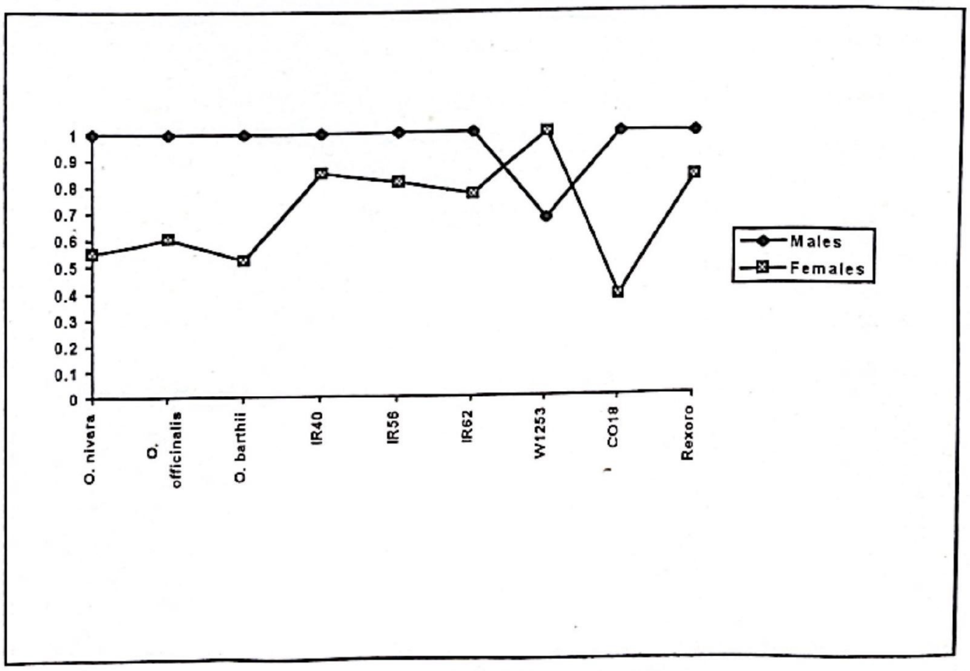

Figure 5. Sex ratios of S. incertulas reared on different rice types

For sex ratio, unlike the 1:1 ratio observed in culture, the sex ratios of the different populations on nine rice hosts showed significant heterogeneity (G = 14.386, P<0.001) (Table 5). All five populations investigated had excess in males although only two populations (IRRI and Batangas) showed significant deviations from 1:1 ratio. The pooled frequency was highly significant indicating that all the populations were deviating in the same direction favoring the male sex (Table 5). This is far different from that observed in culture. When sex ratios within hosts (all population fixed) were analyzed, it was shown that the rice host has a significant effect on the sex ratio of the pest (Table 5). For the three wild rices and one traditional cultivar, the sex ratio has significantly deviated from the 1:1 ratio favoring the males. However, in IRRI cultivated rices and in the traditional rice cultivars Rexoro and W1253, the ratio fitted the 1:1 expectation (Table 5).

The sex ratios of the different populations reported here which deviated from the expected 1:1 ratio favoring the males had no bearing on the variations observed on the emergence times between the populations investigated. The variations in sex ratios as shown in light trap collections favoring the female sex (Nagaraja Rao et al., 1962; Korat and Patel, 1988) were attributed to the high phototrophic nature of the female moths. There were reports that the sex ratio in emerging moths had higher proportion of males than females in light trap collections (Puttarrudriah, 1946) and in emerging moths from pupae collected from the field (Nagaraja Rao et al., 1962). These differences observed was hypothesized to be due to the nature of the rice varieties where the insects were sampled (Nagaraja Rao et al., 1962). The results of our study seem to confirm this hypothesis. The host cultivar is a major factor for the shifts in sex ratio from 1:1 to a ratio where more males develop. The shift is dependent on the quality of rice host, thus is more specific to some species/cultivars.

Conclusion

The results of this study have shown that differences in development times of the yellow stem borer is population specific. The quality of rice hosts has a significant effect on the development and sex ratios of the insects but the extent of its effects is population - dependent. Some populations grow faster in one rice host while other populations do not. There were hosts which increase the frequency of males like the wild rices, but there were those also which were never affected by the rice quality such as IRRI cultivated rices and the traditional W1253 and Rexoro. There were no clear-cut patterns on both development times and sex ratio of the insects as affected by the host and time frame. It seems that the variations observed in this study are population-dependent.

This information is important in host-plant resistance deployment. It is argued that events in colonization are characterized by cycles of host exploitation and subsequent mass migration to new resources. The success however of a colony is dependent, at least in part, on the ability to increase population number rapidly and thus produce a large number of potential founders. The intrinsic rate of increase is affected by environmental conditions and variations in rate increase exist among different populations. It seems arguable that in this study, the yellow stem borer populations in the Philippines have variations in terms of potential colonization of different rice hosts. The findings presented here show the role of rice hosts quality which may have the highest influence for the potential rate of increase of population numbers. The role of specific rice hosts in the shift of sex ratios favoring the males would ensure that females in a population will be mated and could lead to influence populations of the pests. This, however, is dependent on the nature of the population.

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