Dynamics of Philippine and Japanese Populations of the Brown Planthopper: Comparison of Basic Characteristics

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ABSTRACT

Population characteristics of the brown planthopper in the Philippines were analyzed on the basis of data from intensive population censuses in unsprayed paddy fields at or near The International Rice Research Institute, Los Baños. The results were compared with those obtained at the Kyushu Agricultural Experiment Station, Fukuoka, for a Japanese brown planthopper population. Remarkable differences were detected between the dynamics of these two populations, which are summarized as follows:

1. When compared with the Japanese population, the seasonal population pattern of the Philippine population is characterized by high initial density, low population growth rate, and an early density peak.
2. Correspondingly the distribution of individuals in a Philippine paddy field is much less clumped than in Japan, though it similarly shows a non-random pattern conforming to the negative binomial distribution.
3. Year-to-year and field-to-field fluctuations in population density are very large and essentially density-independent. This indicates that the brown planthopper in the tropics, as well as in Japan, is a typical "r-pest" making a sharp contrast to green leafhoppers, *Nephotettix* spp.
4. Proportions of macro- and brachypterous forms in Philippine adults fluctuate rather irregularly during a season, with a general tendency for macropters to dominate. This is because in the tropics, immigration of adults occurs irregularly from time to time throughout a season.
5. As predatory natural enemies, spiders (*Lycosa pseudoannulata*, etc.), a veliid, *Microvelia douglasi atrolineata* and a mirid, *Cyrtorhinus lividipennis*, are regarded as having major importance. Although the density of spiders is at a level roughly the same as in Japan, the densities of the latter two predators are much higher than in Japan. In particular, a high negative correlation was detected between *Microvelia* density and hopper population growth, indicating the critical importance of this tiny predator as a natural control agent of the brown planthopper in the tropics.

The possible causes and ecological implications of these differences in population characteristics are discussed with reference to the control of the brown planthopper in the tropics.

Introduction

The brown planthopper, *Nilaparvata lugens* Stål, is widely distributed in Asia, now being one of the most important insect pests of rice not only in Japan, a temperate country, but also in tropical and subtropical countries such as Indonesia, Philippines and Taiwan (e.g. Dyck *et*

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al., 1979). However recent studies such as that of Ôtake (1978) in Sri Lanka and of Kenmore (1980) in the Philippines have suggested that its populations in these tropical countries often show dynamical, characteristics that are quite different from those of well-clarified Japanese populations (Kisimoto, 1977; 1981; Kuno, 1979). A detailed elucidation of these characteristics for tropical populations would therefore be needed to establish the basic strategy for pest management of the brown planthopper populations in the tropics.

From this viewpoint we analyzed basic characteristics of the population dynamics of this insect pest at the International Rice Research Institute (IRRI), Philippines. On the basis of data from intensive population censuses, the analyses were made in such a way that they can be compared on the same quantitative basis with those for its Japanese populations that have already been made at Kyushu Agricultural Experiment Station, Fukuoka, Japan (Kuno & Hokyo, 1970).

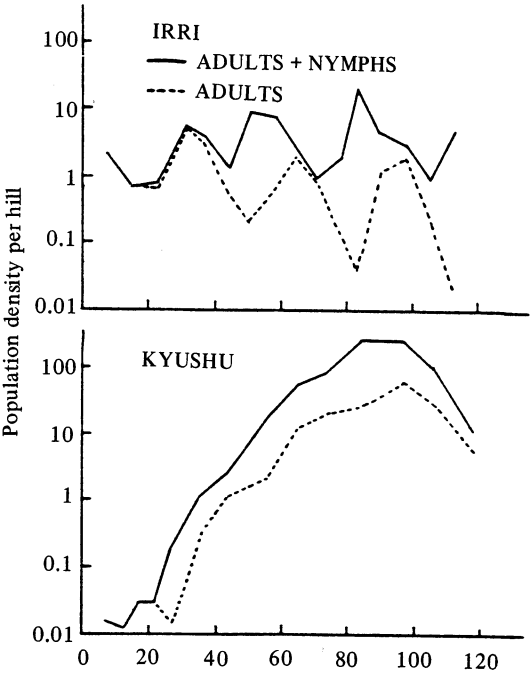

Fig. 1. Examples of population trends of the brown planthopper during one crop season at IRRI, Philippines (1979-80 dry season) and Kyushu Agric. Exp. Stn., Japan (1967).

Source of Data

The data analyzed here are those that were obtained from 7 plots of paddy fields at or near IRRI in different seasons (including both dry and wet ones) during 1978-1980. The area of each plot was about 1000 sq. m in area, having rice plants of variety IR 1917 or IR 20 (susceptible to the pest) grown as hills with a spacing of about 25cm. In all plots census was made at least once a week nearly throughout each rice growing season. The sampling unit was a hill, and either 20 or 40 hills were sampled systematically on each sampling date. Insects from each sampled hill were collected by IRRI's "FARMCOP" method (Cariño *et al.*, 1979), where, after the hill is covered with a fine mesh cage, all the insects on the plant and water surface are caught carefully using a car-battery suction machine. The insects thus collected were carefully identified and counted with a microscope.

Pattern of Seasonal Population Growth

Figure 1 shows temporal trends of adult and nymphal populations of the brown planthopper throughout one season in an IRRI field plot. For comparison a typical example of the seasonal trend of a Japanese population of the same species is also presented. Of course, large variations from field to field or from season to season in the pattern of seasonal population growth were observed. But beyond such variations the Philippine populations of the brown planthopper, as compared with Japanese ones, could definitely be characterized by: (1) high initial densities in paddy fields, (2) low growth rates thereafter, and (3) density peaks reached earlier in the season.

Quantitative analysis of the population

growth pattern was performed as follows: First the crop season under study was divided into 4 periods (I-IV), 11-35, 36-60, 61-85 and 86-110 days after transplanting, the length of each period corrsponding roughly to one insect generation. All census data for each period of each season were then pooled to calculate the overall average density per hill for that period. Although tropical brown planthopper populations generally have overlapping generations which are difficult to discriminate, the above procedure made it possible to treat their growth on a generation-to-generation basis and so comparable to existing data for Japanese populations.

The density values for each period were log-transformed and then used to draw the representative pattern of seasonal population growth as the average of the 7 plots studied (Fig. 2; solid line). The initial population level of the brown planthopper at IRRI is several tens times as high as that of the same species in Kyushu, that its growth stops as early as the second generation, and that the overall rate of population growth till the peak or the second period is only 3 or so, in contrast to the value as high as 500 (or 8 even per generation) for the Kyushu population (see also Table 3).

Pattern of Spatial Distribution

Analysis of spatial characteristics of a population was made using the data from one IRRI plot taken in the 1979-1980 dry season where 40 hills were sampled each time and the insect reached a moderate density level.

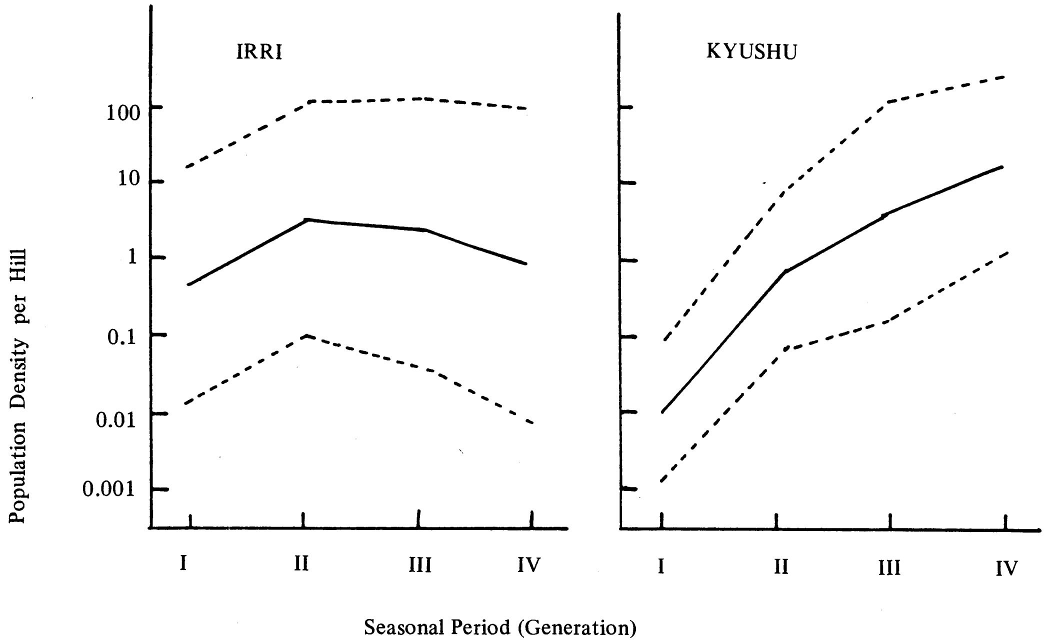

Fig. 2. Average pattern of seasonal population growth (solid line) and the magnitude of season-to-season or field-to-field fluctuation at each seasonal period or generation (broken lines) (see text for details).

The general pattern of frequency distribution of the number of individuals per rice hill was analyzed by means of some statistics (Table 1). The conclusions reached are that 1) distribution was generally clumped, the departure from randomness (as measured by variance/mean ratio) being in many cases statistically significant, 2) the pattern as frequency series can be fitted invariably to the negative binomial distribution, the values of Anscombe's (1950) parameter, $T/\sqrt{V(T)}$, rarely exceeding ±1.96, and 3) the value of parameter k of the negative binomial remains relatively stable among different samples. These conclusions conform exactly to

Table 1. Some Distribution Statistics of the Brown Planthopper Population at IRRI (1979-80, dry season) (based on total counts of adults and 3rd-5th instar nymphs)

Days after transplanting	n	$\bar{x}$	s^2	$\hat{\mu}_3$	s^2/x	$T/\sqrt{V(T)}$
24	50	0.84	1.04	1.05	1.23	-0.87
31	50	5.70	8.09	11.18	1.38*	-0.41
37	50	3.70	6.58	12.73	1.78**	-0.51
44	50	1.36	1.83	2.34	1.34	0.26
50	49	9.86	52.04	512.11	5.28**	0.06
58	50	7.94	43.73	549.81	5.51**	0.52
64	50	3.18	4.27	5.83	1.34	-0.38
71	50	0.98	0.92	0.87	0.94	0.26
78	50	1.98	2.51	3.73	1.27	-0.07
83	50	22.08	135.30	1271.70	6.12**	-0.31
90	50	4.68	9.12	15.85	1.93**	-0.81
98	50	3.20	6.33	12.19	1.98**	-0.76

* and ** indicate significant departures from the random (Poisson) distribution with P smaller than 0.05 and 0.01, respectively.

those for the Kyushu population so far derived (Kuno, 1963; 1968).

A marked difference, however, between the IRRI and Kyushu populations in the degree of aggregation or clumpedness in terms of 1/k was found, the IRRI population being characterized by a much less clumped pattern of distribution as compared with the Kyushu one (Table 2). This difference in distribution can be seen more clearly in Fig. 3 where the relation of Lloyd's (1967) mean crowding (m*) to mean density (m) is shown for both populations.

Table 2. Weighted Estimates of the Parameter 1/k of the Negative Binomial with Confidence Intervals for P=0.95 (based on Bliss and Owen's (1958) method)

IRRI (1979-80)	0.282 ± 0.101
Kyushu (1967)	0.824 ± 0.194

Population Stability and Density-Dependence

The variability of the brown planthopper population among different fields and/or years were analyzed. It is expressed in Fig. 2 (broken lines in a pair) as the range of mean ±1.96 $\sqrt{\text{variance}}$ (i.e, the expected fluctuation range for P=0.95). It is clear that despite the difference in the seasonal growth pattern, high variability or low stability is a common feature of both Kyushu and IRRI populations, the ratio of maximum to minimum level amounting sometimes to as high as about 1000. It is also noticed that the magnitude of density fluctuation has a common tendency to increase in later generations in both populations.

To examine the contents of these large fluctuations, the dependence of population growth on density was then analyzed on the basis of the regression of log overall population growth rate from the initial period (generation) to the peak one (period II for IRRI and IV for Kyushu populations) on the density at the former. No significant departure of the coefficient b from unity could be detected in the regression in either case (see Table 3), indicating that the growth process of both the populations was essentially density-independent. It may thus be concluded that the tropical brown planthopper population at IRRI, as well as the Japanese population, mainatains the definite

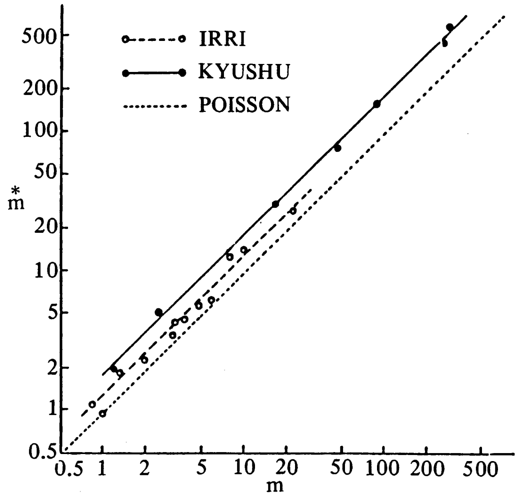

Fig. 3. Relation of mean crowding (m*) to mean density (m) (log scale) in the brown planthopper populations at IRRI (1979-80 dry season) and Kyushu Agric. Ex. Stn. (1967). Straight lines show the theoretical relations for the negative binomial, log m* = log (1+1/K) + log m, drawn using the 1/K values of Table 2.

characteristics of an outbrak-type pest, i.e., high variability and density-independence.

Proportions of Macro- and Brachypterous Adults

The brown planthopper has two wing-forms in the adult stage, macropters which fly and brachypters which do not. The former usually dominate when living conditions become adverse (e.g. Kisimoto, 1956).

In the Japanese populations the prevalence of these wing-forms in the field usually shows a definite seasonal pattern. Namely, the proportion of macropterous females drastically decreases from the initial invasion period to the following period of early population growth, and then increases gradually as the generation proceeds toward the end of the season with increasing density and host senescence. In the case of males the peak of brachypter appearence comes later, in the third generation, reflecting the property that they usually dominate when conditions are moderate.

Such a definite pattern could not, however, be detected in the case of the IRRI population, the proportions of different wing-forms showing rather irregular variations among different periods, fields or seasons (Table 4). Also, apart from such an irregularity and unlike Japanese popullations, macropters have a tendency to dominate throughout the breeding season. This may be because in the tropics, invasion of macropterous migrants into the field occurs irregularly throughout a rice growing season.

Table 3. Comparison of Population Characteristics of the Brown Planthopper Between Philippine (IRRI) and Japanese (Kyushu) Populations

	Average initial density[1]	Average peak density[2]	Fluctuation in peak density	Peak generation (period)	Average rate of population growth[3] overall	per gen.	Density dependence in population growth[4]
IRRI	0.367	2.99	0.163 ~ 62.5 (383.)	II	3.20	3.20	0.926 ± 0.358
Kyushu	0.0105	19.5	3.35 ~ 214.9 (64.1)	IV	513	8.01	0.946 ± 0.805

1. Density of adults / hill.
2. Density of adults + 3 -5th instar nymphs / hill.
3. Net growth rate for adult population.
4. b - values (slope) of the regression of log density of peak generation (period) on that at the initial one.

Populations of Predatory Natural Enemies

The census data analyzed here include counts of major predatory natural enemies of the brown planthopper: several species of spiders such as *Lycosa pseudoannulata,* a veliid, *Microvelia douglasi atrolineata* which attacks

Table 4. Percentage of Adult Macropters in Philippine Populations

Population		Period				Density range (initial ~ peak) (no./hill)
		I (11 ~ 35)*	II (36 ~ 60)	III (61 ~ 85)	IV (86 ~ 110)	
A	♀	95.5 (22)	77.4 (53)	72.0 (118)	61.9 (21)	0.44 ~ 8.07
	♂	100 (2)	89.3 (28)	91.9 (62)	77.8 (9)	
B	♀	62.9 (35)	87.8 (41)	100 (5)	0 (2)	0.49 ~ 3.03
	♂	100 (1)	83.3 (30)	100 (4)	–	
C	♀	100 (3)	57.1 (28)	81.8 (11)	–	0.23 ~ 1.52
	♂	100 (2)	33.3 (6)	100 (1)	–	
D	♀	100 (4)	61.7 (60)	28.4 (208)	91.9 (396)	0.17 ~ 51.64
	♂	100 (8)	100 (16)	49.7 (169)	95.6 (158)	
E	♀	100 (4)	100 (22)	42.9 (7)	75.0 (4)	0.03 ~ 0.34
	♂	100 (1)	100 (4)	40.0 (5)	100 (1)	
F	♀	99.8 (532)	87.4 (2009)	69.1 (392)	42.9 (7)	7.94 ~ 62.52
	♂	100 (503)	93.8 (1765)	86.2 (218)	85.7 (7)	
G	♀	100 (304)	77.9 (163)	15.2 (112)	5.7 (123)	2.40 ~ 6.95
	♂	100 (136)	78.6 (56)	36.0 (25)	13.9 (36)	

Numerals in parentheses are the total numbers examined.
*Days after transplanting

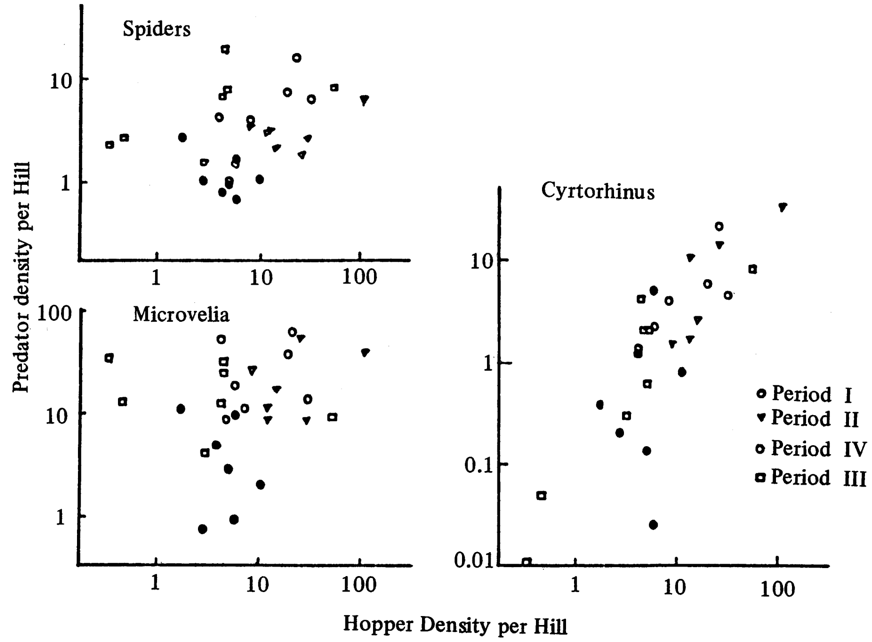

Fig. 4. Relation of population density of different predators to total density of leaf- and planthopper populations at each seasonal period at IRRI.

young nymphs, and a mirid, *Cyrtorhinus lividipennis* which is an egg predator. Such predators are common to both tropical and temperate regional populations of rice planthoppers (e.g. Kuno, 1968; Chiu, 1979; Kenmore, 1980).

Figure 4 shows the population densities (including adults and nymphs) of these predators at each seasonal period for each field or season, in relation to the density of all rice leaf- and planthoppers at that period.

The density of all spiders ranges usually from 1 to 10 individuals per hill, the population levels being roughly similar to those in Kyushu (Kuno, 1968). The population densities of the other two predators, *Microvelia* and *Cyrtorhinus,* are, in contrast, far higher than in Japan, sometimes reaching a level as high as 100 individuals per hill.

Of these predators *Cyrtorhinus* shows the highest positive correlation or numerical response to prey density, inicating that its population is largely dependent on leaf- and planthopper populations. Spider populations also show such a correlation, although much less conspicuous, except for the initial period. Virtually no numerical response can be detected in the case of *Microvelia.*

To examine the effect of these predators on planthopper population dynamics, planthopper population change rates from one period to the next were plotted against the densities of each predator in the previous period (Fig. 5).

Contrary to the numerical response seen in Fig. 4, the closest negative correlation in this analysis is observed in *Microvelia,* suggesting that this tiny predator is an important factor controlling the brown planthopper population in the tropics. Experimental support for this suggestion has been obtained by Nakasuji and Dyck (1984). No such clear correlation can be seen for spiders or *Cyrtorhinus.* It is therefore

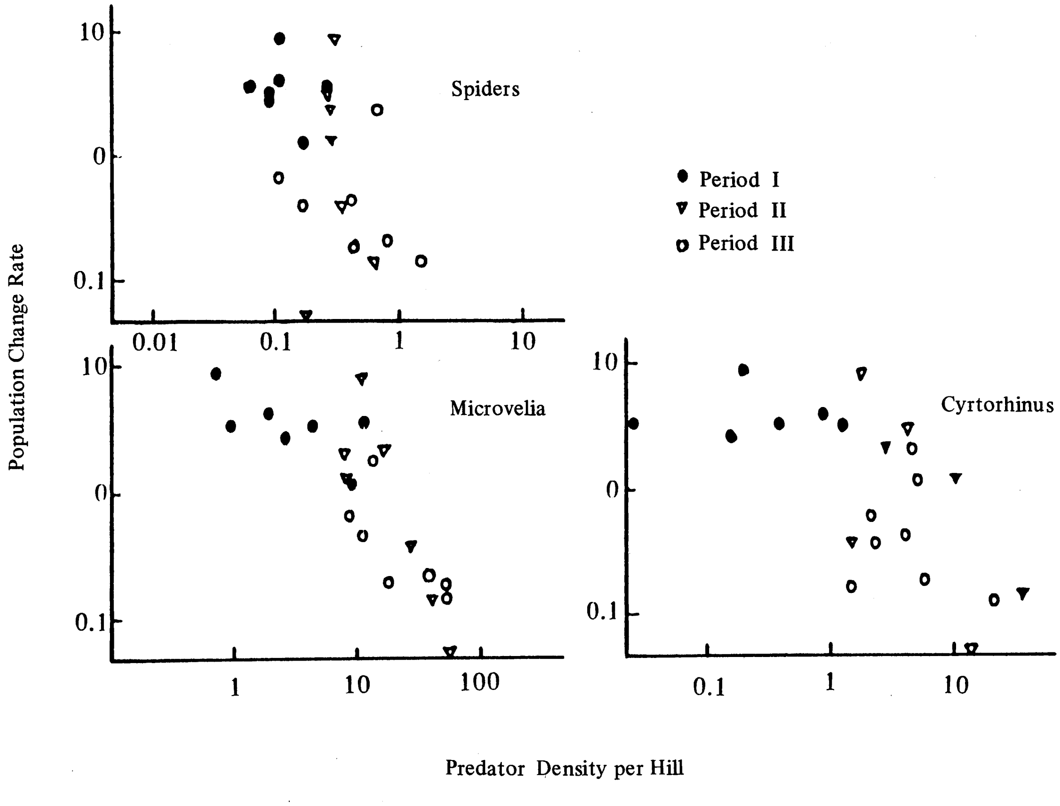

Fig. 5. Relation of population change rate of the brown planthopper from a given seasonal period to the next to population densities of different predators in the previous period at IRRI.

unlikely, despite their rather high densities, that they act as key factors in the population fluctuation of the brown planthopper.

Discussion and Conclusions

We have noted that the IRRI population of the brown planthopper in the Philippines has quantitative properties that are quite different from those of the Kyushu one in Japan (see Table 3 for summary). Among these differences the higher initial densities and the more predominant and consistent appearance of macropterous adults throughout the season may be explained by the IRRI population's status as an indigenous population, while that of Kyushu is fundamentally a temporary fringe population starting its is growth every year from a few overseas immigrants. The more aggregated spatial pattern also is simply explained as a natural statistical outcome of the higher rate of random immigration (Kuno, 1977).

The much lower population growth rates of the IRRI population, on the other hand, may be partly explained by the difference in predation pressure, especially by *Microvelia douglasi* which seems to be much less effective in Japan as a controlling agent of the planthopper. However, in view of the fact that there was no marked difference between IRRI and Kyushu in the density of spiders, which are a most dominant group of predators in paddy fields, it is difficult to explain such a wide difference in population growth rate by differential action of natural enemies alone. There may also be a marked difference in the fecundity of field populations due to either different climatic conditions or different rice varietal types. This has been suggested by life table analyses so far made in both places (Kuno and Hokyo, 1970; Kenmore, 1980), but more detailed comparative studies are needed to confirm this explanation.

In this study we have treated the IRRI population of the brown planthopper as a representative of tropical populations, assuming that the basic conclusions obtained here may apply widely to other tropical areas as well. But no doubt wide diversity in quantitative population characteristics also exist among populations in different regions, since they are subject to varying environments with respect to climate, natural enemies, cultural practices, host plant variety, etc. For further development of the study the analysis should therefore be extended delete to planthopper populations in various other regions. It may be particularly important to study detailed population characteristics in subtropical areas like Taiwan; such studies could bridge the gap between the results obtained in Japan and the Philippines.

Finally, it should be stressed from both ecological and practical viewpoints that despite such apparent large differences in population characteristics, the fundamental population features of an outbreak-type pest or so-called r-epest (Southwood, 1977), i.e. high variability and density-independence, is seen in both the IRRI and Kyushu populations of the brown planthopper as a definite characteristic of the species. It follows that the basic principles of efficient management of this pest suggested in Japan (e.g. Kisimoto, 1977; Kuno, 1984) are applicable to other regions as well, provided that necessary data on local population parameters are obtained through intensive field studies.

REFERENCES

1. Anscombe, F.J. 1950. Sampling theory of the negative binomial and logarithmic series distribution. *Biometrika,* **37,** 358-382.
2. Bliss, C.I. and A.R.G. Owen. 1958. Negative binomial distribution with a common k. *Biometrika,* **45,** 37-58.
3. Cariño, F.O., P.E. Kenmore, and V.A. Dyck. 1979. The FARMCOP suction sampler for hoppers and predators in flooded rice fields. *Int. Rice Res. Newsl.,* 4(4), 21-22.
4. Chiu, S.C. 1979. Biological control of the brown planthopper. In *Brown Planthopper: Threat to Rice Production in Asia,* pp. 335-355, IRRI, Philippines.
5. Dyck, V.A., B.C., Misra, S. Alam, C.N. Chen, C.Y. Hsien, and R.S. Rejesus. 1979. Ecology of the brown planthopper in the tropics. In *Brown Planthopper: Threat to Rice Production in Asia,* pp. 61-98, IRRI, Los Banos, Philippines.
6. Kenmore, P.E. 1980. Ecology and outbreaks of a tropical pest of the green revolution, the brown planthopper, *Nilaparvata lugens* (Stål), Ph. D. Thesis, Univ. California, Berkeley.
7. Kisimoto, R. 1956. Effect of crowding during the larval period on the determination of the wing form of an adult planthopper. *Nature,* **178,**

641-642.

8. Kisimoto, R. 1977. Bionomics, forecasting of outbreaks and injury caused by the rice brown planthopper. In *The Rice Brown Planthopper,* pp. 27-41, Food and Fertilizer Technology Center for the Asian and Pacific Region, Taipei.
9. Kisimoto, R. 1981. Development, behaviour, population dynamics and control of the brown planthopper, *Nilaparvata lugens* Stål. *Rev. Plant Protec. Res.,* **14,** 26-58.
10. Kuno, E. 1963. A comparative analysis on the distribution of nymphal populations of some leaf- and planthoppers on rice plant. *Res. Popul. Ecol.,* **5,** 31-43.
11. Kuno, E. 1968. Studies on the population dynamics of rice leafhoppers in a paddy field. *Bull. Kyushu Agric. Expt. Sta.,* **14,** 131-246.
12. Kuno, E. 1977. Distribution pattern of the rice brown planthopper and field sampling techniques. In *The Rice Brown Planthopper,* pp. 135-146, Food and Fertilizer Technology Center for the Asian and Pacific Region , Taipei.
13. Kuno, E. 1979. Ecology of the brown planthopper in temperate regions. In *Brown Planthopper: Threat to Rice Production in Asia,* pp. 45-60, IRRI, Philippines.
14. Kuno, E. 1984. Pest status, dynamics and control of the rice leaf- and planthopper populations in Japan. *Prot. Ecol,* **7,** 129-145.
15. Kuno, E. and N. Hokyo, 1970. Comparative analysis of the population dynamics of rice leafhoppers, *Nephotettix cincticeps* Uhler and *Nilaparvata lugens* Stål, with special reference to natural regulation of their numbers. *Res. Popul. Ecol.,* **12,** 154-184.
16. Lloyd, M. 1967. Mean crowding. *J. Anim. Ecol.,* **36,** 1-30.
17. Nakasuji, F. and V.A. Dyck.1984. Evaluation of the role of *Microvelia douglasi atrolineata* (Bergroth) (Hemiptera: Veliidae) as predator of the brown planthopper, *Nilaparvata lugens* (Stål) (Homoptera: Delphacidae). *Res. Popul. Ecol.,* **26,** 148-163.
18. Ôtake, A. 1978. Population characteristics of the brown planthopper, *Nilaparvata lugens* (Hemiptera: Delphacidae), with special reference to differences in Japan and the tropics. *J. Appl. Ecol.,* **15,** 385-394.
19. Southwood, T.R.E. 1977. Entomology and mankind. *Proc. 15th Congr. Ent.,* pp. 36-51, Washington.

Insecticide Resistance

Nagata: strongly urged a standard method for testing the R be adopted, recommended topical application for comparison purpose.

Sun: a method is adopted taking into considerations of various needs and the facilities available. will consider shifting from spraying to topical application.

Wang: both methods were used this year for the test. (PPC)

Wang: (Academia Sinica) Devonshire reported in the 60's that topical application was the good for smallsized insects. Don't you think that Sun and Ku's methods were more close to the field conditions?

Nagata: For comparison purpose, one method must be adopted. If this is so, topical application is the best method to choose.

Cheng: For water soluble insecticides, topical application is not good.

Nagata: That is right. Nevertheless, I would like to stress that for comparison purpose, we must choose one method. Most insecticides are soluble in organic solvent while only very few are soluble only in water, such as Padan.

Sun: Mixtures have been used very extensively for BPH control. I personally wonder the logics behind it. Is it still in fashion in Japan?

Nagata: It is still in fashion, though people do not think that it is a promising way to cope with the resistance problem as they did before. I personally do not think it will be helpful as fas as resistance is concerned.

Population Dynamics

Kishimoto: have three recommendations for future work:

1. surveys should be done every 3 days.
2. should determine the number of each stage after 4th nymphs, no. of adults and wingform, long wing female whether preganant or ready to migrate.
3. natural enemies

may use artifioal infestation.

Cheng: difficult to determine the initial population, some come with the seedlings, some infest after transplanting. peak of migration occurs 3 weeks after transplanting.

Kisimoto: smaller BPH: mainly due to migration.

Lin: as a biometrician, I do not see how forecasting is possible. According to my analysis, there was 22% unknown components in forecasting model. In addition, sampling unit is difficult to define to maintain level precision.

Kisimoto: But we biologists still think it is feasible to forecast. There is a discrete begining – the migration of BPH.

Chen: sampling is difficult due to shottage of manpower. the population of natural enemies is difficult to estimate.

Kisimoto: I mean you can make survey every 3 days only in the critical period, not throughout the entire rice growing period. Furthermore, the dispersion of BPH in the field in Taiwan is more even than in Japan. Therefore, I think it is possible for you to decrease sampling number.

Year-round Life History

Kisimoto: In Japan, this topic has gone through discussion for 40 years. There were laboratory evidences supporting overwinting of BPH in Japan. From physiological point of view, overwinter is possible. Some reported eggs overwintered on ration. The adults emerged next April. However, this was useless because of a lack of host plant. Overwinter was also observed around hot springs. However, the long-winged adults dispersed. In Taiwan, the possibility for physiological overwintering is higher. But I wonder if there is ecological overwintering – if there is provision of the environmental requirements.

Nagata: suggest to obtain some BPH from

Kimmen, Matsu islands where small areas of rice paddy exist.

Kisimoto: The Townnet seems too long in Taiwan. Long net will not work when the wind is light. I think lightwind blowing for 1-2 days will be able to carry the BPH. There are two peaks of BPH collected in Taiwan: May-June, September-October. Think the first peak is due to overwintering population, the second peak due to migration carried by north west wind. Any information of the wind direction during these months?

Answers: unclear.

Kisimoto: I do not think there is much genetic difference between Japan and Taiwan popuoations.

Much work was done in Japan 10 years ago in these respect. Some reported morphological differences among the Japanese populations. This was eventually proved wrong. In Kyushu, some reported different response of BPH to germinating onion seedlings. I did not believe in it. If one starts out to look for difference, one will tend to find this difference. It is usually difficult to find there opposite. Depending too much on morphological difference is pitiful.

Liu: July 6-8, 1982, large collection of BPH appeared in Makung. Did the Japanese find similar trend?

Fukamachih: Yes, in Kyushu. The depression (22°N) during those days went through Taipei to Kagoshima. This caused heavy grassy stunt. (from the tropics)

Chen: % of grassy stunt occurrence in Taichung for several years. In Taichung, no special occurrence of this disease observed in 1982. But the symptoms of grassy stunt in Taiwan and Philippines are different. wilt for Taiwan and excessive tillering for the latter type.

Kisimoto: There are 3 routes for migration Major routes): one: Taiwan to Okinawa, two: okinawa to Amami belts, three: Amami to Japan. Not the same routes cover Taiwan and Japan at the same time. If there is, it must be irregular and minor route.

Early of the season, the route is more down south. Later, it goes northward. The third comes from the south from the Philippines.

Fukamachi: Grassy stunt symptoms in Kagoshima is similar to those of the Philippines. I, yet, did not observe the virus particles in the plant, I observed only the symptoms.

Chu: There should be a time lag of the disease infestation.

Geographic Variations

Kisimoto: 1. morphological: needs careful statistical analysis. subtle changes of food, nutrition, environments will cause morphological difference.

2. physiological characteristics. still depends on the rearing conditions. Therefore, must standardize the

@ rearing techniques.
@ isozyme patterns, wing form production also affected by the rearing conditions. temp. food, density.
@ transmission of diseases.