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Population Dynamics of the Brown Planthopper in the Coastal Lowland of West Java, Indonesia

Hiroichi SAWADA*, S. W. Gaib SUBROTO, Edi SUWARDIWIJAYA**, MUSTAGHFIRIN** and Ayi KUSMAYADI*****

*, *** Directorate of Food Crop Protection (Pasar Minggu, Jakarta, Indonesia)
** Jatisari Pest Forecasting Center (Jatisari, Karawang 41374, West Java, Indonesia)

Abstract

Population dynamics of the brown planthopper (BPH), Nilaparvata lugens Stal, was investigated at nine study sites in the irrigated coastal lowland of West Java, Indonesia, where rice was cultivated under intensive modern agricultural practices. The BPH populations in this region were definitely characterized by the low initial immigrants in a year, followed by the subsequent high population growth. In the wet cropping season in particular, populations multiplied about 2,000 times in size in the period from initial to 2nd, or peak, generation, reaching quite often the destructive level despite their low initial densities. In the dry cropping season, however, the levels of the population growth rate and the peak population densities were much lower than those in the wet crops. The abundance of natural enemies such as arthropod predators and parasitic wasps played a major role in determining the population level in the peak generation in the two cropping seasons. The densities in the peak generation were predictable with fairly high accuracy on the basis of the densities of the initial or previous seasonal generation in the wet crops. In the dry crops, in contrast, the population growth rate widely varied depending on the condition of water-supply to each paddy field, which exerted a major influence on the BPH population fluctuations among the fields.

Discipline: Insect pest
Additional key words: driving factor, natural enemy, population fluctuation, population level, rice

Introduction

Brown planthopper (BPH), *Nilaparvata lugens* Stål, is a major pest of rice widely distributed in Asia. In Indonesia, the pest annually caused destructive infestations to rice fields extending to 300,000–800,000 ha in the late 1970s[3,14], when the nation-wide endeavors toward self-sufficiency in food through the national rice intensification program were seriously discouraged[15]. The threats took place successively in the 1980s; serious outbreaks occurred in North Sumatra in 1982–1983, Central and West Java in 1986–1987, and East Java and Lampung in 1987–1988.

BPH became a major pest accompanied by the introduction of high-yielding rice varieties and modern cultivation technologies during the green revolution period. Predominance of high-yielding varieties, areal expansion of irrigation systems and double cropping, and increased use of nitrogen fertilizers and insecticides have caused an enormous increase in BPH populations[4,6]. This paper describes BPH population dynamics in the irrigated coastal lowland of West Java, where rice is cultivated with intensive modern agricultural practices under the BPH threats in rice fields every year.

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* Present address: Faculty of Agriculture, Kyoto University (Kitashirakawa, Kyoto, 606 Japan)

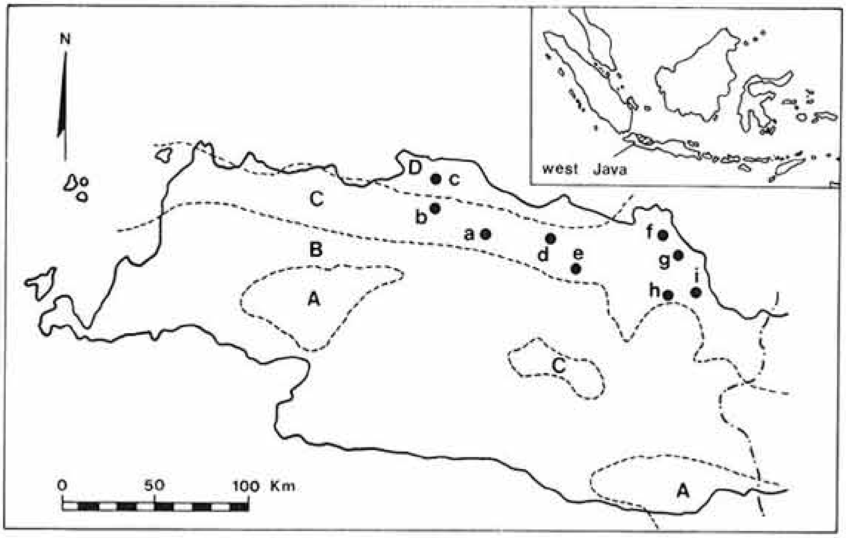

Fig. 1. Locations of 9 study sites (a–i), and the climatic zone in West Java (A–D) A, B, C and D show the area with >9, 6–9, 3–5 and <3 wet months (>200 mm rainfall per month) in a year, respectively.

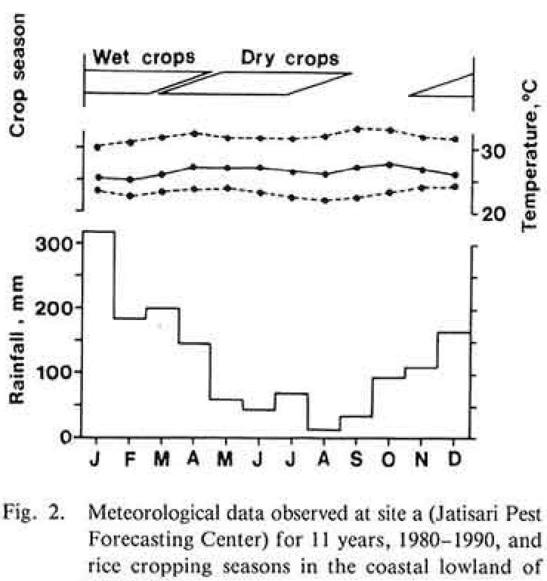

Fig. 2. Meteorological data observed at site a (Jatisari Pest Forecasting Center) for 11 years, 1980–1990, and rice cropping seasons in the coastal lowland of West Java

Histogram shows the mean monthly precipitation. Solid and broken lines show the mean, and maximum and minimum monthly temperatures, respectively.

Study area and methods

The coastal lowland of West Java containing 460,000 ha of rice fields is an advanced area in terms of the adoption of modern rice technologies under a large-scale irrigation system. The study was carried out at 9 selected plots distributed in open paddy fields in this area (Fig. 1). It was implemented in the two rice cropping seasons, i.e. in the 1984/85 wet (December 1984 to March 1985) and 1985 dry (April to August 1985) seasons. Although rice cultivation started soon after harvesting of the wet season crop, a fallow period was clearly interposed after the dry cropping season through the water management of the irrigation systems. It lasted for approximately two months from October to November (Fig. 2). The rice fields were almost completely dried up in the fallow period, when BPH could not survive. It was presumed that BPH populations most probably re-invaded in every wet cropping season from southern, mountainous areas, where rice was continuously cultivated throughout the year.

Size of the study plots was 20×50 m^2 at site a, an experimental field of Jatisari Pest Forecasting Center, or 20×30 m^2 at the other 8 sites in farmers' paddy fields, where a susceptible variety, Pelita I/1, was hill-planted with a spacing of 25 cm. Cultural practices generally followed the standard procedures employed in this region, except that no pesticides were applied in the study. Routine censuses to

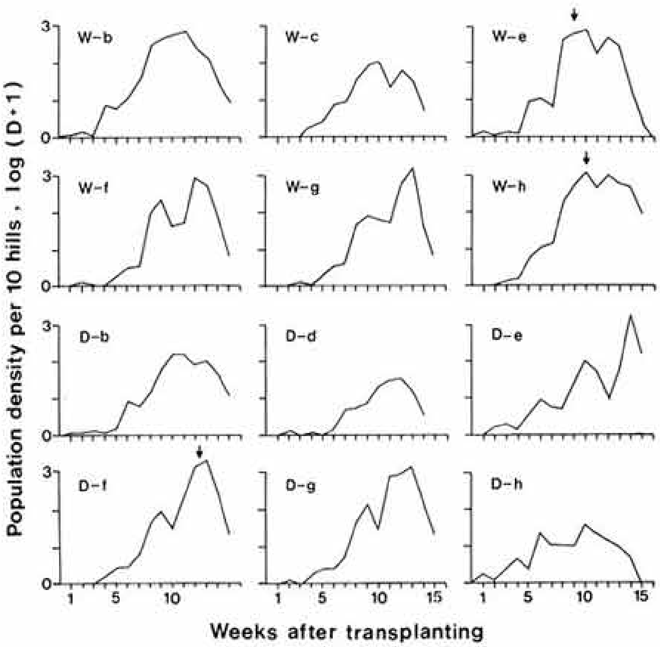

Fig. 3. Examples of the seasonal trend of the BPH population
Sum of adults and 4–5th instar nymphs in the fields, in 1984/85 wet (W) and 1985 dry (D) cropping seasons. Arrows show the occurrence of BPH outbreaks.

estimate population incidences were conducted at a weekly interval throughout the rice growing season. All the insects inhabiting rice plants and water surface were collected with a car-battery suction machine under covering over the hills with a transparent plastic cage. The insects thus sampled were carefully identified and counted under a microscope[9].

Seasonal development of the BPH populations

Seasonal changes of the BPH populations in paddy fields are presented in Fig. 3, which shows variations in the sum of adults and 4–5th instar nymphs. During the first 4–5 weeks after transplanting, macropterous adults that apparently immigrated from the neighboring areas were dominant, though some brachypterous adults that probably originated from the eggs oviposited in the nursery bed were also observed (Table 2). After the small peak of the initial immigrants, three distinct peaks were usually observed at a 3–4 week interval, which corresponded to a period of approximately one BPH generation in the tropics[10]. This may suggest that the population peaks imply generation peaks. Macropterous adults may easily disperse from one field to another, thereby they may cause overlapping generations in BPH populations. However, most BPH populations in Indonesia and other Southeast Asian countries show rather discrete generation cycles[5,9]. This might be caused, at least partly, by the preference of macropterous adults to young rice plants.

The representative population densities were estimated for each seasonal generation by a graphical method[16] based on the population trends shown in Fig. 3 (Table 1). The BPH populations in this region are definitely characterized by the low density of immigrants and the subsequent high population growth. In the wet cropping season, BPH populations multiplied with a great increasing rate, i.e. about 2,000 times in size (91.5 × 27.4 as indicated in Table 1) in the period from initial to 2nd, or peak, generation. After that increase, serious outbreaks took place rather often in the late cropping season, in spite of the low densities of initial immigrants. These patterns of BPH population development are very

Table 1. Population density in each seasonal generation and population growth rate between the two successive generations in 1984/85 wet and 1985 dry cropping seasons

Cropping season	P_0[a)]	P_1	P_2	P_3	r_1[b)]	r_2	r_3
Wet	0.010[c)] (0.146)	0.91 (0.391)	24.9 (0.274)	22.0 (0.271)	91.5 (0.115)	27.4 (0.086)	0.89 (0.303)
Dry	0.015 (0.418)	0.41 (0.106)	4.1 (0.095)	4.0 (1.555)	27.8 (0.173)	10.1 (0.246)	0.96 (1.094)

a): P_0, P_1, P_2, P_3: Population density in initial, 1st, 2nd and 3rd generations, respectively.
b): r_1, r_2, r_3: Population growth rate from initial to 1st, 1st to 2nd, 2nd to 3rd generations, respectively.
c): Values are shown as the geometric mean of 9 study sites in each cropping season. Variances in logarithms are shown in parentheses.

Table 2. Proportion of macropterous adults (%) in each seasonal generation in 1984/85 wet and 1985 dry cropping seasons

Cropping season	Sex	Generation			
		Initial	1st	2nd	3rd
Wet	Female	60.7	6.5	29.8	68.0
	Male	83.8	26.3	43.6	82.6
Dry	Female	85.9	25.0	18.0	50.0
	Male	89.2	49.2	25.2	65.2

Values are shown as the mean of 9 study sites.

similar to those observed in temperate regions like Japan[7]. However, they are quite different from those reported by the earlier studies in the tropics, in which BPH populations were characterized by high initial densities followed by low population growth thereafter[8]. The level of population growth rate and the peak density were much lower in the dry-season crops than in the wet-season crops.

Population fluctuations among paddy fields

The BPH is well known for its typical outbreak-type pest, which is characterized by great fluctuations in population size from year to year and from field to field[1]. In the 1984/85 wet season for instance, the density in the peak (2nd) generation ranged from 5 to 140 insects per hill (sum of adults and 4–5th instar nymphs) at 9 study sites, among which the outbreaks occurred at 3 sites, i.e. sites e, h and i. To analyze the pattern of population fluctuations, field-to-field trends of the population density in each generation and the population growth rate between the two successive generations are shown in Fig. 4 in logarithms. The reciprocal relationship among each of these agents can be examined by the graphical presentation.

In the wet cropping season, it is evident that the population densities fluctuate with a similar pattern in the initial, 1st and 2nd generations, P_0, P_1 and P_2, respectively (Fig. 4, left). This suggests the existence of high correlations with each other. In fact, the values of coefficient of determination, r^2 (r: correlation coefficient) were 0.77 between P_0 and P_1, and 0.78 between P_1 and P_2 (Fig. 5), indicating that P_0 and P_1 could account for approximately 80% of the variation in P_1 and P_2, respectively. These data suggest that the population density in the peak generation, P_2, or the occurrence of BPH outbreaks is predictable with fairly high accuracy on the basis of the population densities in the initial or the previous seasonal generation. These high correlations can be produced by the unvarying population growth rates among the fields, as shown by low values of the variance of population growth rates, r_1 and r_2 (Table 1).

On the contrary, the density in the peak generation, P_2, fluctuated in close correlation with r_2, not with P_0 and P_1, in the dry cropping season (Fig. 4,

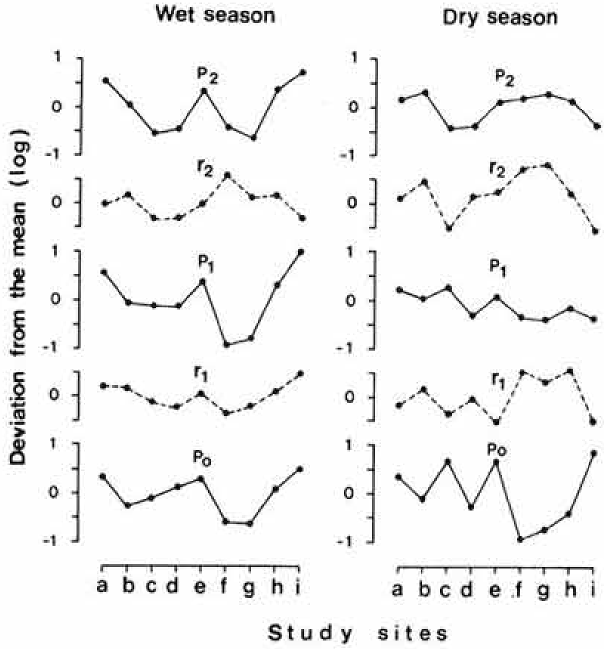

Fig. 4. Field-to-field variations of the BPH population density and growth rate
Field-to-field fluctuations of the population density in each seasonal generation (solid line) and the population growth rate between the two successive generations (broken line), in 1984/85 wet (left) and 1985 dry (right) crop seasons. Values are shown in logarithms.

right). The value of the coefficient of determination between P_2 and r_2 was 0.59, indicating that approximately 60% of the variation in P_2 could be determined by the variation of r_2. Therefore, it is primarily important for the prediction of peak population density in the dry season crops to identify the factors influencing population growth in the middle and late cropping seasons.

Abundance and roles of predatory natural enemies

The results as outlined above indicate that the fundamental features on BPH population dynamics are quite different between the two cropping seasons. In this connection, the influence of predatory natural enemies on BPH population dynamics was evaluated in each cropping season. Among the predators of the planthopper, abundant were several species of spiders, including *Lycosa pseudoannulata*, a water bug, *Microvelia douglasi* which attacks young nymphs, and a plant bug, *Cyrtorhinus lividipennis* which attacks eggs and young nymphs. In addition, *Micraspis lineata, Paederus fuscifes, P. tamulus, Ophionea ishii, Mesovelia vittigera* and some others were also continuously observed in every study plot. However, these enemies were much lower in population densities compared with the first three predators. The representative population densities in each seasonal generation of the predators were estimated as the mean of population incidences in the corresponding period to the generation period of BPH population.

1) Comparison of the predator densities between the two cropping seasons

Table 3 presents the mean population densities of major predators in the 9 study sites. In the early

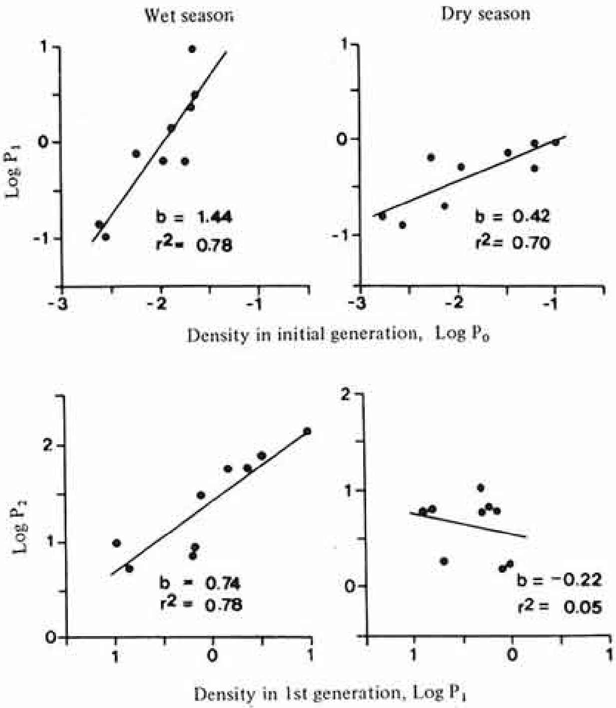

Fig. 5. Relations between the population densities of the two successive seasonal generations
Coefficients of determination expressed in logarithms in the 1984/85 wet (left) and 1885 dry (right) cropping seasons. P_0, P_1, and P_2: population density in initial, 1st and 2nd generations, respectively.

Table 3. Population density of major predators in each seasonal generation in 1984/85 wet and 1985 dry cropping seasons

Predator	Cropping season	Generation			
		Initial	1st	2nd	3rd
Spider	Wet	0.194	0.684	2.689	3.755
	Dry	0.923	1.876	4.667	3.776
Microvelia	Wet	0.048	0.766	3.394	2.104
	Dry	0.455	1.991	2.402	0.674
Cyrtorhinus	Wet	0.005	0.082	1.368	6.896
	Dry	0.015	0.056	0.274	0.453

Values are shown as the mean of 9 study sites.

cropping season, population levels of spiders and the other predators were obviously higher in the dry cropping season; in fact, at the initial generation, they were several times higher than those in the wet season crops. Besides the predators, the abundance of parasitic wasps which attacked planthopper eggs was 10 to 20 times higher than that in the former season, according to the survey results which were obtained by sweeping censuses in 20 spots of paddy fields 3 weeks after transplanting.

Most paddy fields in this region are completely dried up for 2 or 3 months in the fallow period after the harvest of dry season crop (Fig. 2). Under such conditions, the population density of natural enemies remarkably declined during that period, being associated with the decline of the relevant insect community in the region. As a consequence, the low density of natural enemy population is established in the early wet season crops. Consequently, the abundance of natural enemies such as predators and parasitic wasps may possibly be a principal factor conditioning the population levels in the peak generation in the two cropping seasons[11].

2) Variation of the predator density among the fields

Fig. 6 shows numerical correlations between the density of each major predator and the total population density of leaf- and planthoppers, in the period corresponding to the seasonal generation of the BPH population. The spider population shows a significant correlation with the prey density in the initial generation. This high correlation indicates that the initial invasion of spiders into paddy fields takes place to a certain extent in accordance with the density of prey populations existing there. However, such a response of spiders gradually becomes less obvious, and the values of slope b in the regressions are lowered with the progress of seasonal generations. This trend demonstrates that the spider population cannot increase in parallel with such high rates as shown in the planthopper population. In contrast with spiders, *Cytorhinus* shows a high response to the prey density, even in the late cropping season when the planthopper population keeps the peak in density.

Effects of the major predator density on the BPH population growth were examined for each seasonal generation, in the wet (Fig. 7) and the dry (Fig. 8) cropping seasons. In the wet crops, some negative correlations were observed between the two agents in the later generation (Fig. 7), indicating that the BPH population growth rates were considerably influenced by the predator density. The population densities in the peak generation are primarily determined by the densities of initial immigrants in the wet season as shown in Fig. 4. It was observed, however, that the predators also contributed to the BPH population fluctuation to some extent in the peak generation through their influences on the population growth rates among the paddy fields.

The negative correlations were much less obvious in the dry cropping season. Instead of negative, a highly positive correlation was detected between the

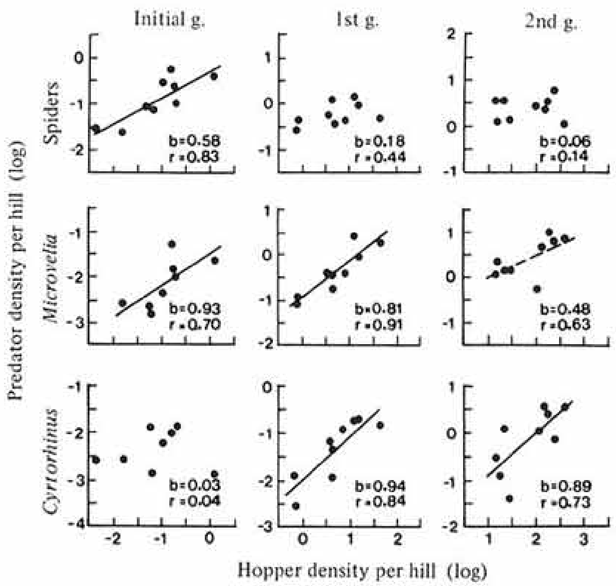

Fig. 6. Correlations between planthoppers and each major predator in each seasonal generation, in 1984/85 wet cropping season
Solid and broken lines show significance of correlation coefficient, r, at $P<0.05$ and $P<0.10$, respectively.

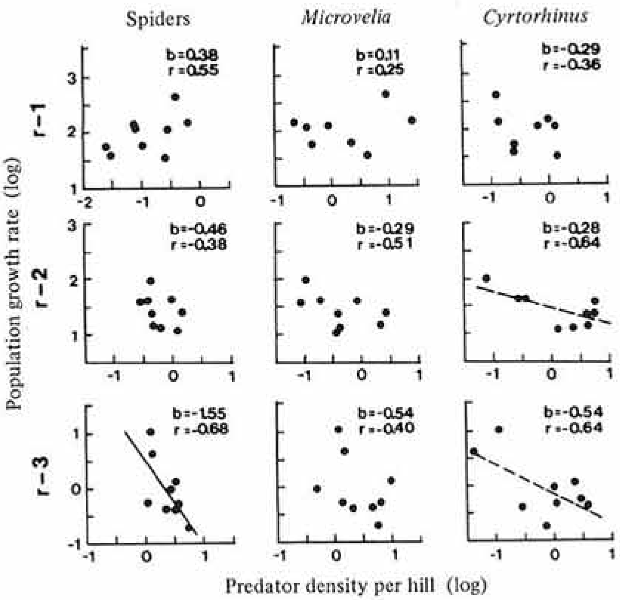

Fig. 7. BPH population growth rates and predator densities (1)
Relations between the population growth rates of BPH from a given generation to the next, and the population densities of major predators in the previous generation, in 1984/85 wet cropping season.
Solid and broken lines: Refer to the footnote of Fig. 6.

density of *Microvelia* and the BPH population growth rate from the 1st to the 2nd generation, r_2. Since *Microvelia* inhabits water surface, its abundance correlates more or less with the existing water supply to fields. Therefore, the positive correlation may suggest that the BPH population growth becomes higher in the field which receives sufficient water supply. More intensive life-table studies suggest that the BPH fecundity widely varies, reflecting the conditions of water supply in paddy fields[12]. Thus, it is concluded that the water status in each field is a primarily important agent that influences variations in BPH population among the fields in the peak generation, because r_2 is the driving force to determine the peak population density in the dry cropping season (Fig. 4, right). In fact, the BPH outbreaks in the dry crop occurred only at the site f (Fig. 3), where the density of initial immigrants was the lowest among the 9 study sites, while the paddy water was fully supplied in the irrigation system throughout the cropping season.

3) *Concluding remarks on the role of natural enemies*

The natural enemies such as predators and parasitic wasps seem to be extremely important as the primary factor that conditions the population levels of the BPH under the various situations of tropical rice cultivation systems. This holds true with both the wet and dry cropping seasons as outlined above, as well as with the various areas under different rice planting dates[17]. Sawada et al.[13] also reported that the natural enemies in general, and the parasitic wasps in particular, play an important role to determine levels of the BPH population growth under the different rice cultivation systems, consisting of synchronous and staggering rice croppings, in Central Java, Indonesia.

It should be noticed, however, that the role of natural enemies was of secondary importance as a driving factor in determining the variations of BPH population dynamics among paddy fields in the same cropping season. In the wet crops, the population densities in the peak generation were primarily

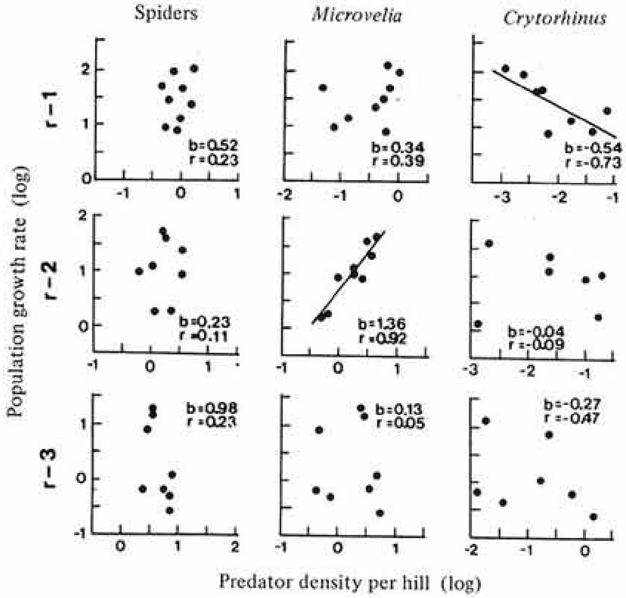

Fig. 8. BPH population growth rates and predator densities (2) Relations between the population growth rates of BPH from a given generation to the next, and the population densities of major predators in the previous generation, in 1985 dry cropping season.
Solid lines: Refer to the footnote of Fig. 6.

determined by the densities of initial immigrants, because the population growth rates were considerably high and stable among the fields. This status suggests that the field condition in the wet season is highly suitable for the BPH population growth as a whole in this region. In the dry cropping season, in contrast, the population growth rate widely varies depending on the condition of water supply in each field, which greatly influences BPH population fluctuations among the fields.

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