Population Growth Patterns of the
Green Leafhopper, *Nephotettix virescens*
(DISTANT) (Homoptera: Euscelidae),
in Small-scale Synchronous and
Asynchronous Rice Fields¹

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Nephotettix virescens (DISTANT) is the most efficient vector species of tungro which became an important virus disease of rice in tropical Asia shortly after the introduction of high-yielding cultivars (HIBINO, 1979; SOGAWA, 1976). The tungro problem in Indonesia has been most serious in Bali where the first outbreak of tungro occurred in the wet season of 1980/81. Large-scale synchronous rice planting, which has been successful in controlling tungro (SAMA et al., 1991), is not implemented in Bali. Irrigation in this province has been managed by a farmer's association, called "subak," which usually consists of 50–200 farmers. Rice is cultivated either synchronously or asynchronously at the subak level. We compared the population growth pattern of *N. virescens* between these two different types of rice cultivation areas as a step to develop a forecasting technology of tungro.

This study was conducted under the Indonesia-Japan Joint Program on Food Crop Protection implemented by the Directorate of Food Crop Protection, Ministry of Agriculture, Indonesia and Japan International Cooperation Agency, Japan.

STUDY AREA AND METHODS

The study was conducted on a total of eight paddy fields in tungro-endemic areas of Badung and

Gianyar, Bali in the dry season of 1987 and the wet season of 1987/88. *N. virescens*-susceptible Krueng Aceh or IR 36 variety was transplanted onto farmer's fields at 25 cm intervals between hills, 21 days after sowing. Dry season crops were transplanted in late July–early August and harvested in November. Wet season crops were transplanted in mid December–mid January and harvested in April. Insecticides were not applied. The maintenance of the fields was traditional.

N. virescens adults and nymphs were collected weekly by 75 strokes of sweeping covering 300 hills with a 42 cm ϕ insect net. All the adults were dissected under binocular microscope to check for parasitism. The egg density was estimated by dissecting 15–80 hills randomly sampled. Egg masses found were kept individually in small glass vials with a piece of wet cotton, and inspected for parasitism 10 days later. Population census of natural enemies was conducted three times at 4, 8 and 12 weeks after transplanting (WAT) using a Farmcop suction sampler (CARIÑO et al., 1979) at 20 4-hill stops.

N. virescens generations were identified as the initial (G_0), the first (G_1) and the second (G_2) after KUNO's (1968) methods based on the observed peak occurrence of G_1 adults and heat units required for the completion of one generation (VALLE et al., 1986). Adults collected at 1–4, 5–8 and 9–12 WAT in the dry season and at 2–5, 6–9 and 10–13 WAT in the wet season were regarded as corresponding to G_0 , G_1 and G_2 , respectively.

RESULTS AND DISCUSSION

The adult density of *N. virescens* on Krueng Aceh variety reached a maximum in G_1 and then greatly decreased in G_2 in the three study fields in the asynchronous planting areas irrespective of the season (Fig. 1). Population peaks in synchronous planting areas on Krueng Aceh also occurred at G_1 . However, in synchronous areas populations grew more steeply from G_0 to G_1 and dropped less between G_1 and G_2 than they did in the asynchronous areas (Fig. 1). Population growth patterns on Krueng Aceh and IR 36 in synchronous areas were similar, except that the populations tended to increase continuously up to G_2 on IR 36.

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Fig. 1. Population growth patterns of *N. virescens* adults in three paddy fields in asynchronous rice cultivation areas and five paddy fields in small-scale synchronous rice cultivation areas in the dry season of 1987 (D) and the wet season of 1987/88 (W). Solid and open circles represent population trends on Krueng Aceh and IR 36 cultivars, respectively.

To analyze the causes of the difference in the population growth rate G_1/G_0 between asynchronous and synchronous rice fields, the total mortality, expressed as the antilogarithm of survival rate from G_0 to G_1 of the adult stage, (K), was divided into three component mortalities: G_0 adult mortality (ka), G_1 egg mortality (ke), and G_1 nymphal mortality (kn) which included the loss of the early stages of adults. Reproductive potential of G_0 adults was assumed to be 200 eggs/individual. Data obtained in synchronous areas were pooled because no significant difference was found in the four categories of mortalities between the two cultivars.

Comparisons of the mortalities between the asynchronous and synchronous areas are given in Table 1. K -values were significantly larger in asynchronous areas than in synchronous areas: by 0.494 and 0.684 for the dry and wet seasons, respectively. Among the three component mortalities,

kn showed the greatest and significant differences which corresponded with the differences in K for both seasons. This indicates that the differences in the population growth rate between the two types of rice cultivation areas were mostly due to the differences in kn .

Parasitism of G_1 nymphs by dryinids and strepsipterans in the study fields was observed exclusively in the wet season. However, the overall parasitism rate of 4th and 5th instar nymphs in this season was on the average 4.1% (0.019 in k -value) and none for the synchronous and asynchronous areas, respectively.

Major predators observed in the study fields were spiders (*Lycosa*, *Tetragnatha*, *Oxyopes*, *Araneus* and *Phidippus*) and insects (*Microvelia*, *Cyrtorhinus*, *Micrapsis*, *Ophionea*, *Paederus* and *Agriocnemis*). Mean numbers of spider and insect predators collected by a FARMCOP at four and eight weeks after transplanting were slightly higher in asyn-

Table 1. Comparisons of the total and component mortalities of *N. virescens* between synchronous and asynchronous rice fields in the dry and wet seasons

Season	Category of mortality ^a	Mortality ($\bar{x} \pm \text{SE}$)		<i>t</i> -test
		Asynchronous area	Synchronous area	
Dry	<i>K</i>	1.754 ± 0.247	1.260 ± 0.128	<i>p</i> < 0.05
	<i>ka</i>	-0.041 ± 0.246	0.167 ± 0.401	ns
	<i>ke</i>	0.223 ± 0.065	0.118 ± 0.105	ns
	<i>kn</i>	1.571 ± 0.133	0.978 ± 0.205	<i>p</i> < 0.01
Wet	<i>K</i>	1.698 ± 0.222	1.014 ± 0.272	<i>p</i> < 0.05
	<i>ka</i>	0.154 ± 0.197	0.152 ± 0.333	ns
	<i>ke</i>	0.350 ± 0.056	0.208 ± 0.169	ns
	<i>kn</i>	1.196 ± 0.213	0.654 ± 0.291	<i>p</i> < 0.05

^a *K*: log (G_0 adults × 200/ G_1 adults), *ka*: log (G_0 adults × 200/ G_1 total eggs), *ke*: log (G_1 total eggs/ G_1 healthy eggs), *kn*: log (G_1 healthy eggs/ G_1 adults).

Table 2. Numbers of predators/80 hills collected by a FARMCOP sampler at 4 and 8 weeks after transplanting in asynchronous and synchronous rice fields (in log)

Season	Predator	Density/80 hills ^a		<i>t</i> -test ^b
		Asynchronous area	Synchronous area	
Dry	Spiders	1.944 ± 0.107	1.917 ± 0.090	ns
	Insects	1.618 ± 0.138	1.209 ± 0.184	ns
Wet	Spiders	1.908 ± 0.172	1.711 ± 0.176	ns
	Insects	1.606 ± 0.201	1.468 ± 0.205	ns

^a Mean ± S.E.

^b ns shows insignificance at *p* = 0.05.

Table 3. Predator abundance per G_1 healthy egg in asynchronous and synchronous fields (in log)

Season	Predator	Predator/healthy egg ^a		<i>t</i> -test ^b
		Asynchronous area	Synchronous area	
Dry	Spiders	-1.048 ± 0.103	-0.581 ± 0.112	ns
	Insects	-1.374 ± 0.153	-1.288 ± 0.146	ns
Wet	Spiders	-0.962 ± 0.237	-1.050 ± 0.153	ns
	Insects	-1.264 ± 0.268	-1.291 ± 0.261	ns

^a Mean ± S.E.

^b ns shows insignificance at *p* = 0.05.

chronous areas, irrespective of the season, but the differences were insignificant (Table 2). On the other hand, the predator density per healthy G_1 egg, which may be a more appropriate measure of predation pressure, tended to be lower in asynchronous areas where *kn* was much higher (Table 3).

The foregoing results suggest that neither para-

sitism nor predator abundance accounts for the differences in population growth patterns between the two types of cultivation areas. Meteorological factors also fail to explain the differences because the five asynchronous and three synchronous areas are located within a radius of 15 km of each other. WIDIARTA et al. (1990) who com-

pared the population growth pattern of *N. virescens* between an asynchronous and a large-scale synchronous rice planting area in Indonesia found that very low population growth rates during the late season (G_2/G_1) were unique to the asynchronous area. They consider that this may be due to the differential effect of inter-field adult dispersal: emigration and immigration in individual paddy fields tend to compensate for each other in synchronous areas, whereas in asynchronous areas the G_1 adult density decreases as a result of emigration to young stages of rice. This effect of adult dispersal is a possible cause of the differences in the population growth patterns observed in this study: high emigration rates of G_1 females in small-scale asynchronous areas have been suggested by low percentage of mature females (WIDRAWAN et al., 1992). Further study is needed to confirm the effect of the adult dispersal.

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Effect of Temperature on the Development of *Trichogramma chilonis* Ishii (Hymenoptera: Trichogrammatidae), an Egg Parasitoid of the Diamondback Moth¹

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The diamondback moth (DBM), *Plutella xylostella* (LINNAEUS), is a serious pest of cruciferous crops in many countries. Recent development of

insecticide resistance in DBM demands the development of alternative control agents, including biological control. An egg parasitoid, *Trichogramma chilonis* Ishii, is an important natural enemy of DBM (IGA, 1985). To establish a control program many basic and applied studies have been done on this species (MIURA, 1992).

Clarifying the development of *T. chilonis* in DBM eggs is valuable in describing their reproductive process. Although studies on the development of *T. chilonis* in other host species were conducted by HIRAI (1986, 1987) and HIRASHIMA et al. (1990), little was known about the development in DBM eggs. Differences in host species may significantly affect the development rate and the survival of the parasitoid. HIRASHIMA et al. (1990) had investigated the development of immature stages of *T. chilonis* in DBM eggs at 24°C and 28°C, but its zero development and the effective heat units for the DBM eggs had not been determined. Our study was done to clarify the influence of the

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