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Rice Tungro Disease Transmitted by the Green Leafhopper: Its Epidemiology and Forecasting Technology

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Abstract

Epidemiological studies of rice tungro disease in paddy fields were conducted with a view to developing its forecasting technology in the rice areas asynchronously planted in Bali. Tungro infections in paddy fields reached the highest peak on average in 6 weeks after transplanting, when the first generation large nymphs of *Nephotettix* virescens were most abundant. About 95% of the variance of the cumulative infections at harvest was explained by an index of infective nymphal density at this stage. Practical control thresholds were established for the monitoring in 2 to 5 weeks after transplanting on the basis of percentage of diseased hills. Onset of tungro dissemination coincided with the beginning of the wet season. The areas which might be infected by tungro in the first half of the wet season could be predicted with the number of infected locations in the second half of the dry season. The increase in tungro incidences was preceded by the population build-up of *N. virescens*. It was recognized that increasing migratory activities of the first generation adults accounted for the population build-up. Tungro outbreaks were triggered by the presence of severely infected paddy fields in the asynchronously transplanted areas. The results obtained indicate that the conditions for the severe outbreaks are: firstly, the tungro intensity in paddy fields under young rice plants is more than 4 times as large as the economic control thresholds, and secondly, at the transplanting time, the mean infective vector index in migrant producing fields in the area is larger than 15/25 strokes/100 hills.

Discipline: Plant disease/Insect pest
Additional key words: control thresholds, insect-borne virus disease, Nephotettix virescens

Introduction

Rice tungro (RTV) disease is a composite virus disease[3,4,9,13)] transmitted mainly by the green leafhopper (GLH), *Nephotettix virescens*[5,7,16)]. The incidences of RTV emerged as one of the most destructive rice diseases in tropical Asia shortly after the introduction of new technologies to increase the rice production in the late 1960s[7,10)]. Extensive planting of high-yielding cultivars and intensive use of fertilizers are particularly responsible for the population build-up of the vector population and tungro outbreaks[7,15,18)].

The present paper is prepared on the basis of the results of the Plant Protection Project (ATA-162), which was jointly implemented by the Japan International Cooperation Agency, Japan, and the Directorate of Food Crop Protection, Ministry of Agriculture, Indonesia, during the period 1980 to 1992.

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The introduction of GLH-resistant cultivars newly developed has been the central strategy of controlling RTV. Yet the breakdown of resistance followed after a few consecutive seasons of cultivation of formerly resistant cultivars[2,6,8,11)]. It appears increasingly difficult to develop a new cultivar which fully fulfils the requirements for high-yielding ability, good grain quality, and resistance against GLH. Large-scale synchronous rice planting combined with periodic fallow span or palawija (secondary crops) planting has been proved to be the most successful strategy for tungro control[14)]. However, tungro problems have never disappeared because there remain huge areas where large-scale synchronous planting is difficult to be implemented. In case a severe RTV infestation occurs in an RTV-endemic asynchronous planting area, it may spread and cause serious damage even to synchronous planting areas. Fundamental solution to the RTV problem is therefore to develop a forecasting technology in RTV-endemic, asynchronous rice planting areas, and to take preventive actions wherever an alarming situation appears. This paper presents some of the results of RTV field epidemiological studies undertaken for this purpose in Bali, which is most frequently and seriously attacked by tungro disease in Indonesia.

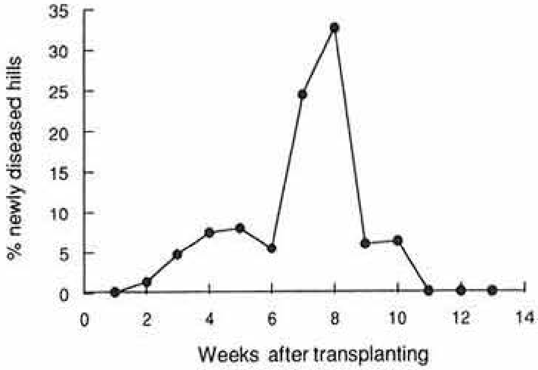

Fig. 1. An example of weekly fluctuations in the percentage of newly diseased hills with visible RTV symptoms in paddy fields
Data were obtained in Padangarak, Bali in the wet season 1987/88.

Methods

Weekly census of GLH and natural enemies was taken with a FARMCOP suction sampler[1)] and/or a sweeping net in the period from transplanting to harvest in farmers' paddy fields in Bali, where GLH-susceptible rice cultivar, either Krueng Aceh or IR 36, was planted. One day before the transplanting, sweeping census was taken at the nursery bed. GLH egg density and mortality were estimated by dissecting randomly sampled 15–80 hills, depending on the rice growing stage. Further details on population census methods and maintenance of census fields are described in Widiarta et al.[19)].

Spatial distributions of RTV-infected hills with visible symptoms were mapped on the same day of the population census in a 10 × 10 m intensive census plot covering 1,600 hills. The plots were set up at the center of census fields.

RTV propagation in paddy fields

RTV occurred in all the 8 census plots set up in the wet season 1987/88. As exemplified in Fig. 1, the percentage of newly diseased hills per week was often bimodal with a much higher peak in the second mode than the first one. The highest peak of diseased hills came 8.1 weeks after transplanting (WAT) on average (Table 1). By taking into account a

Table 1. Peak occurrence of the number of RTV-diseased hills and GLH G1 density in weeks after transplanting in the wet season 1987/88

Peak occurrence	Location								
	SDN1	BLN1	WP	SDN2	BLN2	BAT	PGA	PGB	x̄ ± sd
RTV	8	9	8	5	10	8	8	9	8.1 ± 1.4
Eggs	–	3	3	3	4	4	3	2	3.1 ± 0.6
Small nymphs	6	7	3	4	4	4	4	5	4.6 ± 1.2
Large nymphs	6	8	6	6	6	7	6	6	6.4 ± 0.7
Adults	7	8	6	7	8	7	6	5	6.8 ± 1.0

Source: Suzuki et al. (1989)[17)].

2-week incubation period of RTV in rice plants (Suta et al., unpublished), it was concluded that the peak RTV transmission occurred ca. 6 WAT. This peak time roughly coincided with the peak occurrence of large nymphs of GLH first generation (G1) (Table 1), suggesting that RTV-transmission by G1 large nymphs is responsible for the overall infections which took place from transplanting to harvest.

This could be tested by assuming a simple mechanism of RTV-transmission in paddy fields: for that purpose, the following two assumptions are adopted: 1) the number of newly infected hills at time t depends on the infective vector density at t; and 2) the relation of the former to the latter is of a saturation type expressed by the following equation:

$$HI_{t+1} = H_t\{1-exp(-aV_t)\}, \quad \text{..............} \ (1)$$

where HI: the number of infected hills, H: the number of healthy hills, V: the infective vector density, and a: the transmission efficiency per infective vector.

For the linear regression analysis, the equation (1) can be modified as:

$$Log\ \{H_t/(H_t-HI_{t+1})\} = a'V_t \quad \text{............} \ (2)$$

The test was made with those data obtained in 1888–1890 at Padangarak, where GLH population density was estimated by FARMCOP census. G1large nymphal density at its peak was represented by GLH adult and large nymphal density at 6 WAT. The percentage of infective vectors at 6 WAT is assumed to be proportional to the cumulative percentage of diseased hills at 6 WAT, since this holds at low infection levels (Fig. 2). Thus $a'V$ of the equation (2) is replaced by $a''VI$, where VI is the infective vector index expressed as (GLH density) × (% diseased hills). The magnitude of cumulative infection at harvest is represented by the index of RTV incidence, which is the logarithm of the reciprocal of the proportion of healthy hills at 10 WAT, i.e. $log\{H_0/(H_0-HI_{10})\}$.

Fig. 3 shows the relation of the index of RTV incidence to the infective vector index at 6 WAT after log transformation of both variables. The result confirms that the cumulative infection depends mostly on the infection occurring at approximately 6 WAT by G1 nymphs. Transmission by G1 nymphs was largely responsible for the yield loss as well (Gede et al., unpublished).

Control thresholds

The infective vector index at young rice stages was found most reliable in predicting the cumulative infection (Suzuki et al., unpublished). Yet any method for determining control threshold including accurate GLH population census was considered to be impractical for farmers. Therefore, control thresholds based solely on the percentage of infected

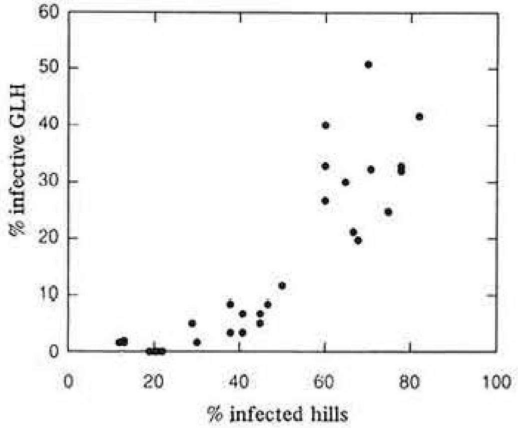

Fig. 2. Dependence of the percentage of infective GLH on the percentage of RTV-infected hills in paddy fields of 5–7 weeks after transplanting
Source: Suwela et al. (unpublished).

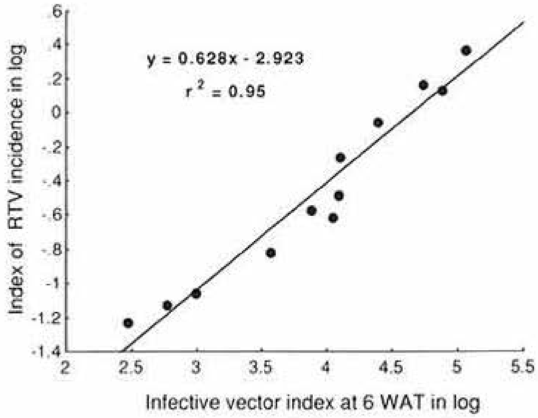

Fig. 3. The relation of the index of RTV incidence to the infective vector index at 6 WAT

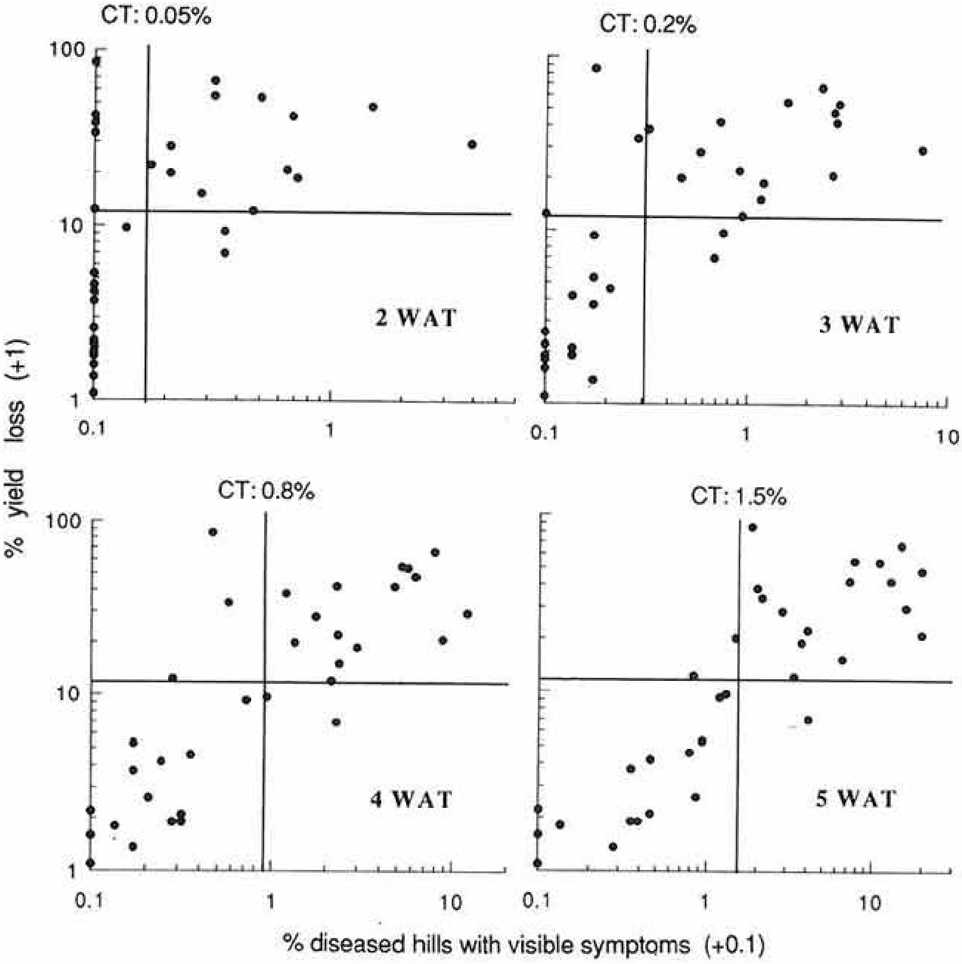

Fig. 4. Control thresholds (CT) based on the relationship between the percentage of infected hills with leaf-yellowing symptoms at 2 to 5 WAT and yield loss
Horizontal lines show an economic injury level of 10% yield loss.

hills bearing visible, leaf-yellowing symptoms were established for the measurements made at 2 to 5 WAT on an empirical basis (Fig. 4). Since there are considerable variations in the peak occurrence of RTV infection caused by GLH immigrant generation (G0), it is recommended to survey the field infections every week from 2 to 5 WAT. Immediate control action should be taken if RTV incidence exceeds the control thresholds.

Seasonal occurrence of RTV and GLH

Biweekly data on the occurrence of RTV have been accumulated by pest observers in Bali since 1983. Monthly fluctuations in an RTV-infected area in one of the most serious RTV-endemic regencies, Badung showed that the beginning of the wet season (monthly rainfall ≥ 200 mm) had close bearing on the onset of RTV infection, and that RTV was severer in the wet season than in the dry season (monthly rainfall ≤ 100 mm), though it often increased again in the transition or early dry season (Fig. 5). It may be concluded that RTV occurrence in the first half of the wet season, October–December would be predictable by the number of RTV-infected locations in the second half of the dry season, July–September, when the least occurrence takes place in the year (Fig. 6).

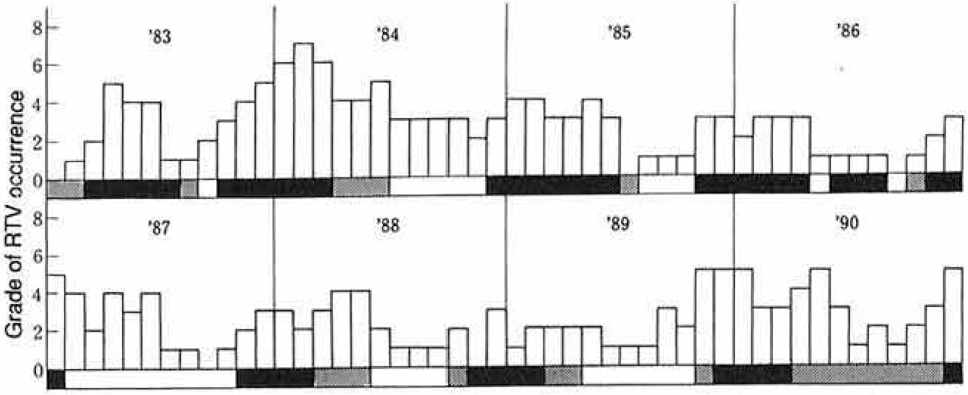

Fig. 5. Seasonal fluctuations in RTV occurrence in Badung, Bali
Grade 0: no infection, Grade 1: log infected area (in ha) <0.5, Grade i ($i \geq 2$): log infected area is between 0.5 ($i-1$) and 0.5i.
Solid, shaded and open horizontal bars denote monthly rainfall of ≥200 mm, 100–200 mm and ≤100 mm, respectively.

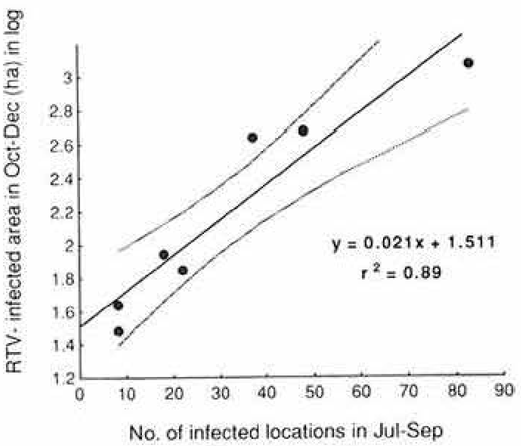

Fig. 6. Regression of RTV-infected area in October–December to the number of infected locations in July–September in main RTV-endemic regencies in Bali in 1983–1989

RTV occurrence and GLH adult and large nymphal density were surveyed weekly for 1 year at Padangarak in Badung. The study site covering about 20 ha was divided into 46 blocks, according to the rice stage and cultivar, and the census was taken in all the blocks except those at flowering-ripening stage.

The mean percentage of RTV-infected hills maintained a low level until the start of the wet season in November, followed by a sharp increase (Fig. 7). The increase in RTV occurrence was preceded by the population increase of GLH (Fig. 7). It is presumed that the onset of RTV dissemination around the beginning of the wet season is associated with the population build-up of GLH. This association was confirmed by the follow-up study which was carried out at Padangarak and other locations (Aryawan et al., unpublished). These results indicate that vector population increase is at least one of the most important factors causing RTV increase.

In asynchronous rice planting areas, GLH population in paddy fields grows from G0 to G1, but sharply drops subsequently since most G1 adults emigrate without leaving G2 eggs[19]. It follows that seasonal fluctuations in GLH abundance in such areas depend largely on the factors inducing fluctuations in the population growth rate of G1/G0 in paddy fields.

To detect the factors, Varley-Gradwell's graphic method was applied to the 14 life table data obtained at Padangarak in the period from 1988 to 1990. The results showed that the key factor was k_n, the combination of nymphal mortality and adult loss including emigration from paddy fields (Fig. 8). Since there was no significant relation between k_n and the predator density/G1 nymphs (Aryawan et al., unpublished), the fluctuations in k_n may be attributed to seasonal differences in GLH migratory activity. Low k_n values in paddy fields transplanted in the transition seasons suggest that areal population

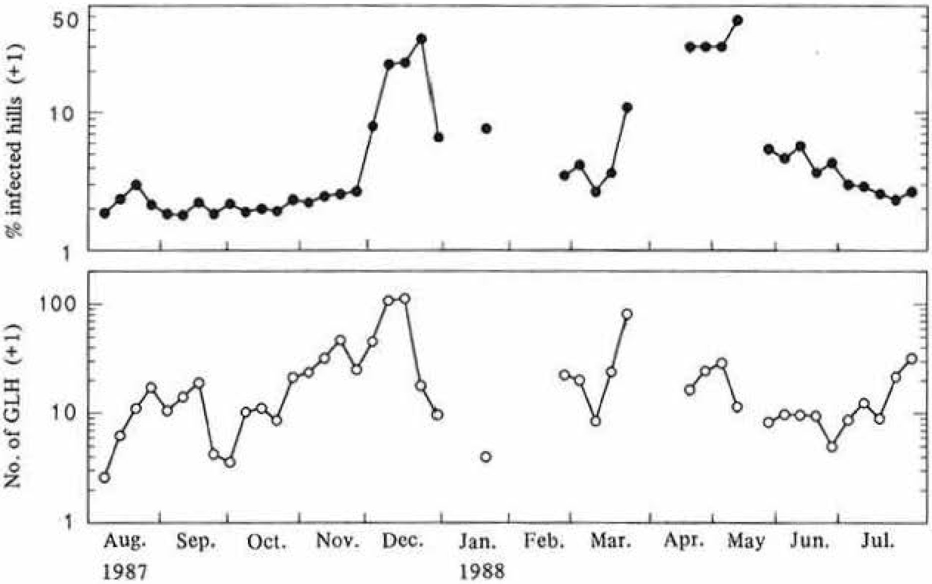

Fig. 7. Fluctuations in the mean percentages of RTV-infected hills and the mean catches of GLH adults and large nymphs/75 strokes on susceptible varieties in paddy fields 5-8 WAT at Padangarak, Badung

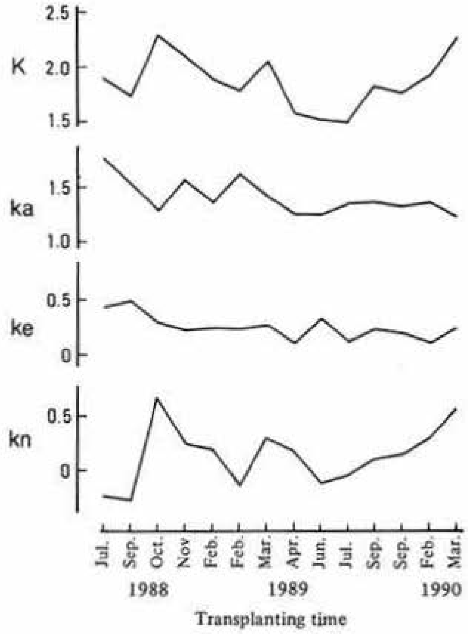

Fig. 8. Comparison of the temporal fluctuation patterns between the overall mortality (K) and the mortality in each stage

ka, ke and kn denote mortalities in G0 adults, G1 eggs and G1 nymphs, respectively.

growth of GLH is the result of active invasion of G1 adults to young paddy fields, where the survival rate of their progeny may be higher than the reproduction rate on old rice plants.

Forecasting of RTV outbreaks

Outbreaks of RTV are triggered by the sporadic occurrence of severely infected paddy fields in RTV-endemic areas around the beginning of the wet season. This is justified by the fact that the proportion of infective GLH sharply increases as the percentage of infected hills exceeds a 60% level (Fig. 3). In other words, forecasting and prevention of the occurrence of highly infected fields is the point for the successful control of RTV.

Severely infected fields (>60% infected hills) occurred with a high probability under the conditions that (1) the percentage of infected hills in young rice stages was more than 4 times as large as the economic control threshold (Fig. 4), and (2) at the transplanting time, the mean infective vector index in migrant producing fields (5-9 WAT) in the asynchronous transplanting area was larger than 15/25 strokes/100 hills (Aryawan et al., unpublished).

The former criterion is useful for farmers to judge the situation and take countermeasures against RTV.

RTV usually starts increasing around the beginning of the wet season (Fig. 5). It is recommended that the first special surveillance for RTV forecasting be carried out shortly before the wet season. Suitable sites for the surveillance are the RTV-endemic locations from which RTV spread frequently in the past, and the locations where tungro incidences are currently reported. On the basis of the above-mentioned criteria, the appearance of dangerous source of infective GLH migrants within 2 months after the surveillance could be specified. RTV forecasting for the 1990/91 wet season in Bali was successfully implemented by combining the special surveillance with the forecasting based on the empirical rules (Fig. 6, Enny et al., unpublished).

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