Pertanika J. Trop. Agric. Sci. 20(1): 65-74(1997)
ISSN: 0126-6128

Action Thresholds of Wet Rice Arthropods for Pest Management Decision-making in Malaysia

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Keywords: arthropods, rice, pest management, thresholds, Malaysia

ABSTRAK

Nilai ambang tindakan untuk membantu penetapan ketentuan dalam pengurusan populasi perosak bagi 11 kategori artropod disarankan secara min densiti populasi per rumpun ($\overline{x}$) *dan perkadaran infestasi (P(I)) unit pensampelan di lapangan. Nilai ambang adalah nilai* ($\overline{x}$) *dan P(I) pada titik tepuan lengkung regresi polinomial yang diperolehi daripada pemplotan* ($\overline{x}$) *melawan P(I) bagi setiap kategori artropod. Nilai yang berkenaan bagi perosak masing-masing adalah: 3.38, 0.92* (Nephotettix *spp.), 6.28, 1.00* (Nilaparvata lugens*), 1.37, 0.72* (Cnaphalocrocis medinalis- *Pyralidae), 2.42, 0.90* (Recilia dorsalis), *3.81, 0.97* (Sogatella furcifera*), dan bagi predator pula: 3.89, 0.98* (Cyrtorhinus lividipennis.*), 2.39, 0.85* (Anatrichus pygmaeus- *Diptera), 2.02, 0.82 (Odonata), 1.65, 0.81* (Casnoidea *sp.), 1.61, 0.64* (Paederus fuscipes*), dan 1.60, 0.69 (labah-labah). P(I) dipengaruhi secara bererti (P<0.001) oleh kategori artropod dan peringkat pertumbuhan tanaman. Nilai-nilai P(I) tercerap sangat berpadanan (kebanyakan* $r^2>0.90$*) dengan model taburan yang berasaskan serakan berkelompok dan serakan Poisson.*

ABSTRACT

Action thresholds to aid pest population management decision-making of 11 categories of wet rice arthropods are suggested in terms of mean population density per hill ($\overline{x}$) *and proportion of infestation (P(I)) of the field sampling units. The thresholds are the* ($\overline{x}$) *and P(I) values at the point of saturation of a polynomial regression curve obtained by plotting* ($\overline{x}$) *against P(I) for each arthropod category. The respective values for pests are: 3.38, 0.92* (Nephotettix *spp.), 6.28, 1.00* (Nilaparvata lugens*), 1.37, 0.72* (Cnaphalocrocis medinalis- *Pyralidae), 2.42, 0.90* (Recilia dorsalis*), 3.81, 0.97* (Sogatella furcifera*), and for predators are: 3.89, 0.98* (Cyrtorhinus lividipennis*), 2.39, 0.85* (Anatrichus pygmaeus- *Diptera), 2.02, 0.82 (Odonata), 1.65, 0.81* (Casnoidea *spp), 1.61, 0.64* (Paederus fuscipes*), and 1.60, 0.69 (spiders). P(I) is significantly (P<0.001) affected by arthropod category and growth stage of the crop. The observed P(I) indicated high fits (most* $r^2>0.90$*) to clumped- and Poisson-based distribution models.*

INTRODUCTION

In a pest management system, its reliability and integrity in decision-making, and hence the output accruing from management actions and strategy, depend to a large extent on threshold values for action decisions. There are many types of threshold mentioned or described in the literature; economic threshold, damage threshold, injury threshold and action threshold. Similarities and differences between these threshold terms have not been critically clarified. The economic injury level and the economic threshold have been defined by entomologists (Stern 1973) and economists (Headley 1971). Nevertheless, it is widely understood that when a pest density is above the threshold, some decisions or appropriate action should be made. It has been readily admitted that it is difficult to estimate economic thresholds under field conditions (Keerthisinghe 1984).

Most threshold values given are static. However, dynamic thresholds are more realistic

(Wilson 1986), and can be easily used in examination of varying feeding damage patterns due to the pest concerned (Hassan and Wilson 1993). Notwithstanding these varying damage patterns, Benedict *et al.* (1989) maintained that most economic thresholds for insects are nominal and not based on damage functions. Any threshold, especially a dynamic one, is not an easy parameter to quantify since there are many influencing variables involved (Graham *et al.* 1972).

Rice is an important world crop since it is a major staple food. However, despite being attacked by many arthropod pests, few attempts have been made to quantify their damage thresholds (e.g. Sogawa and Cheng 1979; Hassan and Ibrahim 1987) relative to other crops such as cotton. Consequently, prophylactic spraying of chemical pesticides is still widely practised in many parts of the world, with subsequent degradation of the ecosystem.

Based on the crude action threshold definition as the mean population density where the proportion of infestation reaches the point of saturation (Hassan and Ibrahim 1987), this paper quantifies the action threshold of eleven arthropod categories in the wet rice ecosystem in Malaysia. The concomitant and relevant dynamics of distribution in terms of proportion of infestation and mean density are also examined.

MATERIALS AND METHODS

Study Areas

Studies were conducted at three separate locations involving plantings of transplanted rice replicated spatially and temporally. The three locations were: plots at a rice estate at the Bukit Cawi village, Seberang Perak, Perak (4°7' N, 101° 4' E); experimental plots at Universiti Pertanian Malaysia (UPM), Serdang, Selangor (3° 2' N, 101° 42' E); and a farmer's plots at Sawah Sempadan, Tanjung Karang (SSTK), Selangor (3° 20' N, 101° 12' E). At the estate, two plots, each measuring 253 x 57 m, were planted with 30-day-old seedlings of MR 84 variety on 12 January 1986. A single simultaneous application of fertilizer, insecticide and weedicide was made 26 days after transplanting (DAT). These chemicals were mixed fertilizer (nitrogen : phosphorus : potassium at 17.5 : 15.5 : 10 w/w respectively) at 2.0 kg per ha, Acmaron® (a.i. endosulfan 3%, inert materials 97% w/w) at 35 kg per ha, and Rumputox® (a.i. 2, 5-D butyl ester 45%, inert materials 55% w/w) at 2.0 kg per ha. At UPM, four adjacent plots (each measuring 30 x 26 m) were planted with 21-day-old seedlings of MR 84 variety on 7 January 1992. No insecticides were sprayed during the entire sampling period of 73 days.

At SSTK, two adjacent plots (each measuring 67 x 61 m) were established using MR 84 variety. Direct seeding was done on 2 February 1992, whereas transplanting was done on 17 February 1992, 21 days after seeding in the nursery. The field was sprayed once with a synthetic pyrethrin insecticide (Fastac®), 40 DAT. At 20 and 40 DAT, mixed fertilizer N:P:K:trace elements (15:15:17:2 by weight) was applied. At 60 DAT, another mixed fertilizer N:P:K:trace elements (12:12:17:2 by weight) was applied. At each site, transplanted seedlings were placed at the normal spacing of 0.25 m.

Sampling

At each site, six observers in two separate groups of three conducted direct visual counting, recorded on tape cassettes, of 22 categories of arthropod; *Nephotettix* spp. (Homoptera: Cicadellidae), *Nilaparvata lugens* (Homoptera: Delphacidae), *Cnaphalocrocis medinalis* (Guenée) (Lepidoptera: Pyralidae), *Recilia dorsalis* (Motschulsky) (Homoptera: Cicadellidae), *Sogatella furcifera* (Horvath) (Homoptera: Delphacidae), *Pelopidas mathias* (Fabricius) (Lepidoptera: Hesperiidae), *Cyrtorhinus* spp. (Reuter) (Heteroptera: Miridae), *Anatrichus pygmaeus* (Lamb) (Diptera: Chloropidae), Orthoptera, Odonata, *Casnoidea* spp. (Coleoptera: Carabidae), *Micraspis* spp. (Coleoptera: Coccinellidae), *Paederus fuscipes* (Curtis) (Coleoptera: Staphylinidae); and the spider families Lycosidae, Oxyopidae, Agriopidae, Clubionidae, Thomisidae, Tetragnathidae, Salticidae, spider nymphs and parasitoids.

At the estate, with one hill as the sampling unit, 100 hills were examined at random in each plot. Sampling was done on three consecutive days every two weeks, at 0900–1200 h in one plot, and 1500–1800 h in the other plot, from 23 December 1985 until 30 May 1986 (total of 30 sampling days). At UPM, weekly sampling was conducted from 20 February until 2 May 1992 (11 sampling days), and at SSTK weekly sampling was carried out from 23 April until 3 June 1992 (7 sampling days) using one hill (for transplanted) and one naturally-formed clump (for direct seeding) as the sampling units. Weekly visual examination of twenty hills/clumps per plot was conducted, at three-hour intervals, during each 24-h duration. At each site, the manner of walking through the field was varied from diagonal to zig-zag and semi-circular, to ensure a good coverage when sampling each plot. Three border rows in each plot were left unsampled. For sampling during the night, waterproof torchlights, with 6V Superheavy Eveready® battery, were used to examine the plants. All the species examined were easily recognized under this light.

Analyses: Mean Action Threshold

At each location, for each combination of species category, date and time of sampling, the mean density ($\bar{x}$) and proportion of infested hill (P(I)) were determined. For each species, values of P(I)s from four distribution models (Wilson and Room 1983); (1) derivation of negative binomial, (2) substitution of Taylor's power law (Taylor 1984), (3) Poisson and (4) modified Poisson were subsequently used separately to derive expected proportion of infestation (P(I)) data.

$$P(I) = 1 - e^{-\bar{x}\,[\ln(s^2\,\bar{x}^{-1})(s^2\,\bar{x}^{-1} - 1)^{-1}]} \quad (1)$$

$$P(I) = 1 - e^{-\bar{x}\,[\ln(a\,\bar{x}^{b-1})(a\,\bar{x}^{b-1} - 1)^{-1}]} \quad (2)$$

$$P(I) = 1 - e^{-\bar{x}} \quad (3)$$

$$P(I) = 1 - e^{-m\,\bar{x}} \quad (4)$$

where P(I) is the proportion of infestation, a & b are Taylor's coefficients, $\bar{x}$ the mean density, s^2 the variance, and m the forced regression coefficient from the following equation

$$m\,\bar{x} = -\ln\,[1 - P(I)] \quad (5)$$

Taylor's coefficients (a,b) were estimated by regressing ln s^2 against ln $\bar{x}$ from the relationship

$$\ln s^2 = \ln a + b \ln \bar{x} \quad (6)$$

In each model, for each arthropod category, all the P(I) calculated were regressed against P(I) observed to obtain the level of fit (r^2). An analysis of variance on r^2, using general linear models procedure (SAS 1990), was run with arthropod categories and models as the major factors. The r^2 values were then compared between categories, and among models, using Ryan-Einot-Gabriel-Welsch multiple range test (Ryan's Q test) (Day and Quinn 1989).

Since inspection of the r^2 values indicates best fits ($r^2 > 0.90$) with models 1 and 3, further analyses only utilise these models. Examination of the P(I) and $\bar{x}$ data indicated eleven species categories with minimum data points of 204; these species categories were then chosen for further analysis. The categories chosen comprised five pests: *Nephotettix* spp., *N. lugens, S. furcifera, R. dorsalis, C. medinalis* and six predators; spiders, Odonata, *Casnoidea* spp., *C. lividipennis*., *P. fuscipes* and *A. pygmaeus*.

Pooling data across dates, times of sampling and the four studies for each species, P(I) values versus $\bar{x}$ were plotted using (1) the actual field data; (2) those derived from model 1 and (3) from model 3. A polynomial regression, up to the fourth power was fitted for each plot. For each arthropod category, the most fit polynomial equation (highest r^2) was then differentiated to obtain a value of where the first dy/dx = 0 occurred. The corresponding P(I) value was then calculated. For each arthropod category, the three values of $\bar{x}$ obtained (field data, model 1, model 3) were subsequently averaged to obtain the mean action threshold in terms of $\bar{x}$ / hill and P(I).

Using pooled data (across times of sampling and methods of planting) from SSTK, for each species category, values of P(I) and $\bar{x}$ were determined at each date, from actual field data and from models 1 and 3. An exploratory data analysis (EDA) (STSC 1991) was done on the pooled observed P(I) data of the three sites, to examine their distribution patterns. Dispersion of residuals versus expected values of the P(I) was also inspected. No transformation of data was necessary since the normality and homogeneity of variance criteria were not violated. A multi-factor analysis of variance (STSC 1991) on P(I) was done with species and date as the main effects. Varying dates represent various stages of growth of the crop.

RESULTS AND DISCUSSION

For each arthropod category, threshold values in terms of mean numbers per hill ($\bar{x}$) vary little among observed, model 1 and model 3 output (Table 1). Exceptions are in *Nephotettix* spp. and Pyralidae where there is an apparent difference between observed (3.76, 1.10) and model 3 (2.96, 1.97) thresholds respectively. However, in terms of proportion of infestation (P(I)), there are more noticeable differences for almost every arthropod category between observed and model 3 values, the largest difference being for Pyralidae (0.61 and 0.95 respectively). Hence it is reasonable to suggest that for each species, output from models 1 and 3 simulate the actual threshold ($\bar{x}$) closely, hence the low variation in threshold values obtained (Table 1). The larger difference in P(I) values is expected since their values are determined by their positions on their respective polynomial curves (*Fig. 1*). Since the P(I) and $\bar{x}$ relationship is curvilinear, and the curves are clearly different comparing the arthropod categories, a difference in $\bar{x}$ values between the categories does not result in the respective similar linear difference in P(I)s. This differential attribute contrasting species is related to the difference in spatial distribution pattern of the species concerned. Various species categories of the cotton crop also showed different distribution patterns (Wilson and Room 1983). However, in contrast to the high fits of models 1 and 3 for rice arthropods, cotton arthropods showed a high fit to model 2, but were similar to rice arthropods in indicating the lowest fit to model 4.

The multi-factor analysis of variance on P(I) indicates that for each group of the P(I) from observed data, from model 1 and from model 3, the effects of arthropod category and growth stage of the crop were significant ($P<0.001$). The significance of the arthropod factor further clarifies the marked difference in values of P(I) when contrasting P(I) values between arthropods from observed, models 1 and 3 stated earlier, and when contrasting the polynomial relationships of P(I) and $\bar{x}$ between the various arthropod categories (*Fig. 1*). The significance of growth stage strongly suggests the possibility of different values of action thresholds as the crop grows. This conforms well with the notion of dynamic economic thresholds in tandem with

TABLE 1

Suggested and published range (Way 1991) in brackets, of action thresholds of 11 caregories of arthropds of wet paddy ecosystem. Values given are in terms of mean numbers per hill ($\bar{x}$) and the equivalent proportions of infestation (P(1) ($n \geq 138$). Field data from Bukit Cawi, Perak (1986), Universiti Pertanian Malaysia and Tanjung Karang, Selangor (1992 crop season).

Arthropod category	Observed		Model 1		Model 3		Mean	
	$\bar{x}$	P(I)	$\bar{x}$	P(I)	$\bar{x}$	P(I)	$\bar{x}$	P(I)
Nephotettix spp.	3.76	0.91	3.43	0.90	2.96	0.96	3.38 (2-20)	0.92
Nilaparvata lugens	6.33	1.00	6.44	1.00	6.06	1.00	6.28 (1-100)	1.00
Cnaphalocrocis medinalis	1.10	0.61	1.03	0.61	1.97	0.95	1.37 (1-5)	0.72
Recilia dorsalis	2.49	0.92	2.45	0.86	2.33	0.93	2.42 (no data)	0.90
Sogatella furcifera	3.87	0.95	4.04	0.96	3.52	1.00	3.81 (1-7)	0.07
Cytorhinus sp.	3.97	0.99	4.01	0.94	3.68	1.00	3.89 (no data)	0.98
Anatrichus pygmaeus	2.19	0.83	2.17	0.80	2.80	0.93	2.39 (no data)	0.85
Odonata	2.07	0.83	1.85	0.76	2.13	0.87	2.02 (no data)	0.82
Casnoidea	1.73	0.82	1.68	0.81	1.53	0.78	1.65 (no data)	0.81
Paederus fuscipes	1.42	0.54	1.66	0.59	1.75	0.80	1.61 (no data)	0.64
Spiders	1.58	0.64	1.66	0.65	1.56	0.79	1.60 (no data)	0.69

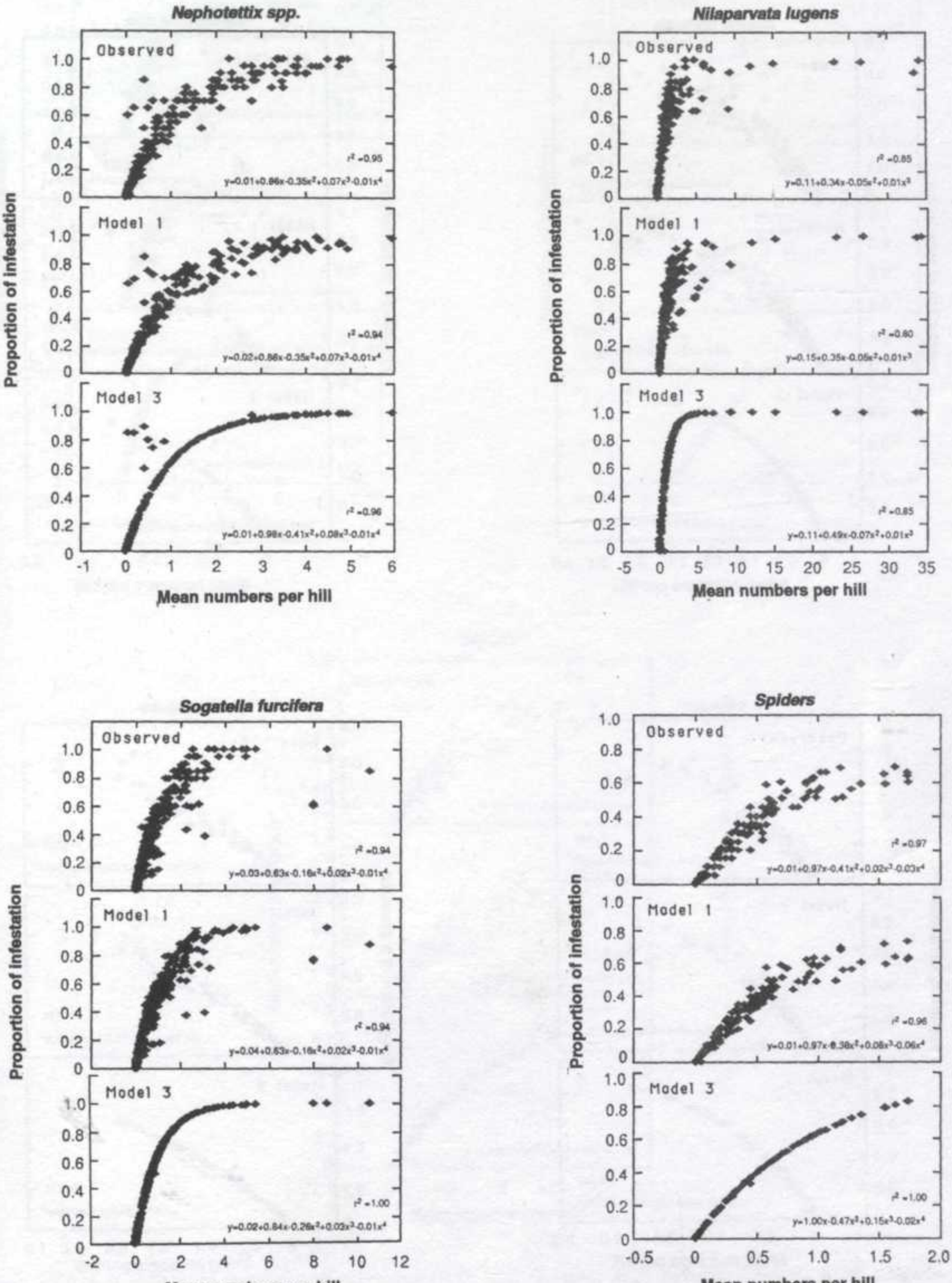
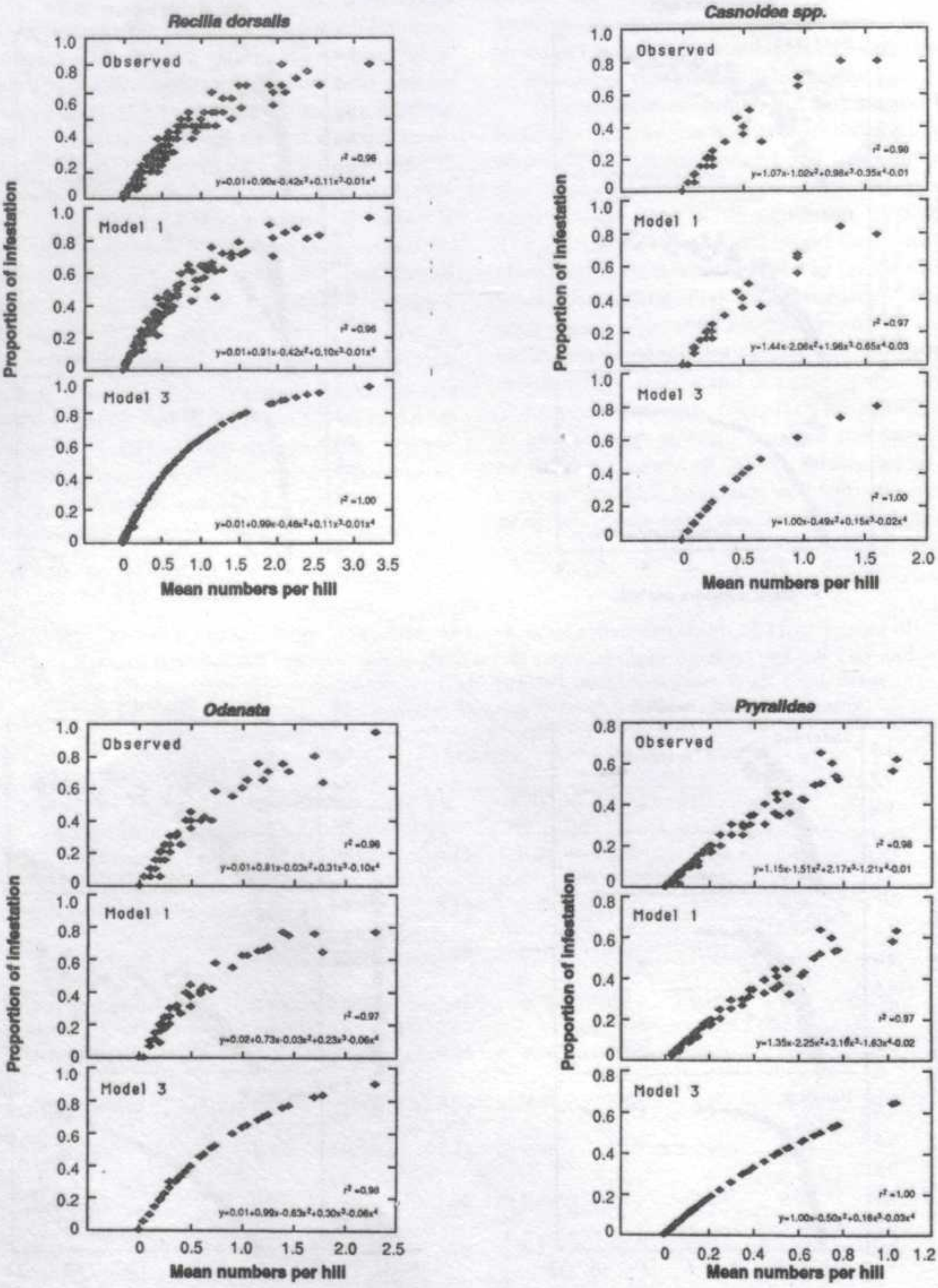


Fig. 1. *(Cont.'d on next page)*



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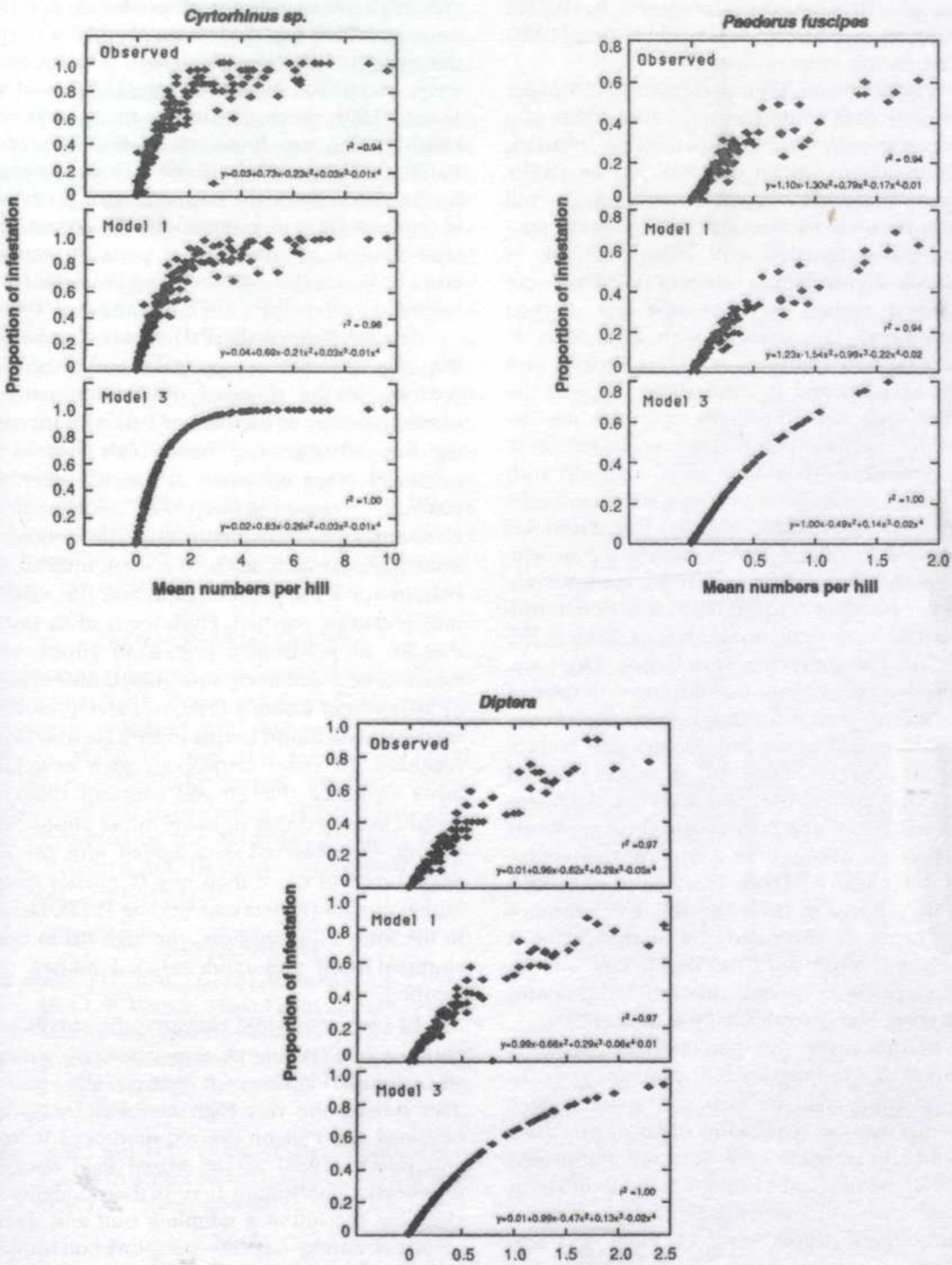

Fig. 1. Pattern of changes in proportion of infestation (P(I)) with changing mean population density of 11 categories of arthropods of wet rice, using data from actual observation, from model 1 (clumped) and model 3 (random) (Wilson and Room 1983). The minimum data point for each diagram is 204. Data from Bukit Cawi, Perak (1986). Universiti Pertanian Malaysia (1992) and Tanjung Karang, Selangor (1992).

crop growth phenology, proposed by Wilson (1986), and applied by Hassan and Wilson (1993) in the cotton crop ecosystem.

Values of thresholds presented in this paper are lower than some suggested thresholds of a few pest species used as guidelines for initiating field treatment. As an example, in the Philippines, a threshold of up to 23 *N. lugens* per hill has been used in formulating sequential sampling plans (Shepard *et al.* 1986). Similarly in Malaysia, slightly higher values of threshold were proposed earlier for *Nephotettix* spp. (Green Leafhopper) (5 compared with 3.98), and *N. lugens* (Brown Planthopper) (7 compared with 6.28) (Hassan and Ibrahim 1987). Most of the earlier suggested thresholds were also not derived from critical pest damage assessment studies. Notwithstanding this, in comparison with the range of values for various species compiled by Way *et al.* (1991) (Table 1), the thresholds suggested in this paper are within the acceptable range given. Moreover, in this study thresholds for predators enable simultaneous determination of status of their populations. Even in the case of the generalist predators; Odonata, *Casnoidea* spp., *P. fuscipes* and spiders, in spite of the lack of precise feeding information, knowing their population status enables pest control decisions to be made on a more rational biocontrol perspective. Simultaneous samplings of a number of pest species and their predators are deemed necessary in a tropical rice ecosystem, such as in Malaysia, due to the simultaneous occurrence of these species. The existence of a range of thresholds for each species is hardly a surprise since thresholds vary with localities, agro-ecosystem conditions and practices and economic constraints (Way *et al.* 1991).

In this study, five pest and six predatory arthropods were considered simultaneously. In any sampling plan for pest management decision-making, the population status of predators should also be considered. It is well known that natural enemies assist in regulating populations of pests such as the green leafhoppers and brown planthoppers (Kenmore *et al.* 1984; Way and Heong 1994). In an integrated management plan, any bias involved in formulating management action/no-action decisions based on the low thresholds of pests suggested in this paper would be compensated by the low thresholds for predators. Our studies were done in fields with no or minimal insecticide input. Hence reasonably high mean density of predators per hill were recorded; e.g. *Cyrtorhinus* sp. 0.98 and spider nymphs 1.22 (Hassan *unpub.*). On the contrary, except for *Nephotettix* spp. (1.73) and *N. lugens* (0.90), mean density for many pests was relatively low, e.g. *R. dorsalis* (0.45), *S. furcifera* (0.63) and *P. mathias* (0.08). These findings further substantiate the importance of predators in suppressing pest populations. Moreover, life table analysis of many insect pests on various crops indicates the overwhelming importance of natural enemies (Price 1987; Sterling *et al.* 1989).

Examination of the P(I) versus $\bar{x}$ relationship (*Fig. 1*) indicates most arthropod categories conform to the clumped distribution pattern where the slope of increase of P(I) with increasing $\bar{x}$ is rather gradual, hence high levels of fit to model 1 are obtained, as noted earlier. In contrast, *N. lugens* shows closer association to Poisson pattern i.e. random dispersion, where a small increase in $\bar{x}$ leads to a large increase in P(I), hence $\bar{x}$ the point of saturation (i.e. threshold) is quickly reached. High levels of fit (most r^2>0.90) to polynomial regression (third- and fourth-order) and to clumped-based distribution of Wilson and Room's (1983) model 1, of P(I) versus $\bar{x}$ data found in this study have also been recorded for other arthropods such as spider mites on maize (Pickett and Gillstrap 1986). It should be noted that in many insect population studies, the observed data agreed with the expected data of more than one frequency distribution models (Pieters and Sterling 1973). Hence in the study reported here, the high fits to both clumped-based and random-based models are justified.

In each arthropod category, the curvilinear patterns of P(I) and $\bar{x}$ association are similar when comparing observed data, models 1 and 3. This reflects the very high fits of the negative binomial and Poisson derived models of Wilson and Room (1983) to the actual field data. A noteworthy implication here is the suitability of choosing the hill as a sampling unit and direct visual counting as the sampling technique (Hassan *et al.* 1992).

In *Nephotettix* spp., some points appear as outliers (*Fig. 1*). However the r^2 values for observed, model 1 and model 3 output are still very high (>0.90), indicating minimal influence of the outliers. For the model 3 output, a perfect fit (r^2=1.00) is registered for every species category, except for *Nephotettix* spp., *N. lugens* and Odonata. This is logical since in model 3 (Poisson), the values of $\bar{x}$ obtained from actual observations directly determine the values of P(I).

In the absence of precise economic and injury level thresholds for pest species of the wet rice ecosystem, the action thresholds presented here are of significant practical importance. Undoubtedly the level of usefulness of these action thresholds lies in actual testing when implementing pest management operations on large, medium and small acreage rice fields in Malaysia. However, it is admitted that the method of determination of action threshold used here does not include pertinent variables such as damage, plant compensation, yield potential, economic and marketing considerations. In conclusion, the action thresholds presented can be used provisionally until better defined thresholds, based upon damage assessment studies and incorporating effects of many influencing variables, are available

ACKNOWLEDGEMENTS

I am most grateful to the Bukit Cawi Rice Estate, Seberang Perak, Perak, the Farm Division, staff, research assistants and students of Universiti Putra Malaysia, and the farmer at Sawah Sempadan, Tanjung Karang, for their various assistance and co-operation. The research grant was provided by the Malaysian National Scientific Research and Development Council (IRPA Project 1-07-05-064).

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(Received 3 July 1996)
(Accepted 22 May 1997)