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Presence/absence Sequential Plans for Pest Management Decision-making, for Arthropods of Wet Rice Ecosystem in Malaysia

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ABSTRAK

Pelan pensampelan berjujukan disediakan bagi 11 kategori artropod untuk membantu pengurusan populasinya dalam sawah padi yang mengandungi pelbagai spesies perosak di Malaysia. Data dari pengamatan visual terhadap 204 sampel, dengan menggunakan 40 dan 100 rumpun dalam setiap sampel, telah diperolehi bagi merumus pelan tersebut. Ambang tindakan bagi setiap satu daripada 11 kategori (lima perosak, enam predator) artropod berkenaan diperolehi melalui regresi polinomial kuasa keempat perkadaran infestasi melawan min densiti populasi, dengan menumpu pada nilai titik permulaan ketepuan infestasi. Species perosak adalah Nephotettix *spp.,* Nilaparvata lugens, Recilia dorsalis, Sogatella furcifera *dan* Cnaphalocrocis medinalis *(Pyralidae) manakala predator pula diwakili oleh* Cyrtorhinus lividipennis, Anatrichus pygmaeus *(Diptera), spiders, Odonata,* Paederus fuscipes *dan* Casnoidea *spp. Tahap risiko Jenis I (α) and Jenis II (β) ditetapkan pada nilai 0.3, kerana nilai yang lebih rendah memerlukan bilangan sampel yang berganda banyaknya. Pelan berjujukan dapat dihasilkan dengan menggunakan program komputer SEQUAN (Talerico dan Chapman 1970). Dalam penggunaan setiap pelan ke atas kawasan yang tidak melebihi 50 ha, adalah dinasihati supaya sekurang-kurangnya 10 sampel diteliti dahulu sebelum membuat apa-apa rumusan pengurusan. Pensampelan serentak perosak dan predator membolehkan status populasi predator diambilkira dalam ketetapan pengurusan populasi spesies perosak.*

ABSTRACT

Presence-absence sequential sampling plans are presented for 11 arthropod categories to assist in management of their populations in the multipest-infested rice crop in Malaysia. Data from visual inspection of 204 samples, with 40 and 100 hills per sample, were used to develop the plans. Action threshold for each of the 11 (5 pests, 6 predators) arthropod categories was obtained through a fourth-order polynomial regression of proportion of infestation against mean population densities, at the point of saturation of infestation. The pest species are: Nephotettix *spp.,* Nilaparvata lugens, Recilia dorsalis, Sogatella furcifera *and* Cnapholocrocis medinalis *(Pyralidae), and the predators:* Cyrtorhinus lividipennis, Anatrichus pygmaeus *(Diptera), spiders, Odonata,* Paederus fuscipes *and* Casnoidea spp. *Risk levels of Type I (a) and Type II error (β) were prefixed at 0.3, since lower levels entail taking a larger number of samples. The sequential plans were then generated using the SEQUAN computer program of Talerico and Chapman (1970). During field operation on not more than 50 ha at a time, it is suggested that at least ten hills should be examined visually before recommending any pest management action. Simultaneous sampling of pests and predators enables status of predators' populations to be considered before recommending any decision.*

INTRODUCTION

Despite claims to the contrary, many pest control decisions on rice in Malaysia are still based on short term *ad hoc* considerations, compared to relatively long term ecological based weightings for sustainable agricultural output. One major factor that obviates development of a nationwide comprehensive pest information-based management decision system (e.g. Song *et al.* 1992) is the inability to continually monitor the status of pest populations on a nationwide scale. However, on a regional basis, surveillance, monitoring and forecasting systems have been attempted (Ooi 1982a, b; Ooi and Heong 1988) and are still operational to a limited extent in some major rice planting areas in the country. To date, determination of pest status is still largely based on the fixed-sample-size sampling system. The inefficiency and limitations of the fixed-sample-size decision-making system have been well elaborated and are applicable to any ecosystem (Sterling and Pieters 1979).

In sequential sampling, the sample size is not prefixed; its rationale, prerequisites for development of the plans, advantages and disadvantages have been described (Onsager 1976; Pieters 1978). The plans can be developed from formulae presented by Waters (1955), and easily produced using the SEQUEN computer program (Talerico and Chapman 1970).

Operational sequential plans for management of pests of major world crops such as cotton are well established (e.g. Sterling 1976; Pieters 1978; Rothrock and Sterling 1982; Plant and Wilson 1985). For rice, the operation of sequential decisions on planthoppers on an experimental basis has been attempted in countries such as Madagascar (Bianchi *et al.* 1989) and the Philippines (Shepard *et al.* 1986). There has been no attempt reported on developing the experimental operation into an area-wide actual farm decision–making strategy. Moreover, the scattered sequential plans developed for rice pests focused on certain species at a time (Nishida and Torii 1970; Kuno 1977, 1986; Shepard *et al.* 1986; Ferrer and Shepard 1987; Shepard *et al.* 1988 a, b) with little emphasis, except in Shepard *et al.* (1989), on developing plans for the predators. In Malaysia, more than one species of pest and predator are usually found simultaneously in a rice crop, thus necessitating sampling plans for those economically important species.

In Malaysia, too, concise and precise economic thresholds and economic injury levels based on insect-caused damage functions are non-existent. In fact, Benedict *et al.* (1989) maintained that most economic thresholds for insects are nominal and not based on damage functions. Consequently, action thresholds (Hassan and Wilson 1993; Hassan 1997) are used in this study based on point of saturation of infestation, on regressing proportion of infestation against mean population density (Hassan and Ibrahim 1987). Although it is not a substitute for economic threshold, it is a reliable numerical species-specific characteristic featuring inherent spatial-temporal distribution entity of the particular arthropod (Sterling 1976; Taylor 1984; Wilson *et al.* 1989).

In this report, for each arthropod category studied, pest or predator, a sequential decision plan that can be operated by professional pest managers and trained farmers was developed based on positive binomial (presence/absence) distribution. Analyses in another paper (Hassan 1996) clearly indicate high fits ($r^2 > 0.90$) on regressing proportions of infestation (P(I)) calculated from binomial family distribution models of Wilson and Room (1983) against P(I) observed. The presence/absence recording scheme is more practical and more efficient, especially for large acreages, than other sequential sampling plans which involve counting of the actual arthropods (e.g. plans based on negative binomial and Poisson distributions).

MATERIALS AND METHODS

Data Collection

Data from 204 sampling occasions (≡ 204 samples, each containing 100 and 40 sampling units at the first, and second and third locations respectively as described below) were used to develop the sampling plans. Of the 22 categories of arthropod recorded, only 11 categories yielded sufficient data enabling calculation of thresholds and other sampling attributes to be used in formulating sampling plans (Hassan and Ibrahim 1987). Visual counts of arthropods on a per hill basis were recorded from three locations: a paddy estate at Bukit Cawi village, Seberang Perak, Perak (4° 7' N, 101° 4' E) (1986), experimental plots at Universiti Pertanian Malaysia (UPM), Serdang, Selangor (3° 2' N, 101° 42' E) (1992), and a farmer's plots at Sawah Sempadan, Tanjung Karang (SSTK), Selangor (3° 20' N, 101° 12' E) (1992). The 11 categories whose data were used to develop the sampling plans are the pests *Nephotettix* spp. (Homoptera: Cicadellidae), *Nilaparvata lugens* (Homoptera: Delphacidae), *Cnaphalocrocis medinalis* (Guenée) (Lepidoptera Pyralidae), *Recilia dorsalis* (Motschulsky) (Homoptera: Cicadellidae), *Sogatella furcifera* (Horvath) (Homoptera: Delphacidae) and the predators: *Cyrtorhinus lividipennis* (Reuter) (Heteroptera: Miridae), *Anatrichus pygmaeus* (Lamb) (Diptera: Chloropidae), spiders, Odonata, *Paederus fuscipes* (Curtis) (Coleoptera:

Staphylinidae) and *Casnoidea* spp. (Coleoptera: Carabidae).

Action Thresholds

Each sample produced mean density ($\bar{x}$) and proportion of infested hill (P(I)) data for each arthropod category. Values of P(I) were also generated from two distribution models (Wilson and Room 1983): (1) derivation of negative binomial, (2) Poisson,

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

$$P(I) = 1 - e^{-\bar{x}} \quad (2)$$

where s^2 is the variance. These two models yielded the highest fit (r^2) when for each arthropod category, the calculated P(I) were regressed against observed P(I) (Hassan and Ibrahim 1987). The P(I) values versus $\bar{x}$ were plotted using firstly the actual field data, secondly using those derived from model 1 and lastly from model 2. A polynomial regression up to the fourth power was fitted for each plot. For each arthropod category, the most fit (usually the fourth order) polynomial equation (highest r^2) was then differentiated to obtain a value of $\bar{x}$ where the first dy/dx=0 occurred (point of saturation of infestation) (Hassan and Ibrahim, 1987). For each arthropod category, the three values of $\bar{x}$ obtained (field data, model 1, model 2) were subsequently averaged to obtain the mean action threshold in terms of $\bar{x}$/hill and hence P(I) (Hassan 1997). These values were then used in developing the sampling plans.

Development of Plans

The binomial sequential plans were generated using the SEQUAN computer program of Talerico and Chapman (1970). This program enabled optimization of each plan for sampling error, width of indecision zones and minimum sample size required to make decisions on action or no-action taken. Action threshold values in terms of P(I); P_{upper} and P_{lower} (with respective equivalents m_1 & m_2; m_1 is the mean population density at which management treatment is needed and m_2 is the no treatment level) used were; 0.96, 0.91 (*Nephotettix* spp.); 0.99, 0.96 (*N. lugens*); 0.95, 0.61 (*C. medinalis*) (Pyralidae); 0.93, 0.92 (*R. dorsalis*); 0.96, 0.95 (*S. furcifera*); 0.94, 0.93 (*C. lividipennis*); 0.92, 0.80 (*A. pygmaeus*) (Diptera); 0.79, 0.65 (spiders); 0.87, 0.76 (Odonata); 0.80, 0.54 (*P. fuscipes*); and 0.82, 0.78 (*Casnoidea* spp.). Their respective thresholds in terms of mean density per hill were; 3.76, 2.96 (*Nephotettix* spp.); 6.33, 6.06 (*N. lugens*); 1.97, 1.10 (*C. medinalis*) (Pyralidae); 2.49, 2.33 (*R. dorsalis*); 4.04, 3.87 (*S. furcifera*); 4.01, 3.68 (*Cyrtorhinus* sp.); 2.13, 1.85 (Odonata); 1.73, 1.53 (*C. lividipennis*); 2.39, 0.85 (A. pygmaeus) (Diptera); 1.75, 1.42 (*P. fuscipes*); and 1.58, 1.56 (spiders). In the sequential plans, the above thresholds are converted to uninfestation proportion (the reverse of infestation proportion), since in practice it is more efficient to count uninfested sample units (Sterling 1976). Consequently, all plans are tailored towards monitoring of uninfested samples. The assigned risks (Type I & Type II errors) of making an incorrect decision α & β respectively were given the values of 0.30 each. Equations for calculating decision lines (d_1 and d_2) are as follows;

$$d_1 = bn - h_1$$

$$d_2 = bn + h_2$$

where d_1 (smaller number column) is the lower threshold of the number of sample units uninfested, when the running total of uninfested sample units is below d_1 the need for treatment is indicated, hence d_1 forms the lower decision line; d_2 (large number column) is the upper threshold of the number of sample units uninfested, when the running total of uninfested samples is greater than d_2, the status of not neccesary for treatment is indicated, hence d_2 forms the lower decision line (between d_1 and d_c is the indecision zone), n is the number of sample units examined, h_1 and h_2 are the intercepts, and b is the common slope of both lines (Waters 1955).

The slope and intercepts are calculated as follows;

$$b = \frac{\log\left[\dfrac{1-m_1}{1-m_2}\right]}{\log \dfrac{m_2}{m_1}\left[\dfrac{1-m_1}{1-m_2}\right]}$$

$$h_1 = \frac{\log\left[\frac{1-\alpha}{\beta}\right]}{\log\frac{m_2}{m_1}\left[\frac{1-m_1}{1-m_2}\right]}$$

$$h_2 = \frac{\log\left[\frac{1-\beta}{\alpha}\right]}{\log\frac{m_2}{m_1}\left[\frac{1-m_1}{1-m_2}\right]}$$

with m_1 & m_2 as defined earlier.

In the implementation of the uninfested plans, absence of the appropriate arthropod category would be recorded as +1 in the running total, whereas a presence would be noted as 0 (zero). The cumulative total would be updated and examined continually as more sample units are examined.

RESULTS AND DISCUSSION

The presence/absence sequential plans are presented in Table 1. In terms of the equivalent $\bar{x}$ values, the thresholds used in this paper are lower than those usually used as guidelines for initiating field treatment (Hassan and Ibrahim 1987). As an example, the mean threshold for *Nilaparvata lugens* used here is 6.28 per hill. In the Philippines, a threshold of up to 23 *N. lugens* per hill has been used in formulating sequential plans (Shepard *et al.* 1986), although the critical economic injury level may be much lower (2 - 5 per hill) (Sogawa and Cheng 1979). Similarly in Malaysia, slightly higher values of threshold have been proposed for *Nephotettix* spp. and *N. lugens*, and other species not considered in this paper (Hassan and Ibrahim 1987). However, counts of *N. lugens* per hill of 25 - 40 only occurred in Malaysia under outbreak situations, such as that observed in the Tanjung Karang area in 1984/85 (Hassan, *unpubl. data*). Counts of less than 10 per hill are more frequent, hence suitable for sampling based on the positive binomial theory (Sterling and Pieters 1979). Thresholds proposed in this paper should then be regarded as provisional guidelines until better defined ones are available. Nevertheless, since we are proposing here the simultaneous usage of pest and predator plans, the possible inadequacy of the plans for pests due to their conservativeness would be compensated by the similarly conservative plans for the predators. Shepard *et al.* (1989) compensated for the presence/absence of predators by having different thresholds for binomial plans with and without predators, in *N. lugens* and *S. furcifera*. However their plans were aimed at preliminary rather than simultaneous sampling of predators.

It is worth noting that the plans presented are based on uninfested sample units, i.e. one uninfested sample unit is given the value of +1 in the running total and one infested unit the value of 0. There is a time-saving advantage in using this procedure (Sterling 1976). These plans are also designed for pest populations that peak in cycles. Many pests of rice in the tropics, such as *N. lugens*, exhibit distinct generations in the field (Dyck *et al.* 1979). Otherwise, the continuous presence of below-threshold level populations for extended periods of time may lead to the cumulative survival exceeding action thresholds and management action may be needed.

Operating the Plans

Since rice is often attacked by a number of pests simultaneously (Kisimoto 1984), plans for the appropriate species of pests and predators should be used simultaneously. These plans can be printed on shirt-pocket-sized cards. A set of plans should be operated to cover not more than 50 ha of paddy field at a time. Otherwise accuracy and precision may be sacrificed (Sterling and Pieters 1979). The manner of walking through the field should be varied on subsequent samplings to enable reasonable coverage of the entire field. Sampling units chosen for visual inspection should be selected at random and showed be a fair representative of the population of plants in the entire field. It is suggested here that one should sample a minimum of ten units at random before making a management decision. Since these plans are for presence/absence of infestation, visual examination of the hill can be done quickly. Absence of the appropriate arthropod category would be recorded as +1 in the running total, whereas a presence would be noted as 0 (zero). The cumulative total would continually be compared with the control and no-control column totals.

Prior to commencing the sampling operation, the operator fills in the concomitant information e.g. locality, plot, date and growth stage of the crop, in the sampling plan cards. After

TABLE 1

Positive binomial (presence-absence) sequential sampling plans for (i) *Nephotettix* spp., (ii) *Nilaparvata lugens*, (iii) *Cnaphalocrocis medinalis* (Pyralidae), (iv) *Recilia dorsalis*, (v) *Sogatella furcifera*, (vi) *Cyrtorhinus lividipennis*, (vii) *Anatrichus pygmaeus* (Diptera), (viii) Spiders, (ix) Odonata, (x) *Paederus fuscipes* (ix) *Casnoidea* sp., with α and β each equal to 0.30

(i)

+VE BINOMIAL, INFESTATION = 0, NO INFESTATION = +1

LOCALITY : DATE : UNINFESTATION THRESHOLD :
PLOT : PLANT GROWTH STAGE :

PEST : *Nephotettix* spp. $\alpha = 0.3$ $\beta = 0.3$ Upper : 4% Lower : 9%

SAMPLE NUMBER	CONTROL	RUNNING TOTAL	NO CONTROL	SAMPLE NUMBER	CONTROL	RUNNING TOTAL	NO CONTROL
1	0		2	26	24		25
2	1		3	27	25		26
3	2		4	28	26		27
4	3		5	29	27		28
5	4		6	30	27		29
6	5		7	31	28		30
7	6		8	32	29		31
8	7		8	33	30		32
9	8		9	34	31		33
10	8		10	35	32		34
11	9		11	36	33		35
12	10		12	37	34		36
13	11		13	38	35		37
14	12		14	39	36		38
15	13		15	40	37		39
16	14		16	41	38		39
17	15		17	42	39		40
18	16		18	43	39		41
19	17		19	44	40		42
20	18		20	45	41		43
21	19		21	46	42		44
22	20		22	47	43		45
23	21		23	48	44		46
24	22		23	49	45		47
25	23		24	50	46		48

(ii)

+VE BINOMIAL, INFESTATION = 0, NO INFESTATION = +1

LOCALITY : DATE : UNINFESTATION THRESHOLD :
PLOT : PLANT GROWTH STAGE :

PEST : *Nilaparvata* sp. $\alpha = 0.3$ $\beta = 0.3$ Upper : 1% Lower : 4%

SAMPLE NUMBER	CONTROL	RUNNING TOTAL	NO CONTROL	SAMPLE NUMBER	CONTROL	RUNNING TOTAL	NO CONTROL
1	0		1	26	25		26
2	1		2	27	26		27
3	2		3	28	27		28
4	3		4	29	28		29
5	4		5	30	29		30
6	5		6	31	30		31
7	6		7	32	31		32
8	7		8	33	32		33
9	8		9	34	33		34
10	9		10	35	34		35
11	10		11	36	35		36
12	11		12	37	36		37
13	12		13	38	37		38
14	13		14	39	38		39
15	14		15	40	39		40
16	15		16	41	40		41
17	16		17	42	41		42
18	17		18	43	42		43
19	18		19	44	43		44
20	19		20	45	44		45
21	20		21	46	45		46
22	21		22	47	46		46
23	22		23	48	46		47
24	23		24	49	47		48
25	24		25	50	48		49

Table 1 (Cont'd)

(iii)

+VE BINOMIAL, INFESTATION = 0, NO INFESTATION = +1

LOCALITY : DATE : UNINFESTATION
PLOT : PLANT GROWTH STAGE : THRESHOLD :

PEST : Pyralidae $\alpha = 0.3$ $\beta = 0.3$ Upper : 5% Lower : 39%

SAMPLE NUMBER	CONTROL	RUNNING TOTAL	NO CONTROL	SAMPLE NUMBER	CONTROL	RUNNING TOTAL	NO CONTROL
1	0		1	26	21		22
2	1		2	27	22		23
3	2		3	28	23		23
4	3		4	29	24		24
5	4		4	30	24		25
6	5		5	31	25		26
7	5		6	32	26		27
8	6		7	33	27		28
9	7		8	34	28		28
10	8		9	35	28		29
11	9		9	36	29		30
12	10		10	37	30		31
13	10		11	38	31		32
14	11		12	39	32		32
15	12		13	40	33		33
16	13		14	41	33		34
17	14		14	42	34		35
18	14		15	43	35		36
19	15		16	44	36		37
20	16		17	45	37		37
21	17		18	46	38		38
22	18		18	47	38		39
23	19		19	48	39		40
24	19		20	49	40		41
25	20		21	50	41		42

(iv)

+VE BINOMIAL, INFESTATION = 0, NO INFESTATION = +1

LOCALITY : DATE : UNINFESTATION
PLOT : PLANT GROWTH STAGE : THRESHOLD :

PEST : *Recilia dorsalis* $\alpha = 0.3$ $\beta = 0.3$ Upper : 7% Lower : 8%

SAMPLE NUMBER	CONTROL	RUNNING TOTAL	NO CONTROL	SAMPLE NUMBER	CONTROL	RUNNING TOTAL	NO CONTROL
1	-		7	26	18		30
2	-		8	27	19		31
3	-		9	28	20		32
4	-		9	29	21		33
5	-		10	30	22		33
6	0		11	31	23		34
7	1		12	32	24		35
8	2		13	33	25		36
9	2		14	34	26		37
10	3		15	35	26		38
11	4		16	36	27		39
12	5		17	37	28		40
13	6		18	38	29		41
14	7		19	39	30		42
15	8		20	40	31		43
16	9		21	41	32		44
17	10		21	42	33		44
18	11		22	43	34		45
19	12		23	44	35		46
20	13		24	45	36		47
21	14		25	46	37		48
22	14		26	47	37		49
23	15		27	48	38		50
24	16		28	49	39		51
25	17		29	50	40		52

Table 1 (Cont'd)

(v)

+VE BINOMIAL, INFESTATION = 0, NO INFESTATION = +1

LOCALITY : DATE : UNINFESTATION
PLOT : PLANT GROWTH STAGE : THRESHOLD :

PEST : *Sogatella* sp. $\alpha = 0.3$ $\beta = 0.3$ Upper : 4% Lower: 5%

SAMPLE NUMBER	CONTROL	RUNNING TOTAL	NO CONTROL	SAMPLE NUMBER	CONTROL	RUNNING TOTAL	NO CONTROL
1	-		3	26	22		27
2	-		4	27	23		28
3	0		5	28	24		29
4	1		6	29	25		30
5	2		7	30	26		31
6	3		8	31	27		32
7	4		9	32	28		33
8	5		10	33	29		34
9	6		11	34	30		35
10	7		12	35	31		36
11	8		13	36	32		37
12	9		14	37	33		38
13	10		15	38	34		39
14	11		16	39	35		40
15	12		17	40	36		41
16	13		18	41	37		42
17	14		19	42	38		43
18	15		20	43	39		44
19	16		21	44	40		44
20	17		22	45	41		45
21	18		22	46	42		46
22	19		23	47	43		47
23	20		24	48	43		48
24	21		25	49	44		49
25	21		26	50	45		50

(vi)

+VE BINOMIAL, INFESTATION = 0, NO INFESTATION = +1

LOCALITY : DATE : UNINFESTATION
PLOT : PLANT GROWTH STAGE : THRESHOLD :

PEST : *Cyrtorhinus* sp. $\alpha = 0.3$ $\beta = 0.3$ Upper : 6% Lower : 7%

SAMPLE NUMBER	CONTROL	RUNNING TOTAL	NO CONTROL	SAMPLE NUMBER	CONTROL	RUNNING TOTAL	NO CONTROL
1	-		7	26	19		30
2	-		8	27	20		31
3	-		9	28	20		32
4	-		10	29	21		33
5	-		10	30	22		34
6	0		11	31	23		35
7	1		12	32	24		36
8	2		13	33	25		37
9	3		14	34	26		38
10	4		15	35	27		39
11	5		16	36	28		40
12	5		17	37	29		40
13	6		18	38	30		41
14	7		19	39	31		42
15	8		20	40	32		43
16	9		21	41	33		44
17	10		22	42	34		45
18	11		23	43	35		46
19	12		24	44	35		47
20	13		25	45	36		48
21	14		25	46	37		49
22	15		26	47	38		50
23	16		27	48	39		51
24	17		28	49	40		52
25	18		29	50	41		53

Table 1 (Cont'd)

(vii)

+VE BINOMIAL, INFESTATION = 0, NO INFESTATION = +1

LOCALITY : DATE : UNINFESTATION
PLOT : PLANT GROWTH STAGE : THRESHOLD :

PREDATOR : Diptera $\alpha = 0.3$ $\beta = 0.3$ Upper : 7% Lower : 20%

SAMPLE NUMBER	CONTROL	RUNNING TOTAL	NO CONTROL	SAMPLE NUMBER	CONTROL	RUNNING TOTAL	NO CONTROL
1	0		2	26	22		23
2	1		2	27	23		24
3	2		3	28	24		25
4	3		4	29	25		26
5	4		5	30	25		27
6	4		6	31	26		28
7	5		7	32	27		29
8	6		8	33	28		30
9	7		9	34	29		30
10	8		9	35	30		32
11	9		10	36	31		32
12	10		11	37	32		33
13	11		12	38	32		34
14	11		13	39	33		35
15	12		14	40	34		36
16	13		15	41	35		37
17	14		16	42	36		37
18	15		16	43	37		38
19	16		17	44	38		39
20	17		18	45	39		40
21	18		19	46	39		41
22	18		20	47	40		42
23	19		21	48	41		43
24	20		22	49	42		44
25	21		23	50	43		44

(viii)

+VE BINOMIAL, INFESTATION = 0, NO INFESTATION = +1

LOCALITY : DATE : UNINFESTATION
PLOT : PLANT GROWTH STAGE : THRESHOLD :

PREDATOR : Spiders $\alpha = 0.3$ $\beta = 0.3$ Upper : 21% Lower : 35%

SAMPLE NUMBER	CONTROL	RUNNING TOTAL	NO CONTROL	SAMPLE NUMBER	CONTROL	RUNNING TOTAL	NO CONTROL
1	-		2	26	18		20
2	0		3	27	18		21
3	1		3	28	19		21
4	2		4	29	20		22
5	2		6	30	20		23
6	3		6	31	21		24
7	4		7	32	22		24
8	5		8	33	23		25
9	5		8	34	23		26
10	6		9	35	24		26
11	7		10	36	25		27
12	7		11	37	25		28
13	8		11	38	26		29
14	9		12	39	27		29
15	10		13	40	28		30
16	10		13	41	28		31
17	11		14	42	29		32
18	12		15	43	30		32
19	12		16	44	31		33
20	13		16	45	31		34
21	14		16	46	32		34
22	15		17	47	33		35
23	15		18	48	33		36
24	16		19	49	34		37
25	17		19	50	35		37

Table 1 (Cont'd)

(ix)

+VE BINOMIAL, INFESTATION = 0, NO INFESTATION = +1

LOCALITY :　　DATE :　　UNINFESTATION THRESHOLD :
PLOT :　　PLANT GROWTH STAGE :

PREDATOR : Odonata　$\alpha = 0.3$　$\beta = 0.3$　Upper : 13%　Lower : 24%

SAMPLE NUMBER	CONTROL	RUNNING TOTAL	NO CONTROL	SAMPLE NUMBER	CONTROL	RUNNING TOTAL	NO CONTROL
1	0		2	26	20		22
2	0		3	27	21		23
3	1		4	28	22		24
4	2		4	29	23		25
5	3		5	30	23		26
6	4		6	31	24		27
7	5		7	32	25		27
8	5		8	33	26		28
9	6		9	34	27		29
10	7		10	35	27		30
11	8		11	36	28		31
12	9		12	37	29		31
13	9		13	38	30		32
14	10		13	39	31		33
15	11		14	40	32		34
16	12		15	41	32		35
17	13		16	42	33		36
18	14		17	43	34		36
19	14		18	44	35		37
20	15		18	45	36		38
21	16		19	46	36		39
22	17		20	47	37		40
23	18		21	48	38		40
24	18		22	49	39		41
25	19		22	50	40		42

(x)

+VE BINOMIAL, INFESTATION = 0, NO INFESTATION = +1

LOCALITY :　　DATE :　　UNINFESTATION THRESHOLD :
PLOT :　　PLANT GROWTH STAGE :

PREDATOR : *Paederus* sp.　$\alpha = 0.3$　$\beta = 0.3$　Upper : 20%　Lower : 46%

	CONTROL	RUNNING TOTAL	NO CONTROL	SAMPLE NUMBER	CONTROL	RUNNING TOTAL	NO CONTROL
1	0		1	26	17		18
2	1		2	27	18		19
3	1		3	28	18		20
4	2		3	29	19		20
5	3		4	30	20		21
6	3		5	31	20		22
7	4		5	32	21		22
8	5		6	33	22		23
9	5		7	34	22		24
10	6		7	35	23		25
11	7		8	36	24		25
12	7		9	37	24		26
13	8		10	38	25		27
14	9		10	39	26		27
15	10		11	40	27		28
16	10		12	41	27		29
17	11		12	42	28		29
18	12		13	43	29		30
19	12		14	44	29		31
20	13		14	45	30		31
21	14		15	46	31		32
22	14		16	47	31		33
23	15		16	48	32		33
24	16		17	49	33		34
25	16		18	50	33		35

Table 1 (Cont'd)

(xi)

+VE BINOMIAL, INFESTATION = 0, NO INFESTATION = +1

LOCALITY :
PLOT :

DATE :
PLANT GROWTH STAGE :

UNINFESTATION THRESHOLD :

PREDATOR : *Casnoidea* sp. $\alpha = 0.3$ $\beta = 0.3$ Upper : 18% Lower : 22%

SAMPLE NUMBER	CONTROL	RUNNING TOTAL	NO CONTROL	SAMPLE NUMBER	CONTROL	RUNNING TOTAL	NO CONTROL
1	-		4	26	18		24
2	-		5	27	18		25
3	-		6	28	19		26
4	0		6	29	20		27
5	1		7	30	21		27
6	2		8	31	22		28
7	2		9	32	22		29
8	3		10	33	23		30
9	4		10	34	24		31
10	5		11	35	25		31
11	6		12	36	26		32
12	6		13	37	26		33
13	7		14	38	27		34
14	8		14	39	28		35
15	9		15	40	29		35
16	10		16	41	30		36
17	10		17	42	31		37
18	11		18	43	31		38
19	12		18	44	32		39
20	13		19	45	33		39
21	14		20	46	34		40
22	14		21	47	35		41
23	15		22	48	35		42
24	16		23	49	36		43
25	17		23	50	37		43

examining ten sample units, the running total should be compared with the control and no control columns. If the running total equals or is less than the figure in the control column, stop sampling for that particular arthropod category, and management action should be considered. On the contrary, if the running total equals or is more than the figure in the no control column, stop sampling; no treatment is needed against that particular pest. A similar operational procedure is performed for the predators, though in this case the respective decisions would be classifying the population level of a particular predator as high or low. However, in both plans for pest and predators, if no decision can be made even at the 50th sampling unit, stop sampling and sample again two or three days later. After completion of sampling a particular area, the need for management action against some particular pest species should be weighted by the levels of predators' populations. In the presence of high levels of predator populations, control actions to suppress pest populations may be left to the natural predators. To date there is ample evidence indicating the regulatory role of natural enemies in paddy fields (e.g. Kenmore *et al.* 1984; Heong *et al.* 1991; Way and Heong 1994).

Advantages of Presence/absence Plans

It is proven that a good pest management system can be achieved by using a sampling technique that is rapid, reliable, reproducible, realistic, and has a low level of risk (Sterling and Pieters 1979). Presence/absence plans can meet these criteria. In addition, binomial sampling is the most feasible field sampling method for many organisms (Binns and Nyrop 1992); also, it is usually faster and therefore less costly on a per-sample unit basis (Wilson 1982). Moreover, the sequential sampling probabilities α and β can be preset as desired, especially considering the damaging status of a particular pest. The α and β levels presented here each equals 0.30. This 30% level of risk has been practically acceptable in management of cotton pests in Australia (Sterling 1976; Wilson 1982). Lower levels of risk entail taking larger number of samples. Although various researchers have further convincingly elaborated on the practicality, especially for small arthropods since no actual counting is necessary, and on the virtues of binomial sampling plans (e.g. Shepard *et al.* 1989; Wilson *et al.* 1989;), the plans presented need to be tested in Malaysian field conditions to determine its practicality, validity and reproducibility.

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