Spatial Distributions of Rice Diseases

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Abstract

Experiments were carried out at the Pathumthani Rice Research Centre and in a farmer's field in 1986 using the rice cultivar RD 23 with direct seeding and transplanting. Five hundred and thirteen hills in a grid had been tagged in the experimental plots to represent the "true" disease incidence of the entire plant population. The spatial distribution of leaf and neck blast, sheath rot, YOLV and dirty panicle in various fields and seasons were analyzed by means of the Morisita index and the variance-to-mean ratio. The effect of various quadrat sizes on both the indices and their statistical significance for contiguous and random placement was tested. Differences existed for incidence levels only, not for diseases, localties and cropping practices. At low incidence (about less than 50%) the disease patterns were aggregated but spatial distribution was random with higher incidence of these rice diseases. But as there are exceptions pilot studies of the disease incidence at which the actual spatial distribution becomes random should precede the decision for an appropriate sampling method.

Keywords : rice, *Pyricularia oryzae, Sarocladium oryzae*, yellow orange leaf virus (YOLV), dirty panicle, spatial distribution

An important role in the development of the national paddy rice pest control programme in Thailand is Integrated Pest Management (IPM). Pest surveillance is a basic strategy in the implementation of such a programme. The establishment of appropriate surveillance methods is only in its early stages and is still being tested for the various disease, pest and weed problems in different methods of rice cultivation. Sampling techniques and pest monitoring are two major components of surveillance.

Materials and Methods

1. The field experiments

1.1 Locations

The experiments were carried out in 1986 in experimental plots and two locations where cultivation methods as well as climatic conditions were somewhat different via Pathumthani Rice Research Centre (PRRC), 40 km north of Bangkok, and a farmer's field in the Chachoengsao Province, 60 km east of Bangkok. At the Rice Research Centre full facilities for irrigation are available, whereas at the other location traditional

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rainfed cultivation methods prevail with low fertilizer use. Soils in both locations are classified as heavy clay with difficult water drainage, typical for the lowland rice cultivation areas of Thailand's central plain.

1.2 Agricultural practices

Land preparation, ploughing, planting, cultural practices, pest control as well as harvesting at the PRRC are more intensive than in the farmer's field. Because of irrigation in the station, time of planting differs from the farmer's field in both wet and dry season crops, i.e. September – December and April – July, respectively, at the PRRC and November – March and June – October, respectively, for the farmer's fields (Disthaporn, 1987). Since the spatial distribution of diseases may change with the cultivation method, both direct seeding and transplaning, were included in the experiments grown concurrently and located side by side, divided only by a dike (Table 1).

Table 1. Field experiments laid out for this study.

No.	Code	Location	Cultural practices	Season	Year	Planting (date)	Harvesting (date)
	PDD 86	Pathumthani	Direct seeded	Dry	1986	Sep. 19, 1986	Jan. 8, 1987
1987							
	PTD 86	Pathumthani	Transplanted	Dry	1986	Sep. 18,1986	Jan. 8, 1987
	FDD 86	Farmer's field	Direct seeded	Dry	1986	Nov. 9, 1986	March 5, 1987
1987							
	FTD 86	Farmer's field	Transplanted	Dry	1986	Nov. 9, 1986	March 5, 1987
	PDW 86	Pathumthani	Direct seeded	Wet	1986	April 4, 1986	July 31, 1986
1986							
	PTW 86	Pathumthani	Transplanted	Wet	1986	April 4, 1986	July 31, 1986
	FDW 86	Farmer's field	Direct seeded	Wet	1986	June 12, 1986	Oct. 7, 1986
1986							
	FTW 86	Farmer's field	Transplanted	Wet	1986	June 12, 1986	Oct. 7, 1986

1.3 Cultivar

Rice cultivar RD 23 as Indica – type was used. The cultivar is semi – dwarf, non – photo – sensitive and responsive to heay nitrogen application, with a growing period of 120 days. The cultivar is highly resistant to the brown planthopper (BPH), *Nilaparvata lugens* (Stal.) but highly susceptible to diseases, particularly blast *(Pyricularia oryzae).*

2. Conduct of the field experiments

2.1 The lay – out of field plots

Each plot size was 20 × 40 m. The plots were cultivated according to common farmer practice and exposed to natural infections by diseases. Insecticides were applied only when necessary to avoid interference with insect damage. For disease assessment 488 to 513 hills as sampling units (i.e. 27 hills in each of 19 rows) were systematically tagged in the plots at a distance of 1.5 m. between rows and 1 m. within rows. One sampling unit in direct seeded rice consisted of 10 – 25 tillers, which were tied together with a string at a maximum tillering stage to be equivalent to a hill ("pseudohill").

2.2 Diseases recorded

The following diseases occurred naturally in the field plots and were recorded for this study : leaf blast *(Pyricularia oryzae),* yellow orange leaf virus, sheath rot *(Sarocladium oryzae),* neck blast *(P. oryzae)* and dirty panicle caused by various sooty molds and bacteria (Ou, 1985). A field record form was designed for a standardized and immediate recording of disease incidences in the field. It contained the following information per sampling unit (i.e. hill) with the growth stages according to Zadoks *et al.* (1974):

LB – leaf blast (% leaf area diseased, i.e. disease severity) at DC 25, 35 and 50

YOLV – yellow orange leaf virus (yes = 1, no = 0) at DC 25

SHR – sheath rot (number of infected tillers) at DC 75

NB – neck blast (number of infected panicles) at DC 75

DP – dirty panicle (% infected seed) at DC 80

NOT – number of tillers

NOP – number of panicles

3. Data analyses

For the analysis of the spatial patterns of the diseases, the field data were arranged in a 19×27 matrix which contained only 1 or 0, i. e. a hill is infested or not by the diseases under consideration, irrespective of the severity. From these 513 hills or pseudohills the disease incidence of each plot was calculated.

To evaluate the goodness–of–fit of certain discrete distributions to frequency count data (i.e. disease incidence), 9 hills were combined in one quadrat as the smallest acceptable quadrat size to minimize overlap. With the plot size available for the experiments and the quadrat size chosen 57 quadrats could have been obtained. However, due to the dimension of the matrix and the geometry of the plots, only 54 quadrats could effectively be used leaving 1 row with 27 hills uncovered. To overcome this problem all the calculations were made twice leaving out the last or the first row. If the spatial distribution of diseased plants would be random, the observed frequency distribution should follow a binomial distribution with n = 9. Because of this fixed low number we could not approximate the binomial distribution with the Poisson–distribution, which is commonly used in this kind of analysis. From the mean $\overline{X}$ and variance S^2 of the number of infected hills within the N = 54 quadrats, the variance–to–mean ratio (VTM) is calculated giving an indication of the degree of aggreagtion. In theory VTM should be less than 1 for the binomial distribution and greater than 1 for contiguous distributions like the negative binomial. Therefore, we tested the goodness–of–fit for the binomial distribution by means of Chi^2– test only if VTM was less than or equal to 1.3. This value is derived from the dispersion test indicating when VTM is significantly different from 1. Under the null hypothesis of randomness VTM multiplied by (N–1) has a Chi^2– distribution with N – 1 degrees of freedom. Thus for N = 54 quadrats an aggregated pattern can be concluded if VTM exceeds 1.339. We did not test the significance for the values less than 1 as a regular spatial distribution of a disease is unlikely as shown by Mihail and Alcorn (1987) for a soilborne disease.

As a second measure for aggregation we calculated the index Idelta of Morisita (1959) which indicates that distribution is regular if Idelta < 1, random if Idelta = 1 and clustered if Idelta > 1. The Idelta–values were calculated for different contiguous quadrat sizes ranging form 4 to 140 hills within the quadrats. We tried to cover the data matrix completely, however, depending on the quadrat size it could happen, that at the edges part of the quadrats could lie outside of the field. In this case the position of the quadrat was corrected to ensure that the last quadrat was completely within the matrix leading to an overlap of certain parts of the matrix. Seven fields with a complete data set of 513 hills were analysed. For the analysis of patterns the programme Clustest (G. Weber, pers. com.) was used, for the mapping the programme PlotIt.

Both, variance – to – mean and the Morisita index, are relatively simple and used by plant pathologists to analyze spatial patterns also of above – ground diseases (Jeger, 1990).

Results and Discussion

The Chi^2 values calculated to test whether an Idelta value or the variance – to – mean ratio (VTM) is significantly greater than 1 are identical. The same result is reported by Mihail and Alcorn (1987). Thus the conclusions, i.e. clustered or random spatial distribution, were the same. Hence, for the effect of quadrat size and quadrat placement as systematic grids (contiguously) or random on these two indices we present Idelta values only (Table 2).

There is practically no difference in using contiguous or random quadrat placement inspite of more overlaps in the latter case, especially with a high number of quadrats. The choice of the quadrat size is usually influenced by the acreage available for a field experiment. Though it is likely to obtain significant Idelta values with larger quadrat sizes this reduces the possible number of quadrats free of overlaps. Hence, the decision on quadrat size will depend on the discretion of the experimenter. We adopted the 3×3 hill quadrat size for Table 3 to have a minimum of overlaps.

The difference between fields and diseases which obviously depend on the level of disease incidence (Table 2). These differences – random or aggregated – apply to practically all quadrat sizes in each of the fields tested. In only one case (FTW) the Idelta values became statistically significant at quadrat sizes of 10 and above.

Whether the spatial distribution of diseased hills of five rice diseases with a wide range of incidence (5.65 to 85.70%) was random or clumped (Table 3).

The irrespective of the kind of cropping practice and locality, which had no effect, the spatial distribution or disease pattern at high disease incidences was random, and clustered at lower incidence (Table 3). For instance, the spatial distribution of DP in 1985 at 85.7% (Disthaporn, 1987), and similarly YOLV, which at 13.84% incidence is aggregated (Table 2), is random at 89.67% with an Idelta value close to 1 (Disthaporn, 1987). In contrast, LB (DC 25) of PDD at a medium level of disease incidence (53.8%, Table 3) shows a clumped spatial distribution, since VTM of both readings (start edge 1 and 2) are higher than 1.3, i.e. 1.85 and 1.90, respectively. In another field this disease was randomly distributed at the same growth stage but at higher incidence (Tables 2 and 3). Hence, for a decision on clumped vs. random distribution reliance on growth stages alone may not suffice as even at an incidences of 79% of SHR and 71% of neck blast were not random in the analysis (Disthaporn, 1987).

It is essentially the incidence level which determines whether the disease in a field is aggregated or distributed at random. The incidence may, however, change with the growth stage of the crop and/or the stage of disease progress, and possibly also for different cropping practices, though such differences were not observed in our experiments (Table 3). We, therefore, recommend to identify the level up to which the incidence of a

Talble 2. Comparison of Idelta values for spatial distribution obtained by different quadrat sizes applied systematically and randomly for selected fields of 1986.

Quadrat placement	Side length hills	Number☆ of quadrats	Leaf blast at DC 25 PDD	25 FTW	50 PTD	50 FTW	Dirty panicle DC80 PDD	YOLV DC25 FDD	SHR DC75 PDD	NB DC75 FDD
Grid△										
	2	140	1.02	0.78	0.83	0.76	0.90	1.11	1.22	0.89
	3*	63	1.16	0.93	1.00	0.90	1.00	1.42	1.28	0.99
	4	35	1.21	0.99	1.02	0.95	1.00	1.49	1.31	0.98
	5	24	1.21	1.01	1.03	0.98	1.00	1.55	1.37	0.98
	6	20	1.31	0.99	1.03	0.98	1.02	1.60	1.19	1.01
	7	12	1.21	1.01	1.01	1.00	1.01	1.36	1.26	1.00
	8	12	1.21	1.01	1.01	0.99	1.01	1.51	1.22	1.00
	9	9	1.16	1.00	1.02	0.99	1.01	1.35	1.12	1.01
	10	6	1.19	1.02	1.01	1.00	1.01	1.63	1.04	1.00
	11	6	1.17	1.01	1.00	1.00	1.01	1.59	1.06	1.00
	12	6	1.16	1.02	1.00	1.00	1.00	1.67	1.08	1.00
Random										
	2	40	1.00	0.76	0.84	0.77	0.77	1.14	1.31	0.78
	3	40	1.18	0.90	0.92	0.90	0.91	1.61	0.99	0.90
	4	40	1.12	0.95	0.97	0.94	0.97	1.56	1.15	1.02
	5	40	1.18	0.97	0.99	0.97	0.98	2.59	1.07	1.02
	6	40	1.16	0.98	1.00	0.98	0.99	1.44	1.05	1.03
	7	40	1.14	0.99	1.01	0.99	0.99	1.96	1.07	1.05
	8	40	1.11	0.99	1.01	0.99	0.99	2.01	1.02	1.03
	9	40	1.12	0.99	1.01	0.99	1.00	1.74	1.03	1.03
	10	40	1.09	0.99	1.00	0.99	1.00	1.78	1.02	1.02
	11	40	1.08	0.99	1.00	0.99	1.00	1.83	1.03	1.03
	12	40	1.11	1.00	1.01	0.99	1.00	1.65	1.03	1.02

Bold figures stand for significant Idelta values > 1 at least at p = 0.05 in the chi^2 – test.

* This quadrat size is used in Table 3 also for the comparison of the observed frequency distributions with discrete probability distributions.

☆ The number of quadrats possible for the experimental plots used (about half a rai), and shape, with each of the quadrat sizes given.

△ This stands for a contiguous quadrat placement on the grid of tagged hills (see Materials and Methods).

Table 3. Results of the spatial distribution of rice diseases at various degress of incidence (DI) per field, computed by CLUSTEST (G. Weber, pers. com.).

Disease	Field☆	DI (%)	Clumped△	Binomial
LB (DC 25)	PDD86	53.80	+	0©
LB (DC 25)	FTW86	89.00	–	–
LB (DC 35)	FTW86	91.40	–	–
LB (DC 50)	PTD86	84.00	–	–
LB (DC 50)	FTW86	94.70	–	–
DP	PDD86	85.70	–	–
YOLV	FDD86	13.84	+	0
SHR	FTW86	5.65	+	0
SHR	PDD86	33.14	+	0
SHR	PTD86	69.20	–	–
SHR★	FDD86	79.01	–	–
SHR▲	FDD86	79.83	–	+
NB	FDD86	68.81	–	+
NB★	FTW86	70.78	–	–
NB▲	FTW86	71.19	–	–
NB	FTD86	86.16	–	–

☆ Designations for fields: 1. position : P = Pathumthani, F = farmer's field; 2. postion: D = direct seeding, T = transplanted; 3. position: D = dry season, W = wet season.

△ Clumped (+) or not clumped (–) according to the Idelta – value of the Morisita index; binomial distribution tested by a goodness – of – fit – test.

★ The last line of the sampling unit (27 numbers) was not computed.

▲ The first line of the sampling unit (27 numbers) was not computed.

© Not tested for binomial distribution once it was found clumped.

disease under given local conditions and cropping practices tends to have a clustered spatial distribution. This will affect the choice of sampling path and possibly, sample size. Whenever there is no significant Idelta value random distribution should be assumed for the choice of the sampling path. Hence, before a sampling method for a disease (under the conditions where it occurs) is developed and proposed a pilot sampling on its actual spatial distribution at relevant stages of the epidemics is required.

In order to assist the development of improved surveillance methods we conducted field experiments during five cropping seasons from 1985 to 1987 (Disthaporn, 1987). The objective of these experiments was to provide actual field information for the subsequent development of suitable sampling methods for rice diseases. We studied two different cropping practices, transplanted and direct seeded rice, at two different locations, and thus obtained 12 fields with recorded disease intensities of leaf and neck blast *(Pyricularia oryzae* Cav., sheath rot *(Sarocladium oryzae* (Saw.) W. Gams & Hawks.), yellow orange leaf virus, and dirty panicle and their spatial distribution in the crop (Disthaporn, 1982). Here we report on the patterns of the incidence of these five diseases in relation to cropping practices and locations for which we here use the data of 1986 only.

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