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PESTICIDE USE BY CHILI FARMERS IN ELLEWEWA BLOCK

A CASE STUDY

by

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Pesticide use by chili farmers in Ellewewa block - A case study

J. R. Burleigh, V. Vingnanakulasingam and W. R. B. Lalith

Introduction

Pesticide use by farmers of horticultural crops in System B is perceived to be excessive by members of the agricultural research and extension communities, yet there are few published accounts that document pesticide use on such crops as chili, gherkin, okra, cantaloupe, and grapes, for example (Piyadasa, 1992). The impression is that farmers of horticultural crops apply pesticides as a first means of defense against insect pests and diseases and that often treatments are made without attention given to pest and disease intensity and to the appropriate pesticide for a specific insect pest or disease. That is, pesticides are thought to be applied when pest and disease intensities do not warrant treatment. As well, pesticides often are ineffective against target pests or disease for reasons that remain largely undocumented but probably are related to: 1) removal of pesticides from foliar surfaces by rainfall immediately following application; 2) pest resistance or tolerance to pesticides and 3) the inappropriate choice of pesticides by farmers because of insect and disease misidentification.

The study described below had three objectives. Objective 1 was to begin construction of a data base on: a) pesticide application frequency and dose by farmers of horticultural crops in System B; b) pesticide safety measures employed by farmers of horticultural crops; and c) target pests and diseases of horticultural crops as perceived by farmers.

Objective conclusions regarding pesticide use by farmers of horticultural crops rely on the acquisition of reliable data; that is, data obtained with minimun bias and minimum systematic error so that inferences about the population from which samples are drawn are accurate. Data to describe a population are generated by a sampling protocol that selects and examines sample units in a statistically acceptable manner. Precision of sample estimators to predict population values requires a fundamental understanding of the distribution of the estimators. Many biological phenomena result in data distributed normally; consequently, much statistical theory is based on fit of data to a normal distribution. If pesticide - use is distributed normally, then means and standard deviations obtained from random samples will be normally distributed and representative of population values. Even if the parent population is anormal, theory states that means of random samples

approach normality as sample size increases. This is quite important as the form of a parent population is rarely known. However, if the parent population is anormal and the spatial arrangement of pesticide - use among farmers is not random it is likely that sample estimators will not be representative of the population and inferences, therefore, inaccurate. Consequently, objective 2 of this study was to describe the spatial pattern of pesticide use among farmers (i.e. random, regular or aggregated). Random means that each crop field has an equal probability of being treated or nontreated; that information from one field provides no information for any other field and that the action of one farmer is independent of others. Aggregation is the antithesis of randomness. That is, each field does not have an equal probability of being treated or nontreated; information from one field provides information for others and the action of a farmer is influenced by his/her neighbors (or that clusters of farmers are influenced by a common factor). Regular refers to a uniform pattern of pesticide use. Objective 3 was to determine the number of farmers to sample to achieve a given level of accuracy in estimating pesticide-use frequency and dose. Objective 3 is a corollary to 2 as sample size depends on the population distribution.

Materials and Methods

Chili is the dominant horticultural crop in System B and previous MARD activity in Ellewewa block suggested that chili and Ellewewa were logical choices to begin the task of building a data base on pesticide use by farmers of horticultural crops. All farmers of chili in Ellewewa constituted our population.

Every chili farmer in Ellewewa block of System B was questioned weekly during Maha 1993-94 and Yala 1994 regarding names of pesticides used, quantities applied, area treated, safety clothing worn, target insect pest or disease and date of treatment. Data collectors were trained to identify common insect pests of chili i.e. aphids, thrips, mites, white flies and army worms as well as the common diseases Cercospora leaf spot and anthracnose. Symptoms of Cucumber Mosaic Virus (CMV) Tobacco Etch Virus (TEV), Potato Virus Y (PVY) and Pepper Mild Mottle Virus (PMMV) were often indistinquishable and therefore, grouped into a single catagory of infection by viruses. Training was integral to the study and frequent on-site visits were made by the plant pathologist to confirm the accuracy of insect and disease identification by data collectors. During Maha 1993-94, ten plants per farm were randomily selected and examined weekly for pest and disease incidence in four of eight units within Ellewewa block. The four units selected were units where trained data collectors lived and worked. During Yala 1994 an additional three data collectors were

trained and pest/disease incidence data collected weekly from 50 randomily selected plants per farm in seven of eight units. No chili was planted in unit Maguldamana in Yala 1994 (see Table 1).

Data were entered into 'Excel ' then transferred to the statistical program 'Systat' where pesticide - use frequency and dose were tested for goodness of fit to a normal distribution by using the Kolmogorov-Smirnov One-Sample Test in the nonparametric module and the probability plot subroutine in the Graph module. Pesticide-use data also were fit to the Poisson distribution to test for randomness. If data failed to fit the Poisson they were then fit to the Negative Binomial to substantiate aggregation or to the Positive Binomial to substantiate uniformity. Goodness of fit to the Poisson and Negative and Positive Binomial distributions was determined by the test criterion Chi-square at $P = 0.05$ with n-1 degrees of freedom, where n= number of classes.

Sample size to achieve a given level of precision for pesticide-use frequency and dose was calculated according to equations by Karandinos as cited in Teng (1987). For the poisson distribution the sample size (n) = $(Z_{\alpha/2}/D)^2 \times (1/xbar)$; where $Z_{\alpha/2}$ is the value of the standard normal deviate at the upper $\alpha/2$ point which is replaced by Student's t when n is likely to be less than 30. If Student's t is used an assumed n must be chosen to determine df for t. In this study $Z\alpha/2 = 1.96$. Xbar is the mean and D is the desired level of precision as a proportion of the mean. For the negative binomial distribution, sample size (n) $=[(Z\alpha/2)^2 \times (1/xbar + 1/k)]/D^2$; where $Z_{\alpha/2}$, xbar, and D are as described above and k is the aggregation parameter $= xbar/(s^2/xbar)-1$, where s^2 is the variance.

Percentage fields treated and the ratio, number of treatments/number of fields in each of 15 size categories from <=100 m^2 to 1500 +m^2 were regressed on chili field size by least squares regression to determine if the number of fields treated and the number of treatments made per field are related to field size.

Results

Seventy-two farmers planted 43711 m^2 (4.37 ha) of chili in Maha 1993-94 (see Table 1). Thirty farmers (42%) made 51 treatments and applied a total of 3700 ml of pesticide product on a total of 29564 m^2 (2.95 ha). Forty two farmers (58%) did not apply pesticides. Gloves, masks and boots were used by 3, 2, and 1, farmer(s), respectively. In contrast, during Yala 1994, 116 farmers planted 43819 m^2 (4.38 ha) of chili. Sixty-five (56%) made 215 treatments

and applied a total of 12206 ml of pesticide product on a total of 111167 m^2 (11.11 ha). Fifty one farmers (44%) did not apply pesticides. In both Maha and Yala the maximum number of pesticide treatments made by one farmer was six.

The percentage of farmers who treated at least once varied markedly by unit (see Figure 1). Where only 21% treated in Pahala Ellewewa in Maha, 92% treated in Kalukelle. During Yala 100% treated in Kalukelle but only 52% in Pahala Ellewewa and 0% treated in Mahadamana. More farmers treated during Yala than during Maha in all units except Mahadamana. Percentage of fields treated and number of treatments per field were not related to chili field size in Maha, but there were highly significant linear relationships in Yala (see Figure 2). The median field size in Pahala Ellewewa during Maha was 1250 m^2 and 21% of the farmers treated; whereas, in Kalukelle the median field size was 490 m^2 but 92% of the farmers treated (see Figure 3). In Bandanagala fields were small and the median size was about 125 m^2 for both seasons yet 62 and 61% of the farmers treated during Maha and Yala, respectively, and that percentage was markedly greater than the percentage for Pahala Ellewewa where field sizes were larger. All farmers treated during Yala in Kalukelle and Pelatiyawewa and the median field size in those units was 500 and 650 m^2, respectively. In Mahadamana no treatments were made in Yala and the median field size was 125 m^2, the same as in Bandanagala. Figure 3 also shows that field size in Yala generally was larger in units Kalukelle andPelatiyawewa than in others.

Monocrotophos is the pesticide (insecticide) of choice by the majority of chili farmers in Ellewewa. During Maha 12 farmers made 21 applications of monocrotophos; whereas, during Yala 41 farmers made 67 applications (see Tables 2 and 3). Monocrotophos and Selecron (a.i. profenofos) were applied 30 times (59%) during Maha. In Yala Monocrotophos, Selecron and Sulfur were applied 123 times (57%). Fungicides were used eight (15%) and six times (3%), during Maha and Yala, respectively.

Most farmers treated for control of insect pests rather than for disease. Eighty percent treated for aphids, thrips, mites, worms and leaf curl during Maha; whereas, 95% treated during Yala (see Tables 2 and 3). White fly was not mentioned by any farmer. In contrast, only 20 and 5% of the farmers treated for disease in Maha and Yala, respectively. Farmer perception of pest and disease problems are in general agreement with observations made by data collectors, but there were some notable differences. Farmers treated 11 times for worms during Maha but incidence values (see Table 1) show that our data collectors did not record the presence of worms (*Spodoptera* sp.). Differences among data collectors and

farmers was even more striking in regard to anthracnose. Data collectors noted a high incidence of anthracnose (*Collectotrichum* sp.) but only three treatments were made by farmers for leaf spot (a symptom of anthracnose). A high incidence of virus infection was recorded by data collectors but 'virus' was not mentioned by any farmer during Maha. Farmers do recognize virus symptoms, however, as evidenced by nine treatments made during Yala specifically for virus. Farmers made nine (17% of all treatments) and 94 (44%) treatments for leaf curl during Maha and Yala, respectively. No farmer mentioned or treated for narrow leaf disorder (NLD) during Yala, the season when NLD generally is most prevalent (personal communication with Mr. Vingnanakulasingam, AO at RARC) However, three treatments were made during Maha for what farmers called 'narrow leaf'.

Chili field size and quantity of pesticide applied are not normally distributed (see Figure 4). Number of pesticide treatments and quantity of pesticide applied per hectare also do not fit a poisson distribution (see Tables 4-7), suggesting that treatment frequency and quantity are nonrandom. The negative binomial did describe the distributions of number of treatments for Maha and quantity of pesticide for Maha and Yala. Fit to the negative binomial was rejected for number of treatments in Yala. No data fit the positive binomial indicating that pesticide use is not uniform among units.

Sample size less than the population size did not permit accurate estimation of mean values for number of treatments and dose (see Table 8). During Maha sampling about 60 to 70 farmers ostensibly would have permitted sample means to be within 40% of population values, but within 25% during Yala, which might be acceptable.

Discussion

The maximum number of pesticide treatments made by any one farmer during Maha and Yala was six, while 58 and 44% of farmers did not treat, respectively. Based on use frequency and number of treatments therefore, it appears that chili farmers (at least in Ellewewa) treat less often and with less product than commonly thought by researchers and extensionists. Our data show that 72 farmers made 42 insecticide treatments on 30 farms and that treatments did not prevent aphid infestation and virus infection (virus was primarily CMV which is vectored by *Myzus persicae* and *Aphis gossypii*) based on their incidences in four units (see Table 1). Similarly, only eight fungicide treatments were made by 72 farmers during Maha for disease control but 87 to 100% of plants were infected with anthracnose in three units and 28% in a fourth unit. Clearly, farmers did not consider

anthracnose a risk to production; whereas, data from studies conducted by us at the Regional Agricultural Research Center- Aralaganwila show that anthracnose infection of stem tissue particularily, frequently causes plant death and was the most severe disease in Maha.

Pesticide treatments made in Yala fit more closely than during Maha the intensity of pest and disease infestations. Five farmers treated with fungicides during Yala and they made only six treatments collectively. Fungus disease was mentioned only by two farmers as reason for treatment and incidence data from seven units suggested that anthracnose was not a threat to production. In contrast, 212 treatments were made for insect pests and virus (vectored by insects) and that number coincides generally with farmer perception of insect pest intensity and independent observations made by our data collectors. Virus was noted by data collectors more often than insect pests or other diseases.

In summary, farmer response to insect pest and disease intensity was closely linked to actual intensities only during Yala. Maha 1993-94 was characterized by heavy and frequent rainfall (2334 mm and 103 days- see records from RARC-Aralaganwila) and several farmers abandoned their fields because of plant death from excessive moisture and probably from anthracnose as well. Therefore, the uncoupling of pesticide treatment from actual pest and disease intensities during Maha 1993-94 might, in fact represent a wise decision by farmers to refrain from treatment during periods when pesticide efficacy was compromised by frequent and heavy rain. Overall, it does not appear that chili farmers in Ellewewa treat excessively with pesticides. Rather, based on virus incidence, treatments were ineffective or inadequate in number and the reason(s) beg close scrutiny. In work described in a companion report we show that three applications of the insecticide Admire (active ingredient - Imidacloprid @ 0.2 l/ha) effectively control aphids, yet of 188 chili farmers surveyed during Maha and Yala, not one used Admire. Instead, farmers relied on Monocrotophos, Selecron, Sulfur, Thiodan, Endosulfan, and Tamaron for aphids and those pesticides did not prevent virus transmission by aphids as evidenced by incidences ranging from 29 to 86% during Maha and from 12 to 78% during Yala. Those materials are not recommended for aphids on chili by the Department of Agriculture (Crop Recommendations Technoguide, 1990) yet they are used by farmers. Clearly, farmers are not using the most effective pesticide available for aphids and therefore, virus. Admire costs 560 Rs for 100 ml in local boutiques but the quantity needed by a grower of 500 m^2 of chili in only 10 ml. Responsible agencies within the DOA might be well advised to promote the judicious use of Admire in their IPM program as a replacement for the

materials commonly used at present. Nevertheless, before sounding the trumpet too loudly for Admire, its potential to create tolerant forms within insect pest populations should be established.

Another explanation for the ineffectiveness of pesticides to limit insect populations and virus transmission is the possible existence of pesticide tolerance. A study sponsored by MARD and conducted by RARC-Aralaganwila has been initiated to determine the presence of insecticide tolerance in thrip populations from System B. Similar studies need to be conducted to test for tolerance in several insect:insecticide combinations.

Farmers generally eschew safety clothing while applying pesticides to chili. That is common knowledge and these data support the view that pesticides are not considered hazardous to human health by farmers. Of the 106 farmers who applied pesticides during the course of our study only eight used gloves and mask (7.5%) and one (0.9%) used rubber boots.

Pesticide - use frequency and dose are nonrandom and appear to be aggregated. Lack of fit by data to the poisson distribution supports nonrandomness but fit to the negative binomial as evidence of aggregation, occurred only with number of treatments in Maha and quantity of pesticide used in Maha and in Yala. Number of treatments in Yala did not fit the negative binomial. Evidence for aggregation, therefore, is preliminary and in part, speculative; yet the map of Ellewewa giving the percentage of farmers who treated shows that the vast majority of farmers treat in some units (Kalukelle); whereas, in others (Pahala Ellewewa and Mahadamana) most do not treat. The reason for the difference is, in part, associated with aphid and virus incidence. For example, in Kalukelle 63% of plants observed were infected with virus during Yala and 19 of 19 farmers treated with pesticides. In contrast, no treatments were made in Mahadamana where 12% of plants were infected with virus. Though comparison of some units supports the apparent association of insect/disease incidence and number of treatments, additional comparisons suggest that other forces might be acting as well. Virus incidence in Ihala Ellewewa, Pahala Ellewewa and Mahadamana during Yala was 15, 16 and 12%, respectively, and 70, 52 and 0% of farmers treated. Here, similar virus intensities prompted dissimilar responses. Perhaps, farmers respond to advice given by extension agents and/or boutique owners. Aggregation occurs possibly because advice is linked to information disseminated by individuals whose perception of risk, method of risk assessment and/or whose power of observation differ markedly. A well-conceived and executed program to train block and unit individuals in

disease and pest diagnosis and methods to assess risk could help standardize farmer response to pest problems. A standard response based on risk plus access to the best, available pesticides would improve farmer income by reducing production costs and lead to continued reduction in pesticide use. There are other components to a training program that are already well know and therefore, not discussed here, e.g. knowledge of pest/predator relationships. The emphasis we make here is that advice given to farmers as well as farmer knowledge must be based on the accurate assessment of disease and pest risk to production and on methods to evaluate the impact of pest and disease populations on farmer income. We are persuaded that training/education of extensionists and farmers in risk assessment would be cost effective and ultimately lead to improved management strategies for horticultural crops and increased income for farmers; and are not those the goals for MARD II?

Sampling is costly and time consuming. By knowing the smallest sample size to give precise estimates of population values cost and time can be reduced. Our study suggests that by sampling 60 to 80% of the farmer population in a block reasonably accurate estimates of population means for pesticide use can be obtained. That may not appear to be much of a savings but if work is done to obtain data from all blocks in System B then the savings in human and material resources would be noticeable and permit accurate estimates to be used for policy decisions rather than perception.

Recommendations

1) Continue to build data base on pesticide use on horticultural crops in System B by surveying 60 - 80% of growers of individual crops in each block. The data will provide factual information on pesticide use frequency and dose.

2) Initiate a program to train farmers and extensionists in pest and disease diagnosis, and in risk assessment methodology, i.e. how to build a relationship between pest intensity: crop production and phenology: farmer income.

3) Prioritize pest and disease problems of horticultural crops to foster appropriate partitioning of resources.

4) Strengthen pesticide: human health awareness programs.

References

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2. Piyadasa, Ranjith B. 1992. Work done on chili. In Integrated pest management for pests of high value crops in System B, by A. I. Mohyuddin. Published by MARD 1992. pp 11-18.

3. Teng, P. S. 1987. Crop Loss Assessment and Pest Management. Published by the American Phytopathological Society, St. Paul, MN. USA. pp. 270.

Table 1. Percent chili plants infested with insect pests and diseases and basic data on pesticide use and area planted to chili during Maha 1993-94 and Yala 1994 in Ellewewa Block.

Season	Unit	Nb. Plants observed	Percent plants infested with insect pests and disease																
			White fly [a]	Aphids [b]	Mites [a]	Thrips [c]	Army worm [d]	Anth. [e]	Virus [f]	Nb. farms [g]	Nb. treat. [h]	Nb. farmers who treated	Gloves [i]	Mask [i]	Boots [i]	Pesticide applied [j]	Chili area [k]	Area treated [l]
Maha	Ihala Ellewewa	- [m]	-	-	-	-	-	-	-	3	2	1	0	0	0	84	760	372
do	P' Ellewewa	1240	12	40	<1	0	-	92	29	19	4	4	2	0	0	1344	21009	5050
do	Kalukelle	1650	11	36	<1	<1	-	87	38	13	27	12	1	2	0	1578	6713	17086
do	Pelatiyawewa	-	-	-	-	-	-	-	-	6	2	1	0	0	0	84	5400	3000
do	Bandanagala	-	-	-	-	-	-	-	-	8	6	5	0	0	1	82	619	1072
do	Ellewewa	270	4	76	0	0	-	100	86	7	1	1	0	0	0	28	3663	180
do	Maguldamana	-	-	-	-	-	-	-	-	4	6	3	0	0	0	325	1272	2629
do	Mahadamana	390	0	26	0	0	-	28	32	12	3	3	0	0	0	172	4275	1175
	TOTAL									72	51	30	3	2	1	3700	43711	29564
Yala	Ihala Ellewewa	4450	<1	1	2	11	4	1	15	10	23	7	0	0	0	1036	2322	5132
do	P' Ellewewa	17000	1	7	2	5	0	7	16	27	41	14	0	0	0	2132	12690	18800
do	Kalukelle	15850	6	13	<1	7	3	1	63	19	81	19	0	0	0	4838	11245	47720
do	Pelatiyawewa	5650	10	12	4	30	1	4	32	10	31	10	3	5	0	2558	8852	30291
do	Bandanagala	4450	0	7	0	2	0	53	78	13	11	8	0	0	0	158	1308	1136
do	Ellewewa	15600	<1	22	0	1	<1	31	65	28	28	15	2	1	0	1484	7402	8088
do	Maguldamana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
do	Mahadamana	600	0	10	1	0	0	0	12	9	0	0	0	0	0	0	1150	0
	TOTAL									116	215	76	5	6	0	12206	43819	111167

[a] Bemesia tabaci.
[b] Myzus persicae and Aphis gossypii.
[c] Scirtothrips dorsalis and frankliniella schultzei.
[d] Spodoptera sp.
[e] Anthracnose - Colletotrichum capsici and C. gloeosporoides.
[f] includes CMV, TEV and PVY.
[g] Number of farms growing chili.
[h] Number of pesticide treatments made by chili farmers.
[i] Number of farmers who used gloves, mask and boots while applying pesticides.
[j] Total quantity (ml) of pesticide applied.
[k] Total area (m^2) planted to chili.
[l] Total chili area (m^2) treated with pesticides.
[m] No data.

Table 2. Pesticides used by all (72) farmers of chili in Ellewewa block during Maha 1993-94 and pest problems treated according to farmer opinion.

Pesticide name	Active ingredient	Number of farmers who applied	Number of applications	Number of applications for control of different pest problems as identified by farmers								
				Leaf curl	Narrow leaf	Leaf spot	Leaf death	Disease	Aphids	Thrips	Mites	Worms
Monocrotophos	Monocrotophos	12	21	2	3	-	-	-	5	2	-	7
Selecron	Profenofos	6	9	5	-	-	-	-	2	1	1	-
Mancozeb	Mancozeb	2	4	-	-	3	1	-	1	-	-	-
Dimethoate	Dimethoate	2	2	-	-	-	-	-	-	1	1	-
Endosulfan	Endosulfan	1	2	-	-	-	-	-	1	-	-	1
Actellic	Pirimiphos-methyl	2	2	-	-	-	1	-	1	-	-	-
Antracol	Propineb	1	2	1	-	-	-	1	-	-	-	-
Lorsban	Chlorpyrifos	1	1	-	-	-	-	-	-	-	-	1
Metasystox	Metasystox	1	1	-	-	-	-	-	-	-	-	1
Lannate	Methomyl	1	1	-	-	-	-	-	-	-	-	1
Kumulus	Sulfur	1	1	1	-	-	-	-	-	-	-	-
Captan	Captan	1	1	-	-	-	-	1	-	-	-	-
Trebon	Ethofenprox	1	1	-	-	-	-	-	-	1	-	-
Topsin	Thiophanate-methyl	1	1	-	-	-	1	-	-	-	-	-
Trimiltox	mancozeb+copper	1	1	-	-	-	1	-	-	-	-	-
Benlate	Benomyl	1	1	-	-	-	-	1	-	-	-	-
Nil Pesticide		42										
Totals			51	9	3	3	4	3	10	5	2	11

Table 3. Pesticides used by all (116) farmers of chili in Ellewewa block during Yala 1994 and pest problems treated according to farmer opinion.

Pesticide name	Active ingredient	Number of farmers who treated	Number of applications	Number of applications for control of different pest problems identified by farmers						
				Leaf curl	Fungus disease	Virus	Aphids	Thrips	Mites	Worms
Monocrotophos	Monocrotophos	41	67	17	-	3	16	4	4	22
Kumulus/Thiovit	Sulfur	21	29	19	1	-	8	-	1	-
Selecron	Profenofos	18	27	17	-	2	6	3	-	-
Actellic	Pirimiphos-methyl	15	23	17	-	-	6	-	1	-
Thiodan	Endosulfan	10	13	1	-	-	8	-	3	1
Tamaron	Methamidophos	8	10	4	-	-	2	-	-	4
Lorsban	Chlorpyriphos	7	9	2	-	2	1	-	-	4
Basudin	Diazinon	3	5	3	-	-	1	-	-	1
Perfekthion	Dimethoate	4	5	-	-	-	1	-	1	3
Tokuthion	Prothiophos	4	5	4	-	-	1	-	-	-
Lannate	Methomyl	4	4	-	-	-	4	-	-	-
Anthio	Formothion	2	3	2	-	-	1	-	-	-
Antracol	Propineb	2	3	-	1	2	-	-	-	-
Lebaycid	Fenthion	3	3	2	-	-	1	-	-	-
Metasystox	Metasystox	2	3	2	-	-	-	1	-	-
Topsin	Thiophanate-methyl	2	2	2	-	-	-	-	-	-
Fruvit	Oxadixyl+mancozeb	1	1	1	-	-	-	-	-	-
Morestan	Oxythioquinox	1	1	1	-	-	-	-	-	-
Zolone	Phosalone	1	1	-	-	-	1	-	-	-
Nil Pesticide		40								
Total		116	214	94	2	9	57	9	10	33

Table 4. Fit to Poisson and Negative Binomial distributions of number of pesticide treatments on ch in Ellewewa block during Maha 1993-94.

Number of treatments (Y)	Observed frequency (O)	Expected frequency (E) (Poisson)	$(O-E)^2/E$ (Poisson)	Expected frequency (E) (Negative Binomial)	$(O-E)^2/E$ (Negative Binomial)
0	42	35	1.40	43	1.00
1	18	25	1.96	19	1.00
2	8	9	0.44	7	1.00
3	2	2	0.00	3	1.00
4 +	2	0.36	7.47	1	1.00
Total	72	71.36	11.27	73	5.00

X^2 (.05) for 5-1 df = 9.49
Therefore reject Ho that data fit a poisson distribution.
Fail to reject Ho that data fit the negative binomial.

Table 5. Fit to Poisson and Negative Binomial distributions of quantity of pesticides used on chili in Ellewewa block during Maha 1993-94.

Liters or Kg product ha^{-1} (Y)	Observed frequency (O)	Expected frequency (E) (Poisson)	$(O-E)^2 / E$ (Poisson)	Expected frequency (E) (Negative Binomial)	$(O-E)^2 / E$ (Negative Binomial)
0	42	42	0.00	44	0.09
0.1 -1.0	15	23	2.78	20	1.25
1.1 - 2.0	10	6	2.66	6	2.66
2.1 +	5	1	16.00	2	4.50
Total	72	72	21.44	72	8.50

$X^2_{(.05)}$ for 4 -1 df = 7.81

Therefore, reject Ho that data fit a poisson distribution.
Also reject Ho that data fit a negative binomial. Fail to reject Ho at $X^2_{(.025)} = 9.35$.

Table 6. Fit to Poisson and Negative Binomial distributions of number of pesticide treatments on chili in Ellewewa block during Yala 1994.

Number of treatments (Y)	Observed frequency (O)	Expected frequency (E) (Poisson)	$(O-E)^2/E$ (Poisson)	Expected frequency (E) (Negative Binomial)	$(O-E)^2/E$ (Negative Binomial)
0	40	18	26.88	31	2.61
1	22	34	4.23	30	2.13
2	18	31	5.45	22	0.72
3	5	19	10.31	14	5.78
4	18	9	9.00	9	9.00
5	8	3	8.33	5	1.80
6	5	1	16.00	3	1.33
Total	116	115	80.20	114	23.37

X^2 (.05) for 7-1 df = 12.6

Therefore, reject Ho that data fit a poisson distribution.
Also reject Ho that data fit a negative binomial.

Table 7. Fit to Poisson and Negative Binomial distributions of quantity of pesticides used on chili in Ellewewa block during Yala 1994.

Liters or Kg product ha^{-1} (Y)	Observed frequency (O)	Expected frequency (E) (Poisson)	$(O-E)^2/E$ (Poisson)	Expected frequency (E) (Negative Binomial)	$(O-E)^2/E$ (Negative Binomial)
0	40	10	90.00	29	4.17
1.0 - 2.0	21	24	0.37	25	0.64
2.1 - 3.0	16	30	6.53	19	0.47
3.1 - 4.0	10	25	9.00	14	1.14
4.1 - 5.0	8	15	3.26	10	0.40
5.1 - 6.0	7	8	0.12	7	0.00
6.1 - 7.0	6	3	3.00	5	0.20
7.1 - 8.0	3	1	4.00	3	0.00
8.1 - 9.0	3	0.35	20.06	2	0.50
9.1 - 10.0	2	0.09	40.53	1	1.00
Total	116	116.44	176.87	116	8.52

$X^2_{(.05)}$ for 10 - 1 = 16.9

Therefore, reject Ho that data fit a poisson distribution.
Fail to reject Ho that data fit the negative binomial.

Table 8. Sample size (number of farmers) to achieve a level of precision (D) relative to the mean for frequency of pesticide treatments farm $^{-1}$ and pesticide dose farmer $^{-1}$ based on fit to the negative binomial distribution.

Maha [a]			Yala [b]		
Relative Precision (D)	Number treatments	Dose	Relative Precision (D)	Number treatments [c]	Dose
0.25	160	137	0.20	99	108
0.30	111	95	0.25	63	69
0.40	62	53	0.30	44	48
0.50	40	34	0.40	25	27

[a] In study n = 72. Mean number of treatments farmer $^{-1}$ = 0.7. Mean dose farmer $^{-1}$ (l or kg product ha $^{-1}$) = 0.5.

[b] In study n = 116. Mean number of treatments farmer $^{-1}$ = 1.8. Mean dose farmer $^{-1}$ (l or kg product ha $^{-1}$) = 2.4.

[c] Basic data did not fit a negative binomial.

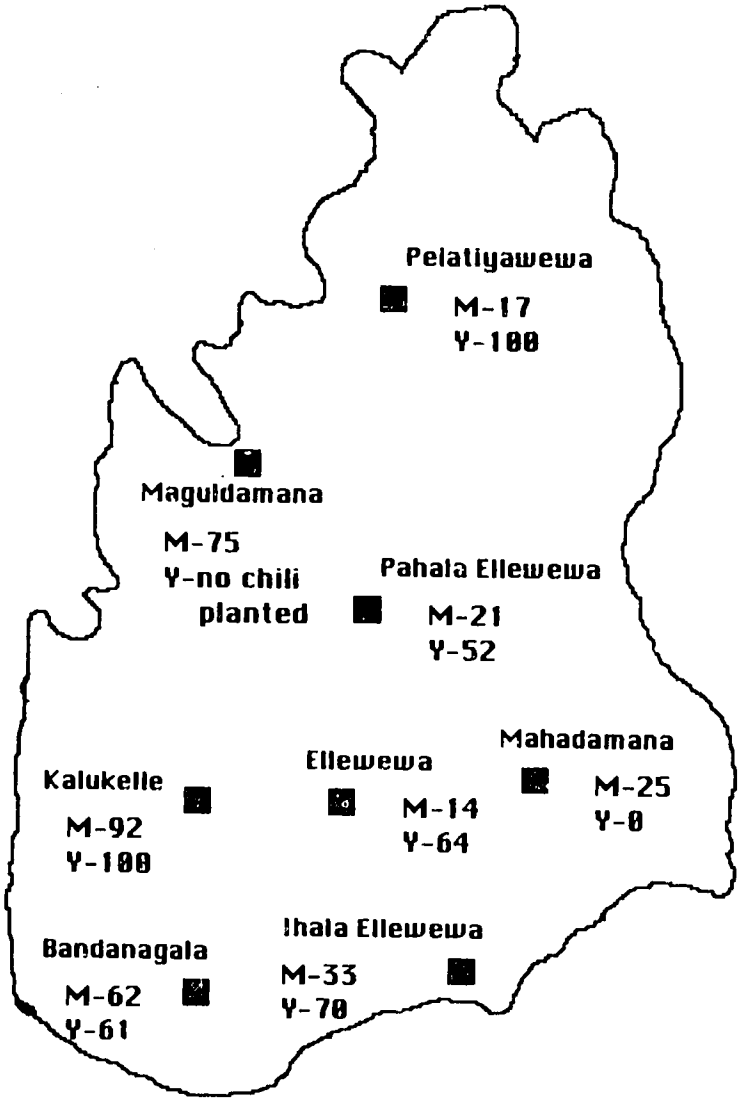

Fig. 1. Map of Ellewewa block and units showing percentage of farmers who treated their chili at least once with a pesticide during Maha 1993-94 and Yala 1994.

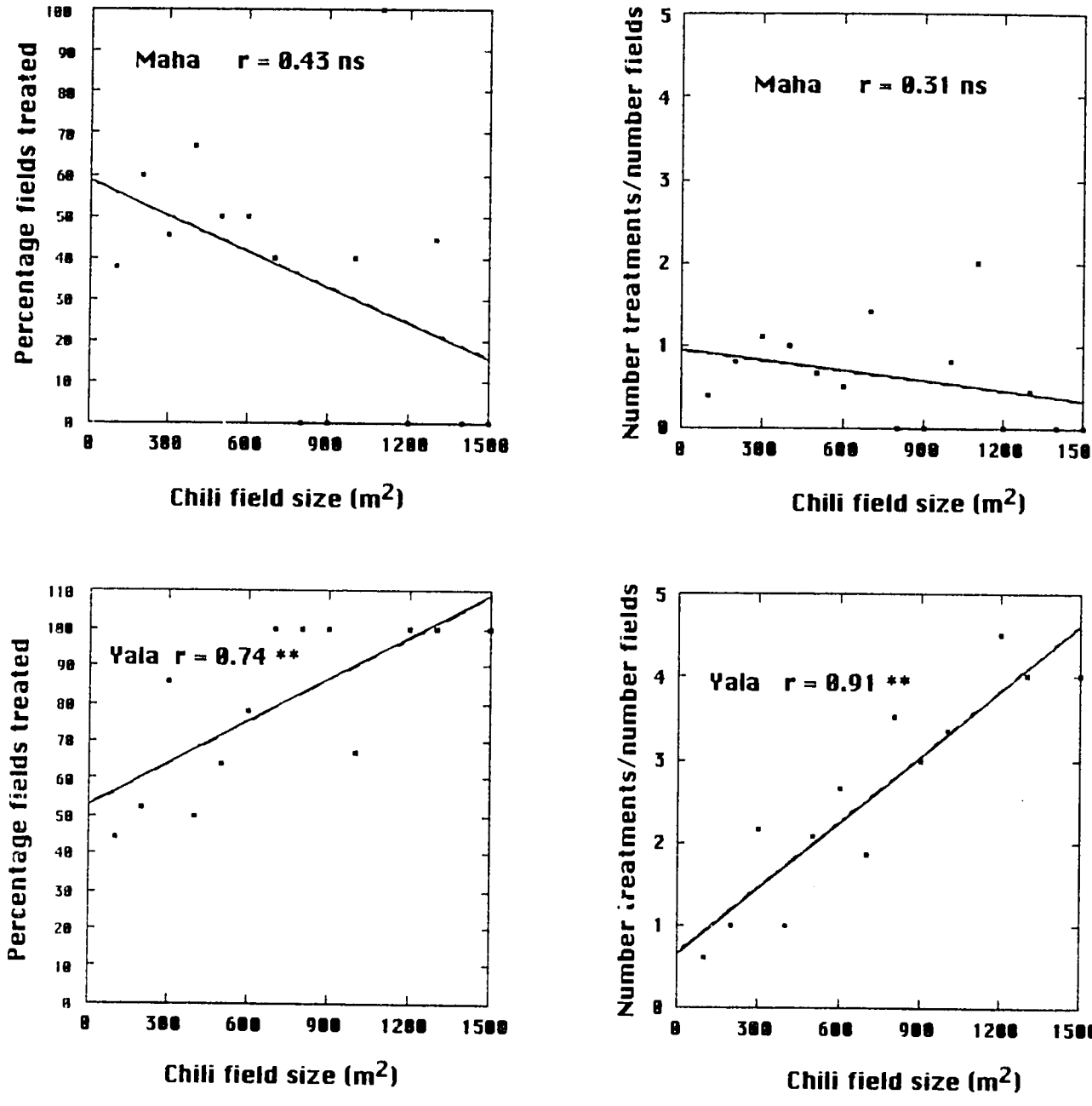

Fig. 2. Percentage of fields treated as function of field size and ratio of number of treatments per total number of fields in each of fifteen size categories from <=100 m^2 to 1500+ m^2.

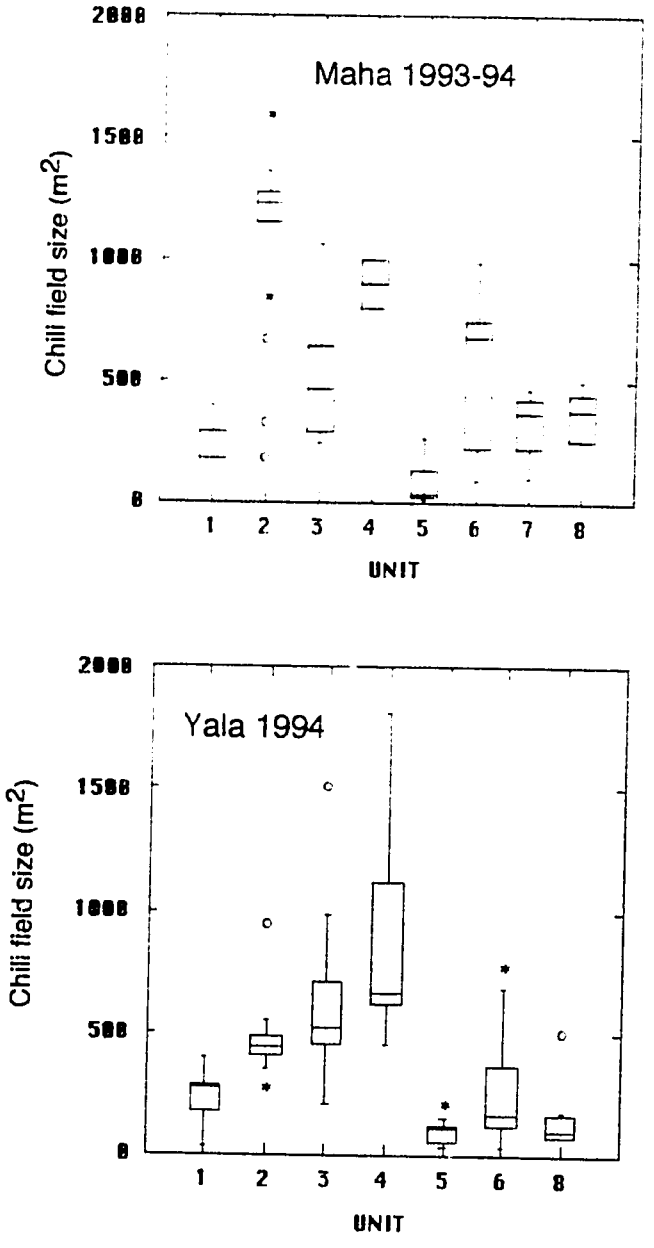

Fig. 3 Box plot of chili field size for all units in Ellewewa block for Maha 1993-94 and Yala 1994. Unit 1 is I'Ellewewa, 2 is P'Ellewewa, 3 is Kalukelle, 4 is Pelatiyawewa, 5 is Bandanagala, 6 is Ellewewa, 7 is Malguldamana and 8 is Mahadamana. The horizontal bar in the box is the median field size. The horizontal bars above and below the median split the remaining halves in half again. The vertical lines give the range of field sizes for each unit. Field sizes 1.5X and 3.0 X outside the box are indicated by an asterisk and by an empty circle, respectively.

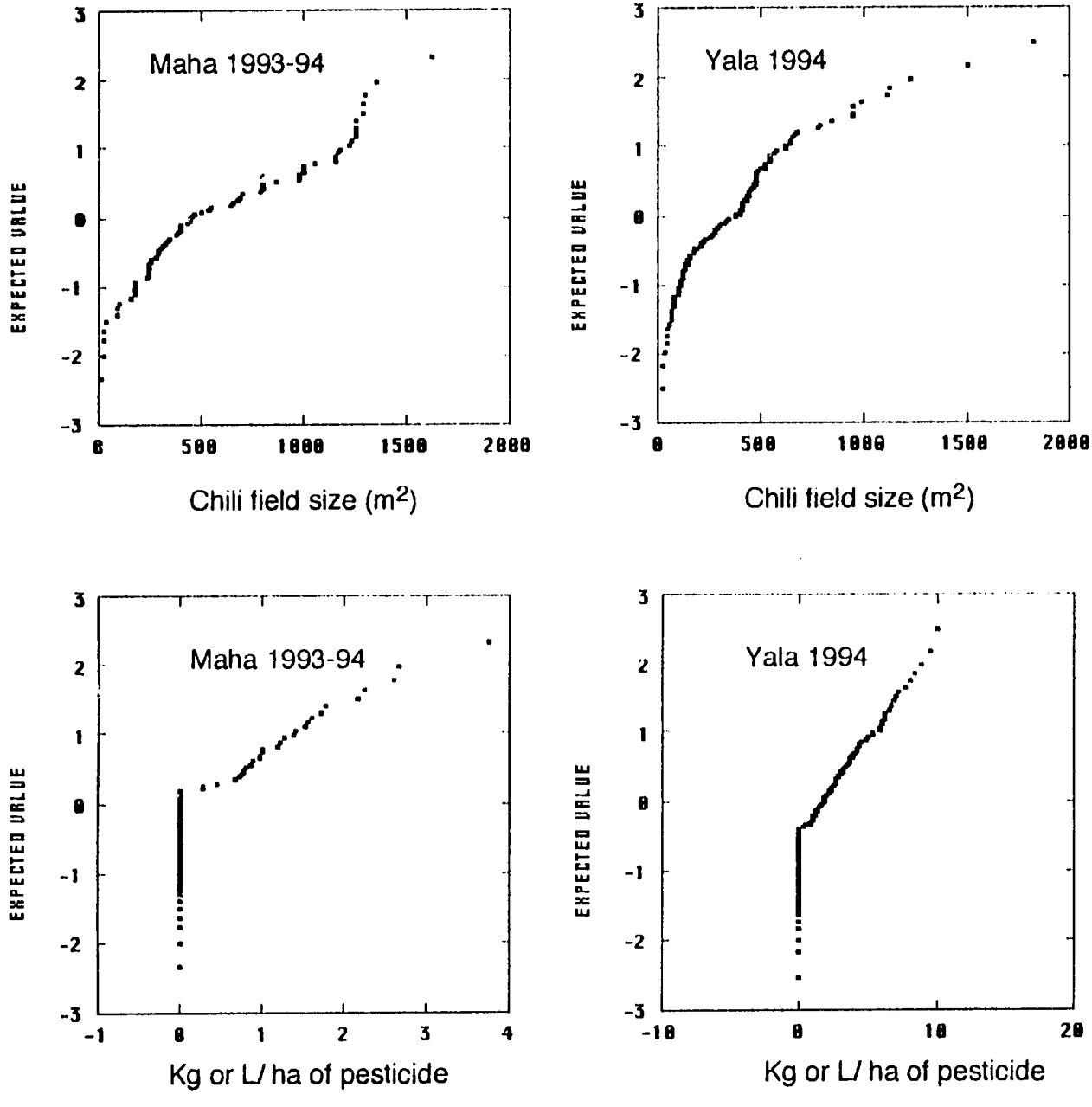

Fig. 4. Fit to a normal distribution of chili field size and quantity of pesticide applied.