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MANAGEMENT OF CHILI IN SYSTEM B FOR INSECT PESTS & DISEASES WITH REDUCED RELIANCE ON PESTICIDES

by

Dr. J.R. Burleigh,

and

V. Vingnanakulasingam

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Management of chili in System B for insect pests and diseases with reduced reliance on pesticides

J. R. Burleigh and V. Vingnanakulasingam

Introduction

Insecticides and fungicides are the only pest management tools used by chili farmers in System B. Other means such as use of resistant cultivars, crop rotation, fallow, and improved tillage practices either are not available or impossible to implement because of farm size constraints. MI-2, the dominant chili cultivar, is susceptible to all insect pests and diseases encountered in System B; whereas, small land holdings (~ 1 ha) preclude use of cultural practices to mitigate pest and disease losses while at the same time providing for even marginal economic success.

Though some farmers do not treat their chili (see " Pesticide use by chili farmers in Ellewewa block - a case study" by J. R. Burleigh, V. Vingnanakulasingam and Lalith) especially during Maha, most treat at least once. Our data show that chili in Ellewewa block, for example, is treated with up to six pesticide applications. Other published accounts (Piyadasa, 1992) have reported up to 10 applications are made on chili in System B; whereas, one extensionist (personal communication from Mr. Y. P. de Silva) has said that 20 applications may be made.

There is no program in System B to monitor insect and disease populations in chili and treatments are applied according to farmer-perceived need. Farmers recognize aphids, thrips, mites and army worms and treat with an array of insecticides but primarily with Monocrotophos, Selecron (Profenofos), Sulfur, Actellic (Pirimiphos-methyl) and Thiodan (Endosulfan). In contrast, farmers seldom recognize fungus diseases such as Cercospora leaf spot and anthracnose and do not, therefore, commonly apply fungicides. Yet, farmers do treat for virus-induced symptoms and for leaf curl, a symptom of complex etiology that probably includes narrow leaf disorder, thrip damage and geminiviruses. Again, Monocrotophos, Selecron, Sulfur, Actellic and Thiodan are the principle pesticides of choice for those symptoms. Farmers often treat when symptoms and insects are first observed without benefit of specific knowledge of the relationship between insect/disease intensity, crop phenology, yield loss and profit. Their pest management strategy results in: 1) a costly delay for aphid-vectored virus management as chili is infected before treatment, 2) crop damage from diseases not managed well and 3) ineffective management

of most insect pests. It appears therefore, that chili farmers lose money through yield loss from insects and diseases and by expenditures for pesticides that are ineffective or are used ineffectively.

The study described herein was conducted to: 1) determine if reduced pesticide use in chili management would place the crop at added risk from insect pests and diseases; and 2) develop an insect pest and disease management program for chili in System B based on reduced pesticide use.

Materials and Methods

RARC trials

In Maha 1993-94 and Yala 1994 chili was transplanted into 36 4 x 4 meter plots arranged in a latin square at the Regional Agricultural Research Center - Aralaganwila (see Figure 1). There were 48 plants per plot spaced 45 cm apart within rows with 60 cm between rows. Plots were separated by 4 m of bare earth to reduce interplot interference by insects and pathogens. Treatments were: T1- conventional pesticide dose, T2 - 75% of conventional, T3- 50% of conventional, T4 - 25% of conventional, T5 - nil and T6 - treatment as recommended by the research team. Conventional was taken from standard practices at RARC. Three insecticides (Pirimiphos-methyl, Sulfur and Imidacloprid) and two fungicides (Propineb and Propineb + Oxadixyl) were applied during Maha to treatments T1, T2, T3, and T4. T5 received nil treatment and T6 received one treatment with Pirimiphos methyl and one treatment with Propineb (see Table 2). One insecticide and two fungicides were used during Yala 1994 (see Table 3). Imidacloprid was applied on five occasions to treatments 1, 2, 3, and 4 and three times to treatment 6. Thiophanate-methyl and Chlorothalonil were applied once each to treatments 1, 2, 3, 4, and 6.

In Maha all plants were observed every 10 - 14 days for aphids, thrips, mites, white flies, army worms, anthracnose (*Collectotrichum capsici* and *C. gloeosporioides*), Cercospora leaf spot (*Cercospora capsici*), virus (a probable combination of cucumber mosaic virus, tobacco etch virus, potato virus Y and pepper mild mosaic virus), narrow leaf disorder (etiology unknown), stem lesions (caused by *C. capsici* and *C. gloeosporioides*), Choanephora blight (*Choanephora cucurbitarum*) and bunchy top (a symptom characterized by small leaves and short internodes - probably similar to or same as chili leaf curl complex caused by thrips and white fly vectored geminivirus). In Yala only the interior 24 plants from

interior rows were observed. Insect and disease incidences were noted on plants observed. Severity of insects was recorded as numbers on 10 leaves of each plant. Anthracnose and Cercospora leaf spot severities were recorded on 10 leaves of each plant according to the scale of Chakraborty (1990) where 0 = no infection, 1 = 1 - 3% tissue showing symptom, 2 = 4 - 6%, 3 = 7-12%, 4 = 13 - 25%, 5 = 26 - 50%, 6 = 51 - 75%, 7 = 76 - 87%, 8 = 88 - 94% and 9 = 95 - 100%. Virus severity was recorded by using the scale of Joshi and Dubey (1973) where 0 = no symptoms, 1 = 25% of plant shows symptoms, 2 = 50% of plant shows symptoms, 3 = 75% of plant shows symptoms and 4 = 100% of plant shows symptoms. NLD severity was based on a scale used by the Department of Agriculture where 0 = no symptoms, 1 = yellowing of young leaves at petiole end, 3 = yellowing of young leaves at petiole end with veins prominant, 6 = severe narrowing of leaves and 9 = stunting of plant and narrowing of leaves. Choanephora blight severity also was based on a DOA scale where 0 = no symptoms, 1 = 0 - 10 branches affected, 3 = 11 - 20 branches affected, 5 = 21 - 30 branches affected, 7 = 31 - 40 branches affected and 9 = 41 - 50 branches affected. For stem lesions only incidence was noted.

Incidence and severity values were used to calculate area under the insect and disease progress curves where AUDPC = $\sum (X_{i+1} + X_i)/2 * (T_{i+1} - T_i)$. X_{i+1} is insect or disease incidence or severity at time T_{i+1} and X_i is incidence or severity at time T_i. AUDPC values were them divided by the number of days during which observations were made to standardize values on a day $^{-1}$ basis. Standardized AUDPC values and yields were subjected to ANOVA and to Fisher's LSD mean separation tests to determine treatment effects. Heavy and frequent rain during Maha 1993-94 destroyed repetitions 4, 5, and 6, consequently only repetitions 1,2, and 3 were used in the analysis and ANOVA was conducted based on a randomized complete block design. In Yala 1994 analysis was based on a latin square as planned.

On-farm trials

On eight farm fields in Wijayabapura during Maha 1993-94 and during Yala 1994 treatments T1, T3 and T6 were installed in replicated trials. Each farm field was divided into nine plots of unequal size and shape with three repetitions of each treatment randomily assigned to plots. Farmers were asked to treat T1 in their conventional manner. T3 was then automatically 50% of T1. T6 was treated as researchers recommended which often was nil. Each farmer determined what was conventional and kept a record of treatments. Incidence and severity observations were made as described

for the RARC trials on 10 plants in each plot. Data were used to calculate standardized AUDPC values for incidence and severity. Standardized AUDPC values and yields were analyzed by ANOVA and by Fisher's LSD for a completely randomized design.

Results

RARC trials

There were significant differences in AUDPC values for incidences of aphids and thrips and for severity of aphids during Maha 1993-94 at RARC (see Table 1). AUDPC values based on incidence were greatest where no pesticides were applied. There were no significant differences among AUDPC incidence values for treatments T1, T2, T3, T4 and T6. However, AUDPC values from T6 for aphid severity were significantly greater than values for all other treatments. There were no treatment effects on mites, army worms, anthracnose, Cercospora leaf spot, virus, NLD and stem lesions. Treatments 1 to 4 received a total of eight pesticide treatments; five insecticide treatments and three fungicide treatments. Treatment 6 received one insecticide and one fungicide treatment (see Table 2). Dry chili yield was variable yet treatments 1, 2, and 4 yielded significantly more than 5, which received nil pesticide. Yields from treatments 1 and 4 were not different. Therefore, a 75% reduction in pesticide dose did not affect yield. Yield from treatment 6 was not different from treatment 5 so researcher recommendations were no better than nil pesticide treatment.

In Yala 1994 treatments T1 to T4 received five applications of imidacloprid, an insecticide, one application of thiophanate-methyl and one of chlorothalonil, both fungicides. Treatment 6 received three applications of imidacloprid, one of thiophanate-methyl and one of chlorothalonil. T5 received nil (see Table 3). Only aphid and thrip populations were affected by treatments (see Tables 4 and 5). There were no treatment effects for white fly, mites, army worms, anthracnose, *Cercospora* leaf spot, viruses, NLD, stem lesions, *Choanephora* blight and bunchy top. AUDPC values among treatments for aphid incidence and aphid severity were significantly different. Values for T5 were greater than values for all other treatments. There were no differences among values for treatments 1, 2, 3, 4, and 6. Thrip incidence was not affected by treatments but severity values for T5 were significantly greater than values for T1, T2, T3 and T6. Imidacloprid reduced aphid intensity and 0.1 l ai ha^{-1} was as effective as 0.4. Imidacloprid also reduced thrip intensity and 0.2 l ai ha^{-1} was as effective as 0.4. There were no significant differences among yields

from treatments 1, 2, 3, 4, and 6. All were significantly greater than yield from T5, however. Clearly, aphid and thrip populations decreased chili yield by about 39% and a 75% reduction in insecticide dose did not place the crop at risk. Fungicides had no impact on disease development and were, therefore, ineffective.

Although aphid intensity was reduced by imidacloprid, virus intensity (vectored by aphids) was unaffected.

On-farm trials

Farmers during Maha treated their chili with 1 to 10 insecticide applications and with 0 to 5 fungicide applications (see Table 6). Pirimiphos-methyl and sulfur were used as insecticides and propineb as fungicide. There were no treatment effects for aphid incidence but on two farms aphid severity was increased by insecticide treatment (see Tables 7 and 8). Similarily, thrip incidence on three farms increased from insecticide treatment and thrip severity increased on one farm. Army worm, anthracnose, and virus intensities were unaffected by treatments. AUDPC values for anthracnose severity were 21 to 71 times greater than values for Cercospora leaf spot indicating that anthracnose was the dominant fungal disease present. Neither was affected markedly by propineb, a fungicide recommended by the DOA.

Only on the farm of Mr. Dharmasena were there significant treatment effects on chili dry weight (see Table 9). Yields were extremely low on all farms.

Eight farmers treated with 11 different insecticides and one fungicide during Yala1994 (see Table 10). Number of treatments ranged from 2 to 10 and quantities applied ranged from 1.84 to 23.34 kg or l ai ha^{-1} (see Table 11). On the farms of Mr. Wimalarathna and Mr. S. Perera aphid incidences were reduced by 10 and 8 treatments, respectively (see Tables 12 and 13). However, 11.36 kg or l ai ha^{-1} was equally effective as 23.34 on the farm of Mr. Wimalarathna and 10.48 was as effective as 13.36 on the farm of Mr. S. Perera. Therefore, a 50% reduction in pesticide dose by Mr. Wimalarathna and a 22% reduction by Mr. S. Perera did not put their crops at added risk. Aphid severity also was reduced by insecticide treatment on the farm of Mr. Wimalarathna and again, T3 was as effective as T1. Mr. I.B. Perera made nine insecticide treatments (seven with sulfur) and thrip incidence and severity were reduced, yet 9.55 kg or l ai ha^{-1} was as effective as 15.23. That is, 37% of the conventional dose was as effective as 100%. White fly, mite, army worm, anthracnose,

Cercospora leaf spot, virus, NLD, stem lesions, *Choanephora* blight and bunchy top were not affected by treatments. Aphid and thrip intensities were generally greater than intensities of all other insect pests. Virus incidence values were similar to those for thrips yet pesticide treatments had no effect on virus incidence and severity.

There were no significant yield differences among treatments within farms (see Table 14). With the exception of Mr. Ginadasa all other farms gave extremely poor yields and yields among repetitions within farms were too variable to be reliable indicators of treatment effects.

Discussion

Among insect pests that attack chili in System B aphids and thrips are the most prevalent and the most severe. Our data show that imidacloprid reduces aphid and thrip intensities whereas, pirimiphos-methyl might increase them. But to take advantage of imidacloprid's insecticidal properties it should be applied at the time of transplanting to prevent virus transmission by aphids. RARC trials and on-farm trials showed that aphid populations were reduced with imidacloprid, but in no instance was virus intensity affected. Infection by aphid-borne viruses (cucumber mosaic virus, tobacco etch virus, potato virus Y and pepper mild mosaic virus) is ubiquitous and must be prevented to improve chili yields in System B.

Anthracnose was very severe in Maha and almost nonexistant in Yala. Farmers commonly apply few fungicides but those who do, treat with propineb, ridomil MZ, thiophanate-methyl or chlorothalonil and they do not limit disease development. Those materials were ineffective in Maha and unnecessary in Yala. Yet chili farmers desperately need some tools or a strategy for anthracnose management as intensity values indicate that it (along with viruses) is a major impediment to satisfactory yields in Maha. Farmers are constrained from rotation and fallow (which could reduce inoculum from plant debris) because all available land must be cultivated each season to maintain even a modicum of economic success. There are no resistant cultivars. Consequently, farmers have turned to the only tools available - pesticides. Unfortunately, those used by farmers are generally ineffective or are used ineffectively.

Leaf, stem and petiole infections of chili by *C. capsici* and *C. gloeosporioides* (cause of anthracnose) are more prevalent than fruit infections. Especially during Maha, chili must

be protected from early infection by those pathogens. Fungicides recommended by the DOA (Chlorothalonil, Propineb, Thiophanate-methyl listed in Crop Recommendations Technoguide 1990) are not effective and cultural practices are impractical for reasons cited above. As a means to reduce inoculum carried by plant debris we recommend that farmers be encouraged to burn or bury chili plants upon termination of harvest. That recommendation is neither new nor novel (burning is recommended by DOA), yet, without resistant cultivars it is the best means available to limit crop loss by the anthracnose pathogens. If all chili growers participated in a program of debris destruction inoculum levels would be reduced. Partial compliance would permit ingress of inoculum from nonparticipatory growers to participatory and lessen the impact of the strategy. A key then to successful management of chili for anthracnose infection is compliance by all growers in a program of debris destruction. Certainly the search for effective fungicides should continue as well and be linked to a program of disease monitoring with treatment only if/when required to prevent economic crop loss.

Yield loss of 39% recorded from RARC trials in Yala was due to infestation by aphids and thrips. Had control been achieved for viruses, NLD, stem lesions, Choanephora blight, and bunchy top we believe the yield difference between treated and nontreated plots would have been greater. And of those diseases virus and NLD infections were the most severe. Cucumber mosaic virus, tobacco etch virus, potato virus Y and pepper mild mosaic virus are the most common viruses of chili in System B (Black, 1991 and results from our laboratory). We have also recently determined through the assistance of the Department of Plant Pathology, University of Wisconsin, that geminivirus (vectored by white fly) also occurs. Some symptoms referred to as 'virus' may, in fact, be from geminiviruses. We do not know at this time the extent to which geminiviruses occur in System B but we have in place a joint effort with the University of Wisconsin to determine their distribution. Nevertheless, even as that study progresses, an parallel strategy should be implemented for white fly management as none of the insecticides used by farmers (see Table 10) affected white fly populations and that includes Imidacloprid. We suggest, therefore, that DOA initiate a study to discover means to manage chili for geminivirus.

Among viruses detected by ELISA (enzyme-linked immunosorbant assay) in our laboratory cucumber mosaic virus (CMV) is the most prevalent, especially during Maha. CMV has many weed and vegetable hosts among members of the Solanaceae (same family as chili) and Leguminoseae. We have recently initiated a study with DOA to determine

the distribution and prevalence of CMV among alternate hosts. That information will tell us if important reservoirs of CMV exist adjacent to chili fields and lead to an improved strategy for chili management.

NLD posses another problem; its etiology and importance to chili production in System B remain unknown, yet during Yala NLD intensity as expressed by AUDPC for incidence exceeds that of aphids, white fly, mites, army worms, anthracnose, Cercospora leaf spot, stem lesions, Choanephora blight and bunchy top. Only AUDPC values for thrips and virus exceeded values for NLD (see Table 4). We do not know if NLD alone is a serious constraint to chili production but we have initiated contact with The University of Minnesota, Department of Plant Pathology to study NLD etiology by immunosorbant electron microscopy (ISEM) as an initial step to chili management for NLD.

On-farm chili yields are extremely low, rarely exceeding 500 kg ha^{-1}. Our data suggest that during Maha infection by anthracnose pathogens and viruses are the principal constraints; whereas, during Yala principal impediments to yield are thrips and viruses. It is important to emphasize that viruses are involved in both seasons and therefore, should receive attention in any chili management program. As stated above, use of Imidacloprid soon after transplanting should prevent aphid infestation and therefore, infection by aphid-borne viruses. However, before Imidacloprid becomes a standard treatment its ability to create resistance in the aphid population should be assessed.

Recommendations

1. Inaugurate insect and disease monitoring program for chili. Build data base on insect and disease intensity: crop phenology: crop yield. Use data base to plan appropriate intervention measures.

2. Use Imidacloprid immediately after transplanting. Apply a second treatment three weeks later. These treatments should inhibit aphid infestation and therefore aphid-borne virus infection.

3. Determine impact of imidacloprid on creation of insecticide resistance in aphid populations.

4. Continue and strengthen study on geminivirus distribution with University of Wisconsin, Department of Plant Pathology.

5. Continue and strengthen cooperative effort with Department of Plant Pathology, University of Minnesota to study NLD etiology.

6. Establish linkage with RARC Aralaganwila and University of Peradeniya for student dissertation research on appropriate and suitable insect and disease management problems such as numbers 1, 7 and 10.

7. Discourage use of commonly used fungicides and insecticides now recommended by DOA. Initiate study on the propitious use of effective biocides based on data from 1 above.

8. Inaugurate a system-wide program to burn or bury chili debris.

9. Strengthen chili improvement program. Build stronger linkage between breeding efort and selection for insect and disease resistance.

10. Initiate study on chili managment for white flies.

11. Involve DOA, U of P, IFS and MEA in an "Integrated attack on production/income generation constraints. The infrastructure to solve agricultural/environmental problems exists. It is not focused. Fund tasks not institutions.

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Table 1. Areas under the standardized incidence and severity progress curves for insects and diseases of chili treated with a standard pesticide dose (T1), 75% of standard (T2), 50% of standard (T3), 25% of standard (T4), nil (T5) and as recommended by researchers (T6) during Maha 1993-94 at RARC Aralaganwila.

	Incidence									Severity		
Treatment	Aphids [a]	Thrips [b]	Mites [c]	Army Worm [d]	Anth. [e]	Cerc. [f]	Virus [g]	NLD [h]	Stem lesions [i]	Aphids [a]	Thrips [b]	Anth. [e]
T1	10.09 b [j]	2.18 b	2.60	1.49	84.39	2.78	28.81	0.54	71.91	0.17 c	0.02	0.04
T2	10.66 b	2.70 b	1.29	0.83	89.53	1.40	24.44	1.35	79.08	0.17 c	0.03	0.04
T3	13.85 b	3.68 b	3.62	1.01	89.24	1.47	27.58	0.50	71.11	0.23 c	0.05	0.04
T4	14.08 b	5.15 b	2.82	2.32	90.85	1.35	30.93	0.38	70.33	0.25 c	0.09	0.04
T5	44.45 a	7.21 a	3.43	1.38	92.59	0.80	27.95	0.17	66.17	0.86 b	0.08	0.05
T6	47.76 a	5.75 b	1.41	0.83	89.01	1.28	29.57	0.20	72.24	1.21 a	0.08	0.05

[a] *Aphis gossypii* and *Myzus persicae*; [b] *Frankliniella schultzei* and *Scirtothrips dorsalis*; [c] species unknown; [d] *Spodoptera* sp.; [e] *Collectotrichum capsici* and *C. glocosporioides*; [f] *Cercospora capsici*; [g] Cucumber mosaic virus, Potato virus Y and Tobacco etch virus; [h] narrow leaf disorder, etiology unknown; [i] *C. capsici* and *C. glocosporioides*.; [j] values in a column followed by a different letter are significantly different according to Fisher's LSD test. All other values are not significantly different.

Table 2. Chili yield and number of pesticide treatments and dose at RARC-Aralaganwila during Maha 1993-94. T1 is standard; T2 is 75% of of standard; T3 is 50% of standard; T4 is 25% of standard,; T5 is nil and; T6 is as recommended by researchers.

	Pirimiphos-methyl		Sulfur		Imidacloprid		Propineb		Propineb + oxadixyl		Yield [a]
Treatment	nb. treat.	l a.i. ha^{-1}	nb. treat.	kg a.i. ha^{-1}	nb. treat.	l a.i. ha^{-1}	nb. treat.	kg a.i.ha^{-1}	nb. treat.	kg a.i.ha^{-1}	kg ha^{-1}
T1	2	0.62	1	1.75	2	0.20	2	4.66	1	2.33	645 abc
T2	2	0.46	1	1.33	2	0.15	2	3.49	1	1.75	1283 a
T3	2	0.30	1	0.87	2	0.10	2	2.32	1	1.16	536 abc
T4	2	0.16	1	0.46	2	0.05	2	1.17	1	0.58	1201 ab
T5	0	0	0	0	0	0	0	0	0	0	242 c
T6	1	0.31	0	0	0	0	1	2.91	0	0	268 bc

[a] Yield values without a letter in common are significantly different according to Fisher's LSD test at $P<=0.09$. Values followed by at least one common letter are not significantly different.

Table 3. Chili yield and number of pesticide treatments and dose used at RARC - Aralaganwila during Yala 1994. T1 is standard, T2 is 75% of standard, T3 is 50% of standard, T4 is 25% of standard, T5 is nil and T6 is as recommended by researchers.

	Imidacloprid		Thiophanate- methyl		Chlorothalonil		
Treatment	Number trt.	l a.i. ha $^{-1}$	Number trt.	kg a.i. ha $^{-1}$	Number trt.	kg a.i. ha $^{-1}$	Yield [a] (kg ha $^{-1}$)
T1	5	0.4	1	3.72	1	0.82	843 a
T2	5	0.3	1	2.79	1	0.61	784 a
T3	5	0.2	1	1.86	1	0.41	744 a
T4	5	0.1	1	0.92	1	0.20	784 a
T5	0	0	0	0	0	0	482 b
T6	3	0.2	1	3.72	1	0.2	719 a

a Yield values followed by different letters are significantly different according to Fisher's LSD test at P = 0.05. All other values are not significantly different.

Table 4. Area under the standardized incidence progress curve for insects and diseases of chili treated with standard pesticide dose (T1), 75% of standard (T2), 50% of standard (T3), 25% of standard (T4), nil (T5) and as recommended (T6) during Yala 1994.

Treat.	White fly [a]	Aphids [b]	Thrips [c]	Mites [d]	Army worm [e]	Anth. [f]	Cerc. [g]	Virus [h]	NLD [i]	Stem lesions [j]	Choa. blight [k]	Bunchy top [l]
T1	0.22	0.64 b	14.39	2.06	0.02	1.10	0.01	12.83	7.20	4.36	2.26	0.61
T2	0.16	0.39 b	13.88	2.43	0.02	1.43	0.11	13.44	7.50	3.61	1.73	0.76
T3	0.06	0.36 b	15.17	2.95	0.06	1.02	0.00	14.07	10.43	4.30	1.61	0.93
T4	0.18	0.47 b	15.71	2.44	0.00	1.45	0.04	13.86	6.74	3.41	1.90	0.80
T5	0.15	2.48 a	15.70	1.72	0.00	1.48	0.08	13.10	6.97	3.15	1.33	0.80
T6	0.21	0.14 b	14.28	2.06	0.02	1.77	0.00	13.27	6.94	3.60	1.65	1.08

[a] *Bemisia tabaci*; [b] *Aphis gossypii* and *Myzus persicae*; [c] *Frankliniella schultzei* and *Scirtothrips dorsalis*; [d] Species unknown; [e] *Spodoptera* sp.; [f] *Collectotrichum capsici* and *C. gloeosporioides*; [g] *Cercospora capsici*; [h] Cucumber mosaic virus, Potato virus Y and Tobacco etch virus; [i] Narrow leaf disorder, etiology unknown; [j] *C. capsici* and *C. gloeosporioides*; [k] *Choanephora cucurbitarum*; [l] etiology unknown but suspect gemini viruses; [m] values followed by different letters within species are significantly different according to Fisher's LSD test at P = 0.05. All other values are not significantly different.

Table 5. Area under the standardized severity progress curve for insects and diseases of chili treated with standard pesticide dose (T1), 75% of standard (T2), 50% of standard (T3), 25% of standard (T4), nil (T5) and as recommended (T6) during Yala 1994.

Treat.	White fly [a]	Aphids [b]	Thrips [c]	Mites [d]	Army worm [e]	Anth. [f]	Cerc. [g]	Virus [h]	NLD [i]	Stem lesions [j]	Choa. blight [k]	Bunchy top [l]
T1	0.28	1.75 b	43.13 bc	6.79	0.01	1.87	0.01	14.89	16.83	4.36	3.46	1.54
T2	0.20	1.16 b	38.72 c	12.21	0.02	2.89	0.11	13.89	14.52	3.61	2.25	2.65
T3	0.06	0.43 b	41.44 bc	7.57	0.08	1.74	0.00	17.18	30.32	4.30	2.42	3.69
T4	0.21	0.62 b	50.90 ab	8.51	0.00	2.34	0.04	15.12	16.37	3.41	3.37	2.91
T5	0.20	8.52 a	61.13 a	5.60	0.00	2.97	0.12	14.70	11.87	3.15	1.91	2.78
T6	0.25	0.29 b	41.74 bc	7.93	0.02	3.29	0.00	13.88	14.98	3.60	2.53	3.28

[a] *Bemisia tabaci*; [b] *Aphis gossypii* and *Myzus persicae*; [c] *Frankliniella schultzei* and *Scirtothrips dorsalis*; [d] Species unknown; [e] *Spodoptera* sp.; [f] *Collectotrichum capsici* and *C. gloeosporioides*; [g] *Cercospora capsici*; [h] Cucumber mosaic virus, Potato virus Y and Tobacco etch virus; [i] Narrow leaf disorder, etiology unknown; [j] *C. capsici* and *C. gloeosporioides*; [k] *Choanephora cucurbitarum*; [l] etiology unknown but suspect geminiviruses; [m] values followed by different letters within species are significantly different according to Fisher's LSD test at P = 0.05. All other values are not significantly different.

Table 6. Number of insecticide and fungicide treatments and quantity applied to chili as farmer standard dose (T1), one-half standard dose (T3), and nil (T6) by eight farmer-cooperators during Maha 1993-94 in System B, Sri Lanka.

	Number of Treatments			Quantity Applied (a.i.)								
	Actellic [a]	Sulfur [b]	Antracol [c]	Actellic (l/ha)			Sulfur (kg/ha)			Antracol (kg/ha)		
Farm				T1	T3	T6	T1	T3	T6	T1	T3	T6
Dharmasena	5	5	5	3.10	1.55	0.00	3.20	1.60	0.00	1.75	0.91	0.00
T. G. Jayathua	2	2	2	0.30	0.15	0.00	0.80	0.40	0.00	0.56	0.28	0.00
A. G. Premarathna	1	0	0	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P. G. Punchibanda	4	4	4	2.80	1.15	0.00	3.12	2.00	0.00	0.42	0.14	0.00
R. G. Somapala	1	0	0	1.25	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P. G. Upulsantha	1	1	1	0.50	0.25	0.00	1.04	0.48	0.00	0.28	0.14	0.00
P. G. Wijarathna	1	1	1	0.35	0.35	0.35	0.48	0.48	0.48	0.07	0.07	0.07
P. D. Wimalarathna	2	2	2	0.60	0.30	0.00	0.88	0.44	0.00	0.28	0.14	0.00

a Insecticide-active ingredient 50% pirimiphos-methyl.
b Insecticide-active ingredient 80% elemental sulfur.
c Fungicide-active ingredient 70% propineb.

Table 7. Area under the standarized incidence progress curve for chili insects and diseases from eight farms with three pesticide treatments per farm (T1- farmer standard dose; T3- one-half standard dose; T6- nil) during Maha season 1993-94 in System B, Sri Lanka.

	Aphids [a]			Thrips [b]			Armyworm [c]			Anthracnose [d]			Cercospora leaf spot [e]			Cucumber mosic virus		
Farm	T1[f]	T3	T6	T1	T3	T6	T1	T3	T6	T1	T3	T6	T1	T3	T6	T1	T3	T6
Dharmasena	3.1	2.0	2.6	0.8	0.1	0.2	0.3	0.3	0.2	8.5	8.8	8.2	2.1b	3.2a	1.0b	6.7	4.8	6.3
T. G. Jayathua	4.7	3.9	3.4	1.1b	1.8a	0.4b	0.1	0.3	0.2	6.8	7.8	7.0	2.3	3.0	1.7	4.2	4.8	4.2
A. G. Premarathna	3.4	3.6	4.3	0.6a	0.2b	0.3b	0.0	0.0	0.0	6.1	5.8	6.2	0.5	0.5	0.8	1.6	2.6	2.4
P. G. Punchibanda	3.1	2.7	2.8	0.6	0.5	0.7	0.4	0.5	0.2	7.3	8.2	7.7	2.8	2.6	2.5	4.2	5.0	5.1
R. G. Somapala	3.3	2.9	3.1	3.4a	1.5b	1.8b	0.1	0.1	0.2	7.1	7.2	7.1	2.6a	0.8b	0.9b	4.4	3.7	3.7
P. G. Upulsantha	4.0	4.4	3.7	1.0	0.3	0.7	0.6	0.6	1.0	8.1	8.4	8.5	1.6	1.8	1.5	5.5	4.7	4.9
P. G. Wijarathna	3.6	3.9	3.5	0.6	1.0	0.6	0.0	0.0	0.0	5.8	6.5	4.8	0.3	0.8	0.2	1.9	3.0	1.4
P. D. Wimalarathna	3.4	3.1	3.7	2.2	1.7	2.6	0.3	0.2	0.3	8.1	8.5	8.4	2.1	2.9	2.0	4.4	4.0	4.5

a *Aphis gossypii* and *Myzus persicae*.
b *Frankliniella schultzei* and *Scirtothrips dorsalis*.
c *Spodoptera sp.*
d *Colletotrichum capsici* and *C. gloeosporioides*
e *Cercospora capsici*
f values followed by different letters are significantly different according to Fisher's LSD test. at P = 0.05. All other values are not significantly different.

Table 8. Area under the standarized severity progress curve for chili insects and diseases from eight farms with three pesticide treatments per farm (T1- farmer standard dose; T3- one-half standard dose; T6- nil) during Maha season 1993-94 in System B, Sri Lanka.

	Aphids [a]			Thrips [b]			Armyworm [c]			Anthracnose [d]			Cercospora leaf spot [e]		
Farm	T1[f]	T3	T6	T1	T3	T6	T1	T3	T6	T1	T3	T6	T1	T3	T6
Dharmasena	0.9	0.5	0.6	1.8	0.1	0.4	0.3	0.3	0.2	46.0	50.1	46.3	1.4	0.8	0.3
T. G. Jayathua	1.1a	1.1a	0.7b	1.9	4.6	1.2	0.1	0.3	0.2	50.0	57.5	51.9	2.6	0.7	3.2
A. G. Premarathna	1.0	1.0	1.0	1.0	0.4	0.6	0.0	0.0	0.0	21.2	21.2	22.2	0.0b	0.0b	0.6a
P. G. Punchibanda	0.6	0.7	0.6	1.4	1.0	1.2	0.4	0.6	0.2	57.1	71.0	66.7	0.9	0.7	1.6
R. G. Somapala	0.7	0.8	0.9	9.1a	3.4b	3.6b	0.1	0.1	0.2	41.6	38.5	37.6	3.1	0.0	0.0
P. G. Upulsantha	1.1a	1.0a	0.8b	1.4	0.6	1.2	0.8	0.7	1.1	51.5	58.6	55.9	0.3a	0.5a	0.0b
P. G. Wijarathna	1.1	1.2	0.9	1.1	2.5	1.1	0.0	0.0	0.0	23.9	28.9	25.1	0.8	1.1	0.0
P. D. Wimalarathna	0.7	0.7	0.8	7.5	4.5	7.1	0.3	0.2	0.4	40.9	54.7	49.7	1.7	1.1	0.7

a *Aphis gossypii* and *Myzus persicae.*
b *Frankliniella schultzei* and *Scirtothrips dorsalis.*
c *Spodoptera sp.*
d *Colletotrichum capsici* and *C. gloeosporioides*
e *Cercospora capsici*
f values followed by different letters are significantly different according to Fisher's LSD test at P = 0.05. All other values are not significantly different.

Table 9. Dry weight of chili (kg/ha) harvested from eight farms with three pesticide treatments per farm in System B, Sri Lanka during Maha 1993-94.

	Treatments [a]		
Farm	T1[b]	T3	T6
Dharmasena	1322 a	776 ab	368 b
T. G. Jayathua	372	510	97
A. G. Premarathna	355	151	207
P. G. Punchibanda	138	195	219
R. G. Somapala	480	208	237
P. G. Ulpulsantha	217	205	264
P. G. Wijarathna	- [c]	-	-
P. D. Wimalarathna	271	276	180

a T1 refers to the farmer's standard pesticide treatment schedule and dose; T3 refers to one-half the farmer's standard and T6 to nil pesticide applied.

b values followed by different letters are significantly different according to Fisher's LSD test at P = 0.05. All other values are not significantly different.

c field not harvested.

Table 10. Number of pesticide treatments to chili made by eight farmers in System B Sri Lanka during Yala 1994.

		Pesticides [a]												
Farmer	Treat [b]	Mono	Prof	Imid	Rido	Meta	Sulf	Chlor	Carb	Phen	Form	Dime	Zoln	Total
Ginadasa	1	3	2	2	1	0	0	0	0	0	0	0	0	8
do	3	2	2	2	1	0	0	0	0	0	0	0	0	7
do	6	2	0	0	0	0	0	0	0	0	0	0	0	2
Somadasa	1	0	0	2	0	3	2	0	0	0	0	0	0	7
do	3	0	0	2	0	3	2	0	0	0	0	0	0	7
do	6	0	0	0	0	0	1	0	0	0	0	0	0	1
Upulsantha	1	0	7	1	0	0	0	0	0	0	0	0	0	8
do	3	0	7	1	0	0	0	0	0	0	0	0	0	8
do	6	0	0	0	0	0	0	0	0	0	0	0	0	0
Wimalarathna	1	1	0	0	0	0	4	2	2	1	0	0	0	10
do	3	1	0	0	0	0	4	2	2	1	0	0	0	10
do	6	0	0	0	0	0	0	0	0	0	0	0	0	0
Somapala	1	3	0	2	0	0	2	0	0	0	2	0	0	9
do	3	3	0	2	0	0	2	0	0	0	2	0	0	9
do	6	0	0	0	0	0	0	0	0	0	0	0	0	0
I.B.Perera	1	0	0	0	0	0	7	0	0	0	0	2	0	9
do	3	0	0	0	0	0	7	0	0	0	0	2	0	9
do	6	0	0	0	0	0	0	0	0	0	0	0	0	0
S. Perera	1	0	1	0	0	0	3	0	0	0	1	2	1	8
do	3	0	1	0	0	0	3	0	0	0	1	2	1	8
do	6	0	0	0	0	0	0	0	0	0	0	0	0	0
Karunarathna	1	2	0	0	0	0	0	0	0	0	0	0	0	2
do	3	2	0	0	0	0	0	0	0	0	0	0	0	2
do	6	0	0	0	0	0	0	0	0	0	0	0	0	0

[a] Monocrotophos, Profenofos, Imidacloprid, Ridomil MZ, Metasystox, Sulfur, chlorpyrifos, Carbaryl, Phenthoate, Formothion, Dimethoate and Zolon.

[b] T1 is farmer standard; T3 is 50% standard; and T6 is as recommended by researchers.

Table 11. Quantity (kg or l a.i. ha $^{-1}$)of pesticide to treat chili by eight farmers in System B Sri Lanka during Yala 1994.

		Pesticides [a] kg or l a.i. ha $^{-1}$												
Farmer	Treat [b]	Mono	Prof	Imid	Rido	Meta	Sulf	Chlor	Carb	Phen	Form	Dime	Zoln	Total
Ginadasa	1	6.37	2.54	0.39	0.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.92
do	3	2.93	1.46	0.22	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.98
do	6	2.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.88
Somadasa	1	0.00	0.00	0.41	0.00	0.95	11.34	0.00	0.00	0.00	0.00	0.00	0.00	12.71
do	3	0.00	0.00	0.22	0.00	0.53	8.63	0.00	0.00	0.00	0.00	0.00	0.00	9.39
do	6	0.00	0.00	0.00	0.00	0.00	3.22	0.00	0.00	0.00	0.00	0.00	0.00	3.22
Upulsantha	1	0.00	10.35	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.55
do	3	0.00	6.32	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.44
do	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wimalarathna	1	1.93	0.00	0.00	0.00	0.00	12.67	1.61	5.49	1.61	0.00	0.00	0.00	23.34
do	3	0.94	0.00	0.00	0.00	0.00	6.17	0.78	2.67	0.78	0.00	0.00	0.00	11.36
do	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Somapala	1	3.77	0.00	0.51	0.00	0.00	2.48	0.00	0.00	0.00	1.10	0.00	0.00	7.88
do	3	2.30	0.00	0.27	0.00	0.00	1.51	0.00	0.00	0.00	0.66	0.00	0.00	4.75
do	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I.B.Perera	1	0.00	0.00	0.00	0.00	0.00	14.43	0.00	0.00	0.00	0.00	0.79	0.00	15.23
do	3	0.00	0.00	0.00	0.00	0.00	9.02	0.00	0.00	0.00	0.00	0.53	0.00	9.55
do	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S. Perera	1	0.00	2.49	0.00	0.00	0.00	6.14	0.00	0.00	0.00	0.98	1.99	1.74	13.36
do	3	0.00	3.29	0.00	0.00	0.00	4.06	0.00	0.00	0.00	0.65	1.31	1.15	10.48
do	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Karunarathna	1	1.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.84
do	3	0.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.93
do	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

[a] Monocrotophos, Profenofos, Imidacloprid, Ridomil MZ, Metasystox, Sulfur, chlorpyrifos, Carbaryl, Phenthoate, Formothion, Dimethoate and Zolon.

[b] T1 is farmer standard dose; T3 is 50% of standard; and T6 is as recommended by researchers.

Table 12. Area under the standardized incidence progress curve for chili insects and diseases from eight farms with three pesticide treatments per farm (T1 - farmer standard dose; T3 - one-half standard dose; T6 - as recommended by researchers) during Yala 1994 in System B.

	Whitefly [a]			Aphids [b]			Thrips [c]			Mites [d]			Army worms [e]			Anthracnose [f]		
Farmer	T1 [g]	T3	T6	T1	T3	T6	T1	T3	T6	T1	T3	T6	T1	T3	T6	T1	T3	T6
Ginadasa	0.08	0.03	0.07	0.35	0.20	0.57	7.52	6.70	6.79	0.58b	0.43b	1.60a	0.00	0.07	0.00	0.03	0.09	0.16
Somadasa	0.16	0.04	0.00	0.28	0.24	0.53	3.89	4.09	4.83	0.00	0.00	0.12	0.00	0.00	0.04	0.00	0.01	0.01
Upulsantha	0.00	0.04	0.09	0.06	0.19	0.84	6.55	6.89	5.98	1.08	0.24	0.29	0.00	0.00	0.06	0.00	0.00	0.11
Wimalarathna	0.00	0.12	0.16	0.30b	0.78b	2.58a	7.72	6.98	6.96	2.54	3.41	3.06	0.11	0.00	0.00	0.00	0.00	0.00
Somapala	0.05	0.00	0.07	1.02	0.93	0.58	7.50	6.47	6.59	3.60	1.39	2.28	0.00	0.00	0.06	0.00	0.00	0.00
I.B.Perera	0.15	0.10	0.09	0.49	0.47	0.50	3.91b	4.08b	5.50a	0.10	0.16	0.33	0.00	0.00	0.00	0.00	0.00	0.00
S. Perera	0.00	0.00	0.01	0.09b	0.06b	0.41a	5.40	5.90	6.48	0.79	1.08	1.03	0.06	0.06	0.04	0.00	0.03	0.00
Karunarathna	0.11	0.10	0.05	0.60	0.37	0.63	6.33	6.32	6.91	0.68	0.53	0.35	0.06	0.01	0.00	0.04	0.14	0.03

[a] *Bemisia tabaci*; [b] *Aphis gossypii* and *Myzus persicae*; [c] *Frankliniella schultzei* and *Scirtothrips dorsalis*; [d] Species unknown; [e] *Spodoptera* sp. [f] *Colletotrichum capsici* and *C. gloeosporioides* ; [g] values followed by different letters among treatments within species and farmer are significantly different according to Fisher's LSD test at P = 0.05. All other values are not significantly different.

Table 13. Area under the standardized severity progress curve for chili insects and diseases from eight farms with three pesticide treatments per farm (T1 - farmer standard dose; T3 - one-half standard dose; T6 - as recommended by researchers) during Yala 1994 in System B.

	Whitefly [a]			Aphids [b]			Thrips [c]			Mites [d]			Army worms [e]			Anthracnose [f]		
Farmer	T1 [g]	T3	T6	T1	T3	T6	T1	T3	T6	T1	T3	T6	T1	T3	T6	T1	T3	T6
Ginadasa	0.01	0.00	0.01	0.08	0.02	0.35	5.25	6.51	4.83	0.07	0.08	0.19	0.00	0.01	0.00	0.00	0.01	0.03
Somadasa	0.01	0.00	0.00	0.06	0.02	0.32	1.33	1.77	2.15	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Upulsantha	0.00	0.00	0.01	0.00	0.13	0.08	6.14	7.70	5.23	0.31	0.07	0.04	0.00	0.00	0.00	0.00	0.00	0.01
Wimalarathna	0.00	0.01	0.01	0.07b	0.15b	1.86a	5.31b	3.83c	9.59a	1.72	6.20	2.40	0.01	0.00	0.00	0.00	0.00	0.00
Somapala	0.00	0.00	0.00	0.27	0.32	0.25	3.71	2.49	3.03	3.46	0.50	1.21	0.00	0.00	0.00	0.00	0.00	0.00
I.B.Perera	0.01	0.01	0.01	0.12	0.14	0.08	0.95b	1.20b	2.29a	0.01	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.00
S. Perera	0.00	0.00	0.00	0.02	0.00	0.01	2.07	3.13	3.48	0.30	0.25	0.47	0.00	0.00	0.00	0.00	0.00	0.00
Karunarathna	0.12	0.01	0.00	0.09	0.03	0.12	3.87	3.39	3.77	0.10	0.08	0.03	0.01	0.00	0.00	0.00	0.02	0.00

[a] *Bemisia tabaci*; [b] *Aphis gossypii* and *Myzus persicae*; [c] *Frankliniella schultzei* and *Scirtothrips dorsalis*; [d] Species unknown; [e] *Spodoptera* sp.
[f] *Colletotrichum capsici* and *C. gloeosporioides* , [g] Values followed by different letters among treatments within insect species and farmers are significantly different according to Fisher's LSD test at P = 0.05. All other values are not significantly different.

Table 14. Dry weight of chili (kg/ha) harvested from eight farms with three pesticide treatments per farm in System B, Sri Lanka during Yala 1994.

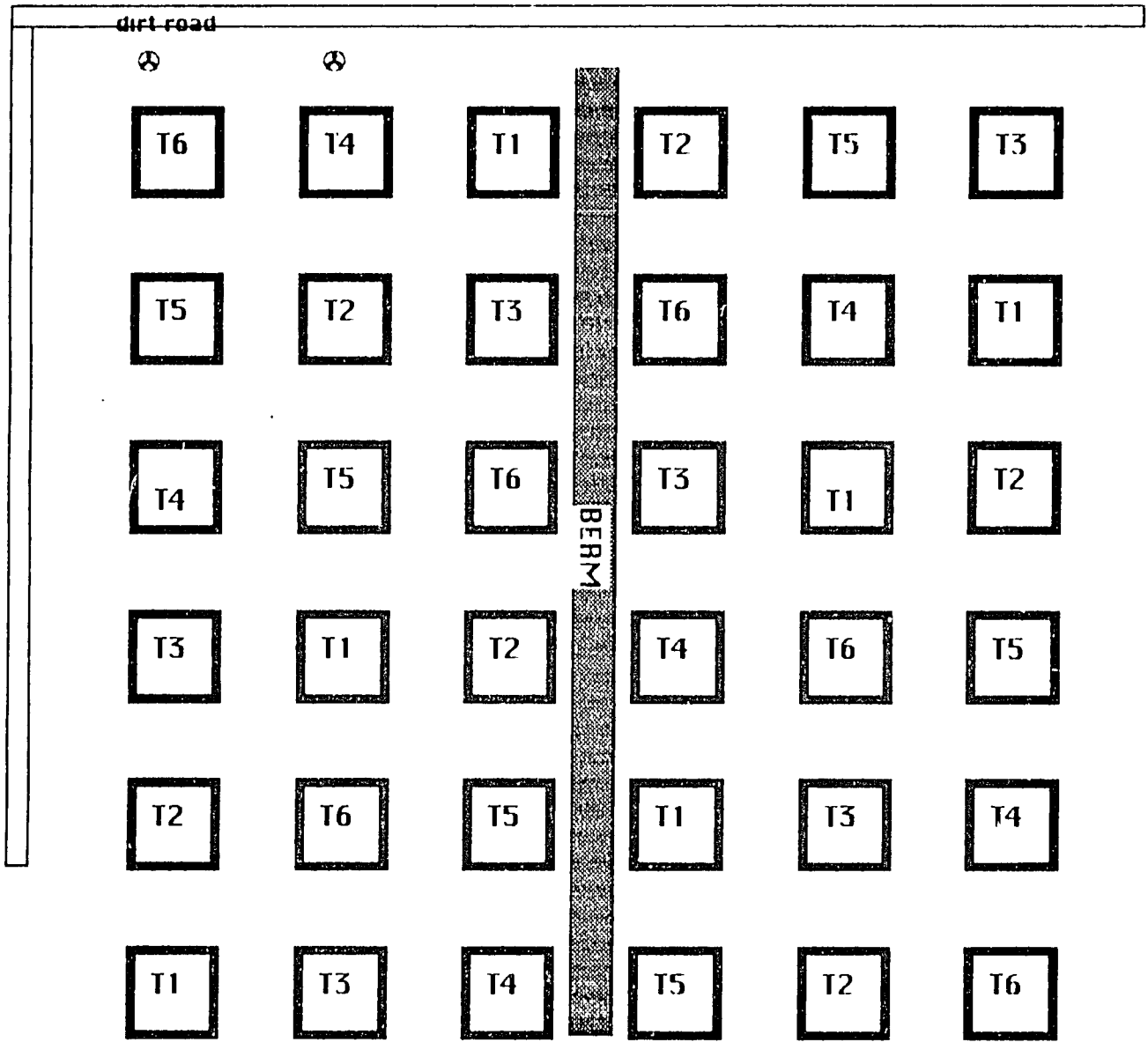
	Treatments [a]		
Farm	Treatment 1	Treatment 3	Treatment 6
Ginadasa	1362 [b]	1078	1170
Somadasa	72	52	34
Upulsantha	330	154	223
Wimalarathna	527	387	106
Somapala	132	100	88
L. Bandula Perera	137	83	35
Susantha Perera	255	178	88
Karunarathna	- [c]	-	-

[a] Treatment 1 refers to the farmer's standard treatment schedule and dose; Treatment 3 refers to one-half the farmer's standard and Treatment 6 to nil pesticide applied.

[b] No significant differences among treatments within farms.

[c] Field not harvested.

Fig. 1 TREATMENT ASSIGNMENT - CHILLI TRIAL
MAHA 1993-94 and YALA 1994



T1 = 100% CONVENTIONAL
T2 = 75% CONVENTIONAL
T3 = 50% CONVENTIONAL
T4 = 25% CONVENTIONAL
T5 = 0%
T6 = AS RECOMMENDED