EPIDEMIOLOGY OF CHILLI LEAF CURL DISEASE IN SRI LANKA

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ABSTRACT

Leaf curl epidemics develop in all agroclimatic regions in Sri Lanka. In the cooler and wet high altitude areas the epidemic is tardy while in the dry, warm coastal and inland areas the disease spread is rapid particularly in the dry months and in the dry seasons. Marked differences were obtained for the rates of spread of LCD in the four chilli varieties tested in the disease plots. In the wet season despite a large amount of inoculum the progress of LCD epidemics was slow. It is suggested that the slow spread of the epidemic was due to reduced mobility of the vector rather than to inadequate inoculum. The diversities in the rates of spread of LCD in the chilli varieties were associated with factors that affect the course of LCD epidemics. The slow spread in varieties Wanni and TBS were associated with poor host receptivity to the vector, reduced infection potential, lack of generation of secondary inoculum and longer time taken by the vector for acquisition and inoculation of the disease agent. Likewise, the explosive LCD epidemic in chilli variety Skantha was associated with good host receptivity to the vector, generation of secondary inoculum, high infective potential and shorter periods for acquisition and inoculation feeding, resulting in efficient dissemination and transmission of the disease.

INTRODUCTION

The leaf curl disease affects a range of crops in Sri Lanka (Fernando and Pieris, 1957, Shivanathan, 1976, 81 & 83). It causes yield reductions of 30–70 percent in most years on chilli, (*Capsicum frutescens, Capsicum annuum*), tomato, (*Lycopersicon esculentum*), tobacco, (*Nicotiana tabacum*) and other plants of economic importance. The causal agent of the disease is transmitted by white-fly (*Bemisia tabaci*) in a persistent manner. The spread of many plant diseases has been shown to be of a continuous or discontinuous type (Van der Plank, 1975, 1963 and Thresh, 1974). The progress of leaf curl epidemics present interesting diversities in respect of climate and host varieties in the different agroclimatic regions of Sri Lanka. The account presented in this paper is based on studies of leaf curl disease epidemics conducted at Maha Illuppallama, and relates to the effects of climate, host, vector and the disease agent in the epidemiology of the disease.

LCD epidemics in the different agroecological regions of Sri Lanka

Chilli is grown in diverse agroclimatic regions in Sri Lanka. The progress of LCD epidemics was measured every three weeks until crop senescence in 0.25 ha plots (25,000 plants/ha) distributed in the main chilli growing areas. In surveys the entire plant population in the test plot was scored for number of infected plants and presence of vector. Four climatic regions in the wet and dry areas were chosen for the mapping of the LCD epidemic in the chilli variety MI 2. The epidemiological data for the spread of LCD are in Table 1. The disease percentages were converted to $\text{Log}_e \frac{x}{1-x})$ and plotted against time in weeks to determine the apparent rates of spread of the disease in the agroecological regions. Figure 1 illustrates the progress of the epidemic.

Table 1—LCD incidence in the agroecological regions

Characteristics of the region	*Percentage LCD infection at weeks/[a]* 3	6	9	12	15	17	21
Over 1500 m 12–30 °C.	0	0	1 (–4.596)[b/]	1 (–4.595)	2 (–3.891)	6 (–2.751)	8 (–2.440)
500–1500 m 16–32 °C.	0	1 (–4.595)	2 (–3.891)	2 (–3.891)	9 (–2.313)	24 (–1.152)	31 (–0.800)
Coastal (latersol) 22–32 °C.	2 (–3.891)	2 (–3.891)	6 (–2.751)	15 (–1.734)	18 (–1.516)	27 (–0.994)	42 (–0.322)
Inland RBE/[c]	4 (–3.178)	12 (–1.992)	36 (–0.575)	72 (0.994)	82 (1.516)	84 (1.658)	89 (2.090)

a. Percent LCD infection in chilli variety MI.2

b. Figure in parenthesis is $\text{Log}_e \frac{x}{1-x})$, van der Plank, 1963.

c. RBE–Reddish brown earth soils.

In the cooler, wet, high altitude areas the LCD epidemics start 6 to 9 weeks later and progress slower than in the coastal warmer and sunny inland areas. The alternative weed hosts for LCD eg. *Ageratum conizoides* L. and *Acanthosperumum hispidum* L. are less dense in the high altitude areas and in the coastal sandy and lateritic regions. In the RBE and coastal latersols continuous cropping of chilli in the wet and dry seasons provides continuity of inoculum and vector for the disease to develop into an epidemic in a short period.

ARTIFICIAL EPIDEMICS OF LEAF CURL DISEASE

The disease plot for the development of artificial epidemics of LCD consisted of a block 0.25 ha (40,000 plants/ha) in with a border of five rows of LCD infected alternative hosts, *Acanthospermum hispidum* L., *Ageratum conizoides* L. and a susceptible chilli variety Skantha, The chilli varieties to be screened for resistance were planted in randomized replicated rows within the disease plot. Every third plant in a test row was an infected chilli variety Skantha. Infected weeds were planted between rows in the ratio 2 weeds for each test chilli seedling. Whitefly populations in the disease plot were augmented when required from laboratory colonies maintained on cotton.

Artificial LCD epidemic in the wet season

Five chilli varieties Skantha, MI 1, MI 2, Wanni and TBS were selected for this study. Skantha is a susceptible chilli variety while MI 1 and MI 2 are popular commercial varieties. Wanni and TBS are varieties grown extensively in the chena[1]. The latter are poor yielding varieties grown as mixed crops for an extended period of time in Sri Lanka, before the introduction in the last 4 decades of exotic chilli varieties for commercial cultivation. The epidemiological data for the spread of LCD in the five chilli varieties in the disease plots are in Table 2.

The progress of the epidemic is shown in figure 2 (p 103).

Table 2—LCD incidence in five chilli varieties in the disease plot

Variety	*Percent LCD infection at weeks/*[a]						
	3	6	9	12	15	18	21
Skantha	17 (–1.589)[b]	54 (0.160)	68 (0.754)	92 (2.442)	97 (3,476)	100 (4.701)	100
M.I.1	2 (–3.892)	13 (–1.900)	42 (–0.323)	64 (0.575)	81 (1.450)	88 (1.992)	94 (2.751)
M.I.2	0	2 (–3.982)	6 (–2.751)	28 (–0.944)	34 (0.664)	49 (–.0.040)	62 (0.490)
Wanni	0	1 (–4.595)	1 (–4.595)	4 (–4.595)	8 (–2.442)	8 (–2.442)	14 (–1.815)
TBS	0	0	1 (–4.595)	1 (–4.595)	1 (–4.595)	2 (–3.982)	2 (–3.982)

a. Percent disease in chilli variety MI 2.

b. The figure in parenthesis is $\text{Log}_e \frac{x}{1-x})$ from Van der Plank, 1963.

1. A system of shifting cultivation where forest is cleared by fire and cultivated with mixed crops for 4–7 years.

LCD epidemics within 'disease' plots in the dry season

The procedure for testing the progress of the epidemic in different varieties of chillies within the disease plot during the dry season was similar to that of the wet season. Figure 3 (p, 104) illustrates the progress of the epidemic within the disease plot in the dry season. The epidemiological data are in Table 3. The rate of progress of LCD epidemic was slow only in the traditional chilli varieties TBS and Wanni.

Table 3—LCD incidence in 5 chilli varieties within a disease plot

Variety	*Percent disease at weeks*						
	3	6	9	12	15	18	21
Skantha	8 a/(–2.442)	47 (–0.120)	89 (2.090)	100 (4.701)	100	100	100
M.I.2	11 (–2.090)	17 (–1.586)	32 (–0.753)	58 (0.323)	82 (1.516)	100 (4.701)	100
Wanni	2 (–3.891)	2 (–3.891)	8 (–2.442)	14 (–1.815)	53 (0.120)	68 (0.754)	84 (1.658)
TBS	0	0	1 (–4.595)	6 (–2.751)	6 (–2.751)	8 (–2.442)	8 (–2.442)

a The figure in parenthesis is Loge x/(1–x) from Van der Plank, 1963.

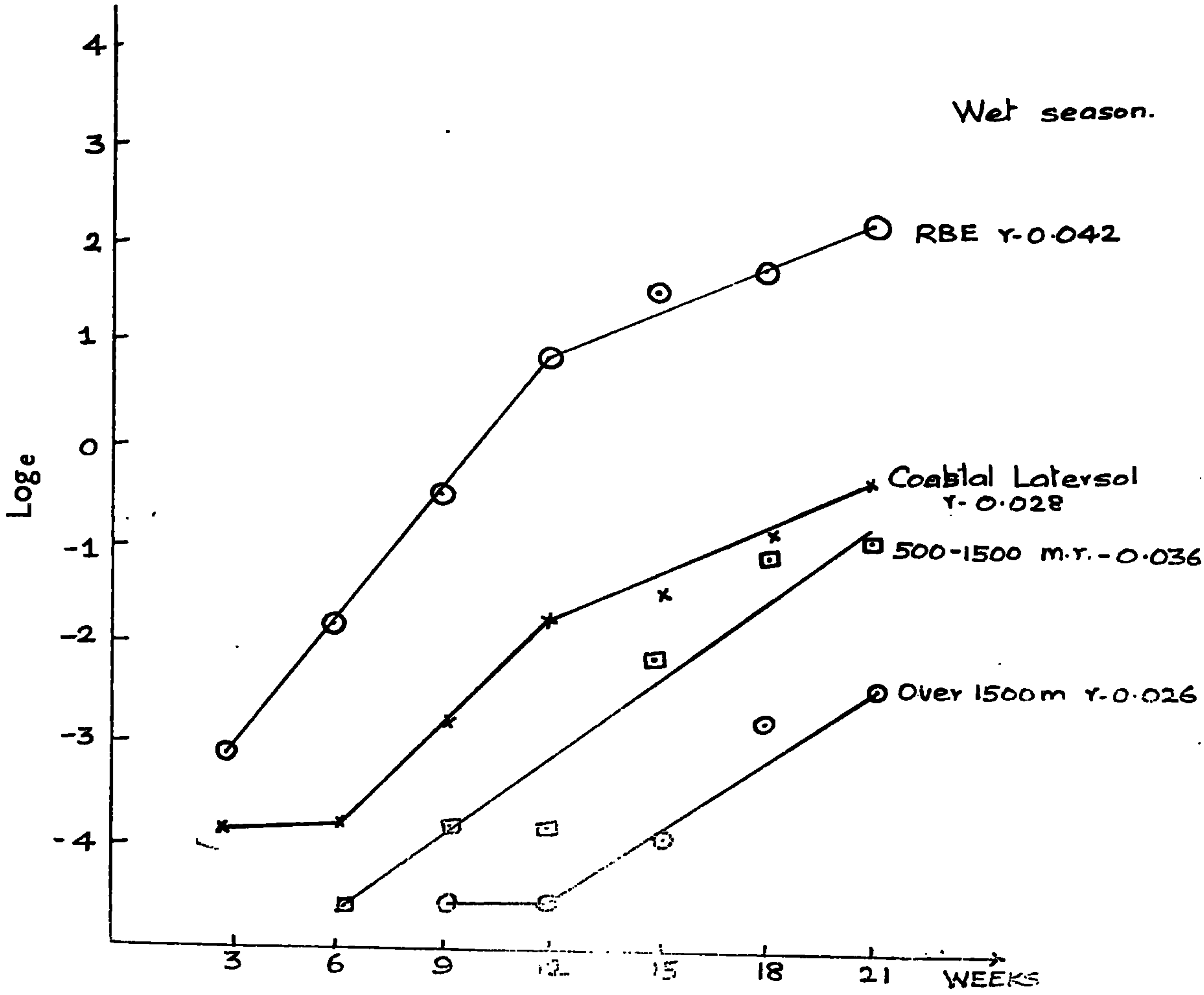

Fig. 1. LCD epidemics in agroclimatic regions.

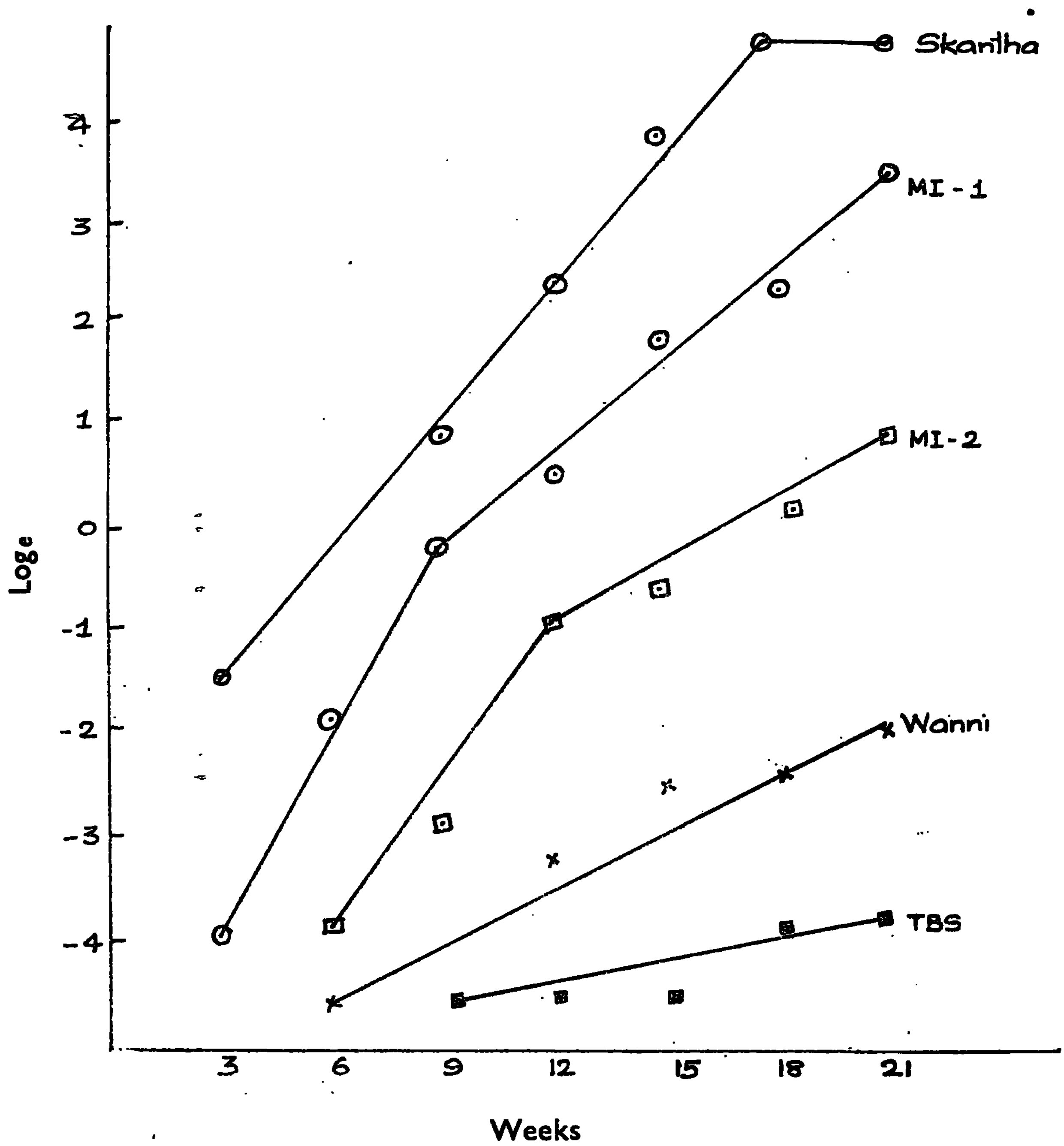

Fig. 2. LCD epidemics in chilli varieties within a 'disease' plot.

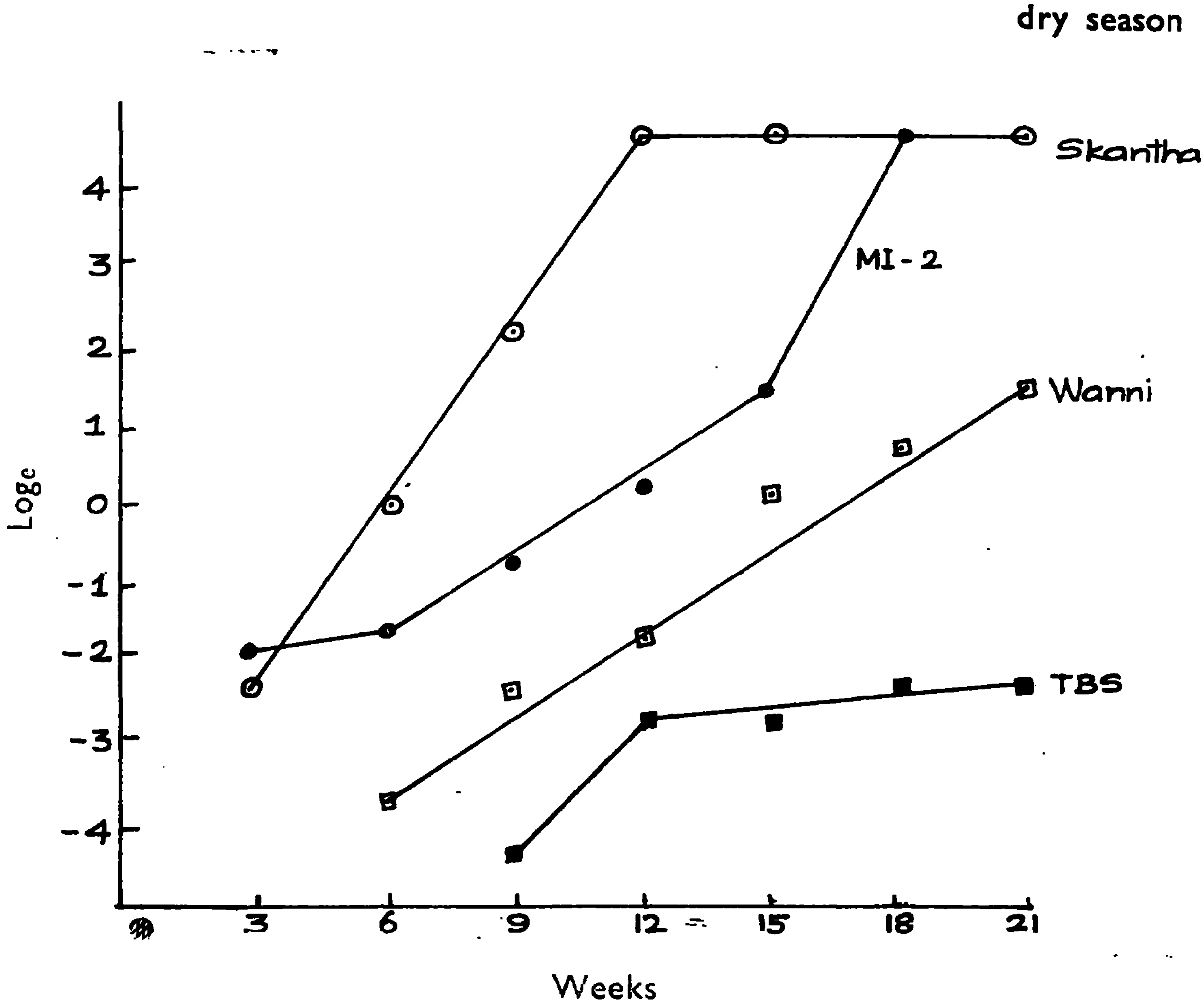

Fig. 3. LCD epidemic in five chilli varieties within disease plot.

THE SEQUENCE OF LCD EPIDEMICS

Arrival of inoculum at $x = O$

The arrival of the initial inoculum is of importance in plant disease epidemics. The arrival of LCD into a crop is by the movement of infectious whiteflies from outside. The number of chilli seedlings infected by arrival of infectious whiteflies per calendar month was estimated by planting 1000 MI 2 chilli seedlings and exposing them to natural infection for 50 days. The duration of life cycle of the whitefly on chilli is 3–4 weeks. The incubation period of the LCD agent on chilli is between 18 to 21 days. The percentage disease at the end of 50 days was therefore due to primary infection by movements of whiteflies that arrive from outside the crop. Table 4 compares the percentage disease in each calendar month, with the percent disease in natural and artificial epidemics.

Table 4—A comparison of percent disease per calendar month with percent disease in natural and artificial epidemics

Season	*Month*	*Disease in 50 days (%)*	*Nymphs/100 plants*	*Disease in natural epidemic (%)*	*Disease in artificial epidemic (%)*
Wet	Nov.	6.5	124	2	2
	Dec.	5.1	562	9	13
	Jan.	6.3	928	34	42
	Feb.	6.5	494	42	64
	Mar.	1.2	106	46	81
	Apr.	1.6	290	51	94
Dry	May	1.5	238	9	11
	Jun.	1.9	206	12	17
	Jul.	4.	54	48	58
	Aug.	2.4	0	74	82
	Sep.	5.	18	82	100
	Oct.	6.	34	86	100

In the wet season more plants were infected per calendar month than in the dry season. The development of the epidemic was faster during the dry season despite the low infection by whitefly movements from outside and reduced nymph development in the crop. The greater number of nymphs that developed in the wet season did not have a corresponding impact on the rate of spread of LCD.

Host receptivity to the vector

The host receptivity to the vector was determined by releasing whiteflies maintained on cotton variety HC101 into cages containing four varieties of chilli. The distribution of 200 whiteflies per cage in a total of four cages was studied. The distribution of whiteflies per plant together with the number of ovipositions per plant over a period of 14 days are in Table 5.

Table 5—Receptivity of chilli varieties to whitefly

Variety	*No. of whiteflies per plant on day* 1	3	7	10	12	*No. Nymphs on day* 14
Skantha	48	56	64	47	32	668
M.I.2	39	44	51	36	19	186
Wanni	42	49	17	31	15	43
TBS	06	0	1	0	3	0

Whiteflies tended to avoid the chilli variety TBS. There was no definite preference for any of the other varieties although significantly greater numbers of nymphs developed on the susceptible chilli variety Skantha. In the more resistant varieties TBS and Wanni few or no nymphs developed.

Factors in the increase of inoculum

An increase in the amount of LCD inoculum in crop can arise by the movement of infectious whiteflies from outside and by multiplication of whiteflies within the crop. The amount of whitefly multiplication within the crop in the early stages of the epidemic was determined by estimating the number of nymphs that developed on ten percent of the crop. The duration of the life cycle of whiteflies in the chilli varieties showed variations ranging from 14 days to 30 days, depending on the season and the host. The results are in Table 6.

Table 6—Differences in whitefly multiplication and duration of life cycle in chilli varieties

Variety	*Nymphs on* 100 cm^2 *of leaf at* 6 *weeks*	*Duration of life cycle* *wet*	*dry*
Skantha ...	168	22–28	14–18
Wanni ...	58	26–30	20–26
TBS ...	4	—	—

The whiteflies did not multiply on chilli variety TBS. In susceptible varieties the number of nymphs that developed on every 100 cm^2 of leaf surface was greater and the duration of the life cycle of the insect was shorter. In comparison, in the more resistant varieties the generation of secondary 'infectious entities' within the crop was negligible.

Infective potential

The infective potential of a vector with regard to a particular host is the number of host plants a single infectious vector could inoculate during the entirety of its infective life. In the case of whitefly transmitted pathogens this value depends on a number of factors such as the disease agent, season, the host and the sex of the insect. The data in Table 7 details the infective potential of whiteflies with regard to two chilli varieties Skantha and Wanni. Three inoculation feeding periods were tested to obtain the maximum infection for each host-pathogen combination.

Table 7—Infective potential of whitefly in chilli varieties

Variety	*Sex*	*No. of plants infected at inoculation feeding periods of:*[a]			*Average Infective potential per insect*
		30 (*min.*)	1 (*hour*)	3 (*hours*)	
Skantha ...	Male	23	34	14	
	Female	54	62	29	48
Wanni ...	Male	0	3	5	
	Female	0	7	9	7

a. Mean value of the number of plants infected. In each test for infective potential a total of 10 insects was used.

Different values have been obtained for the infective potential of whiteflies in the chilli varieties. An inoculation feeding time of three hours was inadequate for the whiteflies to inoculate the chilli variety TBS. By contrast, in the chilli variety Skantha one hour inoculation feeding time resulted in maximum number of infections while in chilli variety Wanni greater numbers of seedlings were infected when whiteflies were given 3 hours inoculation feeding.

The time taken by the vector to acquire and inoculate the disease agent is important in the efficiency of transmission of disease. The minimum acquisition feeding period required by whiteflies to become infectious when fed on a LCD infected host showed wide variability. The whiteflies could not acquire the pathogens from LCD infected chilli variety TBS at the end of two day acquisition feeding period. By contrast whiteflies took 12 hours to acquire the LCD agent from infected Wanni chilli while from the chilli variety Skantha it acquired the LCD agent in 30 minutes. Likewise, the minimum inoculation feeding period required by whiteflies to infect the chilli varieties differed from 15 minutes in Skantha, 1 hour in Wanni, to over 48 hours in the variety TBS.

Incubation period of LCD in chilli varieties

Seedlings of four chilli varieties, Skantha, MI 2, Wanni, and TBS were inoculated with LCD agent at 3–4 leaf stage. Non infected whiteflies were allowed to acquire the disease agent from the growing regions of the inoculated seedlings. The whiteflies were given over-night acquisition feeding on the inoculated test seedlings at intervals of 5 days and were later transfered to test chilli seedlings of variety MI 1. The inoculation feeding time on test seedlings was one day. The results are in Table 8.

Table 8—Inoculation period of LCD agent in chilli varieties

Variety		*Recovery of LCD agent from inoculated plants (%)* [a]						
	5 [b]	10	15	20	25	30	35	40
Skantha [c]/ ...	0	0	5	80	100	100	100	100
MI 2 ...	0	0	0	20	90	100	100	100
Wanni ...	0	0	0	0	5	20	40	40
TBS ...	0	0	0	0	0	0	0	0

a. Between 12–15 whiteflies were used per each recovery test.
b. Refers to number of days from inoculation
c. Numbr of inoculated seedlings per each variety is 20.

The whiteflies acquired the LCD agent efficiently from the susceptible chilli varieties Skantha and MI2. The acquisition efficiency of LCD agent by whiteflies from the chilli variety Wanni was poor in comparison to variety Skantha. In the susceptible chilli varieties the acquisition efficiency increased with time while in the variety Wanni there was no increase of LCD acquisition with time. Only 4 to 20 seedlings of chilli variety TBS were infected by LCD and recovery of the disease agent was not obtained at the end of 40 days from any of the infected seedlings. In the more resistant varieties the incubation period is longer and the vector takes a longer time to inoculate and acquire the disease agent.

Whitefly movements

The frequency and duration of visits made by infectious whiteflies are of importance in disease transmission and epidemics. The movements of whiteflies as observed in the field under two contrasting climatic conditions are in Table 9.

Table 9—Field movements of whitefly on chilli [a]

No. of insects observed	*Climatic condition*	*Filed movements of whitefly 6 a.m.–4 p.m.*			*No. of plant to plant $ movement per insects*
		No. of movements range	*No. of movements mean*	*Duration of visits range (minutes)*	
34	Overcast 22–26 °C Wet [b]	4–16	6	24–196	0.2
52	Sunny 27–32 °C Wind: 4–10 mph Dry [c]	27–85	52	2–64	3.8

a. Chilli variety MI 2 in field 0.25 ha in extent.
b. Wet season (November and December of 1975).
c. Dry season (March, April, May and June of 1976).

In the wet season the whitefly movements were restricted but the duration of each visit by the vector was longer and the chances of pathogen transmission was better. In the dry season the whiteflies moved frequently and made significantly more plant to plant movements that were of importance in the spread of the disease. Leaf movements due to wind often initiate whitefly movements in the field. Bright sunshine, high temperatures and light to moderate winds in the dry season result in greater mobility of the vector. The greater spread of the LCD in the dry season despite low levels of multiplication and generation of secondary inoculum may be attributed to vector mobility or vector migration.

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