Theor Appl Genet (1987) 73:707–710

Sources and inheritance of resistance to leaf curl virus in *Lycopersicon*

M. K. Banerjee and Kalloo *

Department of Vegetable Crops, Haryana Agricultural University, Hisar-125 004, India

Received July 25, 1986; Accepted October 31, 1986
Communicated by G. S. Khush

Summary. One hundred and twenty-two varieties, lines and wild accessions of *Lycopersicon* were screened under three different regimes during the autumn/winter season of 1982–83 and 1983–84 for resistance to tomato leaf curl virus (TLCV). *L. hirsutum* f. *glabratum* ('B6013') and *L. hirsutum* f. *typicum* ('A1904') proved to be highly resistant to TLCV in all three environments. Various accessions of *L. peruvianum* were also highly resistant. *L. pimpinellifolium* ('A1921') exhibited no TLCV symptoms within 90 days. Of the cultivated varieties, 'Acc 99' exhibited the minimim score for susceptibility; 'AC 142', 'Collection No. 2', 'Kalyanpur Angurlata' and 'HS 101' had a low rating for virus incidence. The inheritance of resistance was studied in the interspecific crosses between a TLCV resistant line of *L. pimpinellifolium* ('A1921') and five ('HS 101', 'HS 102', 'HS 110', 'Pusa Ruby' and 'Punjab Chhuhara') susceptible cultivars of *L. esculentum*. Parents, F_1, F_2 and backcross progenies were artificially inoculated with local strains of TLCV using vector the viruliferious whitefly, *Bemisia tabaci* (Genn.). Data indicated that the resistance of *L. pimpinellifolium* ('A1921') is monogenic and incompletely dominant over susceptibility.

Key words: *Lycopersicon* – Tomato leaf curl virus – Resistance – Variety tests

Introduction

Tomato leaf curl (TLCV) disease is a limiting factor for the successful cultivation of tomatoes in India (Varma et al. 1980).

The disease is mainly confined to tropical and subtropical Asian Countries and parts of Africa (Hayati 1978) where yield losses due to this disease have been calculated to be over 90% in some places (Sastry and Singh 1973). In certain parts of Northern India, tomato cultivation in the autumn season has been discontinued due to the high occurrence of this disease. The incidence can be reduced to some extent with the application of insecticides (Sastry and Singh 1971) but this is not economical and there is a high degree of residual effects from the insecticides. Thus there is a need to develop TLCV resistance cultivars. Donors for resistance are needed and information on the inheritance of resistance is useful. Sources of resistance have been reported by Naraini and Vasudeva (1963), Varma et al. (1980) and Joshi and Choudhary (1981), however, these sources are now no longer resistant.

Therefore, this study was undertaken to screen cultivated and wild species of *Lycopersicon* to find sources of resistance and to study the inheritance of resistance.

Materials and methods

One hundred and twenty-two entries, consisting of promising varieties, lines and wild species collected from different sources were grown under field, screenhouse and greenhouse conditions in the Department of Vegetable Crops, Haryana Agricultural University, Hisar during the autumn winter seasons of 1982–83 and 1983–84. The seedlings were transplanted in the field in rows at 60×45 cm spacing in 3 replications. All the recommended agronomic practices were adopted. In the screenhouse, sowing was done in 12 inch clay pots and seedlings were transplanted in 6 inch clay pots. Ten to twelve plants of each entry were grown. In the greenhouse 7–8 seedlings of each entry were transplanted into beds. Disease inoculum was maintained by propagating infected plants of a local strain. White flies were raised in the infected plants.

To assess the resistance of a given strain, symptom severity grades, designated with numerical values of 0–4, were given on the basis of visual observations. To quantify the disease severity, calculations were made as shown in Table 1. The percent disease was calculated by the formula:

$$\% \text{ disease} = \frac{\text{Number of diseased plants}}{\text{Total number of plants observed}} \times 100$$

* To whom correspondence should be addressed

Table 1. A scale for classifying disease reaction of *Lycopersicon* species to tomato leaf curl virus

Symptoms	Symptom severity grade	Response value	Coefficient of infection	Reaction
Symptoms absent	0	0	0– 4	Higly resistant (HR)
Very mild curling (up to 25% leaves)	1	0.25	5– 9	Resistant (R)
Curling, puckering of 26–50% leaves	2	0.50	10– 19	Moderately resistant (MR)
Curling, puckering of 51–75% leaves	3	0.75	20– 39	Moderately susceptible (MS)
Severs curling, puckering of > 75% leavers	4	1.00	40– 69	Susceptible (S)
			70–100	Highly susceptible (HS)

Table 2. Number of highly resistant, resistant, moderately susceptible, susceptible and highly susceptible, accessions of *Lycopersicon* to tomato leaf curl virus

Accessions	Natural condition	Artificial condition	
	Field	Screen-house	Green-house
Total	122	120	100
Highly resistant	8 (6.56)	8 (6.67)	8 (8.00)
Resistant	1 (0.82)	1 (0.83)	1 (1.00)
Moderately resistant	Nil (0.00)	Nil (0.00)	1 (1.00)
Moderately susceptible	9 (7.38)	7 (5.83)	6 (6.00)
Susceptible	50 (40.98)	54 (45.00)	51 (51.00)
Highly susceptible	54 (44.26)	50 (41.67)	33 (33.00)

Figures in parenthesis showing percent occurrence

The coefficient of infection was calculated by multiplying the % disease by the "response value" assigned to each severity grade. Thus, the coefficient combined the amount of infection and its severity. The reaction grades assigned to each entry were added together for two years and the mean values were calculated. Of the coefficient of infection values: 0 to 4 were considered highly resistant, 5 to 9 resistant, 10 to 19 moderately resistant, 20 to 39 moderately susceptible, 40–69 susceptible and 70–100 highly susceptible.

To elucidate the nature of inheritance of resistance to TLCV, *L. pimpinellifolium* 'A1921', was crossed with five *L. esculentum* susceptible varieties, i.e. 'HS 101', 'HS 102', 'HS 110', 'Pusa Ruby' and 'Punjab Chhuhara'. The F_1 plants were selfed to produce F_2 seeds and backcrossed with their respective parents to produce B_1 and B_2 seeds. The disease reaction was studied in all parents, F_1, F_2, and back crossed populations. In all the tests, plants were inoculated with TLCV in the screenhouse. Three week old plants grown in screenhouse were exposed to viruliferious whiteflies, *Bemisia tabaci* (Genn.) for 5–7 days in inoculation chambers under insect-proof cages. The pots were subsequently placed on benches in a screenhouse. In order to make sure of the inoculation, the potted plants were again exposed to viruliferous whiteflies under muslin cloth nets. This was done in the screenhouse where the TLCV-affected (infector row) and potted plants to be screened were arranged on the benches in rows. After 25 days these infected rows were removed. The inoculated potted plants were kept under cover of the muslin cloth nets for another 40 days, then the nets were removed. Plants were evaluated for TLCV reaction 75 days after inoculation. Each plant was assigned a disease score. The plants were classified as resistant (no visible symptoms), intermediate (very mild curling upto 25% leaves of total plant) and susceptible (curling of > 25% leaves of total plant).

Results and discussion

The reactions of various cultivated and wild accessions of *Lycopersicon* to TLCV under natural (field) and artificial (screenhouse and greenhouse) conditions in the autumn season are summarised in Table 2. *L. hirsutum* f. *glabratum* 'B6013', *L. hirsutum* f. *typicum* 'A1904' were highly resistant to TLCV as there were no symptoms of TLCV until maturity under all the environments during both years (Table 3). Under natural conditions *L. hirsutum* f. *glabratum* 'B6013' exhibited a low frequency of whitefly (*Bemisia tabaci*), which may be due to non-preference and it may be one of the probable reasons of TLCV resistance. However, under artificial conditions, all inoculation by viruliferous whiteflies was more certain. *L. hirsutum* f. *glabratum* is easily crossable as male parent to *L. esculentum* and thus is a good donor for the resistance.

Various accessions of *L. peruvianum* were also highly resistant. The low incidence of TLCV in *L. peruvianum* has also been reported by Naraini and Vasudeva (1963). *L. pimpinellifolium* 'A1921' exhibited no TLCV symptoms up to 90 days. After 90 days mild symptoms were observed but only on the terminal growing shoots of the plants. This degree of resistance is desirable for a resistance breeding program as TLCV symp-

Table 3. Reaction of some *Lycopersicon* genotypes to tomato leaf curl virus

Accessions	Field		Screenhouse		Greenhouse		Final grade[c]
	C.I.	Reaction	C.I.[a]	Reaction[b]	C.I.	Reaction	
L. hirsutum f. *glabratum* 'B 6013'	0.00	HR	0.00	HR	0.00	HR	HR
L. hirsutum f. *typicum* 'A 1904'	0.00	HR	0.00	HR	0.00	HR	HR
L. hirsutum 'PI 127826'	0.00	HR	0.08	HR	0.20	HR	HR
L. peruvianum 'EC 148898'	0.00*	HR	0.35	HR	0.00	HR	HR
L. peruvianum 'B 6002/77'	0.35	HR	0.08	HR	0.00	HR	HR
L. peruvianum 'EC 148897'	0.71*	HR	0.20	HR	1.13	HR	HR
L. peruvianum f. *typicum* 'B 6002'	2.15	HR	0.85	HR	1.66	HR	HR
L. peruvianum f. *glandulosum* 'B 6005'	3.21	HR	1.74	HR	3.01	HR	HR
L. pimpinellifolium 'A 1921'	7.56	R	6.84	R	6.41	R	R
L. pimpinellifolium 'Pan American'	27.37	MS	33.12	MS	21.26	MS	MS
L. pimpinellifolium 'EC 65992'	32.47	MS	29.77	MS	44.30	S	MS
L. pimpinellifolium 'PI 205009'	35.73	MS	41.62	S	52.95	S	S
L. esculentum cv. 'Acc 99'	20.65*	MS	–	–	15.00*	MR	MR
L. esculentum cv. 'AC 142'	30.15	MS	39.15	MS	40.02	S	MS
L. esculentum cv. 'Collection no. 2'	35.41	MS	46.99	S	22.86*	MS	MS
L. esculentum cv. 'Kalyanpur Angurlata'	38.17	MS	47.08	S	33.04	MS	MS
L. esculentum cv. 'HS 101'	41.08	S	39.09	MS	46.92	S	S

[a] C.I. = coefficient of infection. * Value is for one year only
[b] HR = highly resistant; R = resistant; MR = moderately resistant; MS = moderately susceptible
[c] Overall mean of all environments

Table 4. Reaction of parents, F_1, F_2 and backcross generations to local strains of TLCV

Population	Reaction (no.)			P-value
	Resistant	Intermediate	Susceptible	
Parents	–	–	–	
'HS 101'			20	
'HS 102'			21	
'HS 110'			19	
'P.R.'			20	
'Pb.Chh.'			20	
'A 1921'[a]	52	–	–	
F_1 hybrid				
'HS 101'×'A 1921'	3	18	–	
'HS 102'×'A 1921'	–	19	–	
'HS 110'×'A 1921'	–	21	1	
'P.R.'×'A 1921'	2	17	–	
'Pb.Chh.'×'A 1921'	–	23	1	
F_2				1:2:1
'HS 101'×'A 1921'	32	80	30	(0.30–0.50)
'HS 102'×'A 1921'	24	54	38	(0.10–0.20)
'HS 110'×'A 1921'	26	64	45	(0.05–0.10)
'P.R.'×'A 1921'	46	79	37	(0.50–0.70)
'Pb.Chh.'×'A 1921'	39	61	34	(0.30–0.50)
Backcross to susceptible parents				1:1
('HS 101'×'A 1921')×'HS 101'	1	24	37	(0.10–0.20)
('HS 102'×'A 1921')×'HS 102'	–	23	31	(0.30–0.50)
('HS 110'×'A 1921')×'HS 110'	–	22	35	(0.10–0.20)
('P.R.×'A 1921')×'P.R.'	2	29	25	(0.50–0.70)
('Pb.Chh.'×'A 1921')×'Pb.Chh.'	–	27	39	(0.10–0.20)
Backcross to resistant parent				1:1
('HS 101'×'A 1921')×'A 1921'	21	29	–	(0.30–0.50)
('HS 102'×'A 1921')×'A 1921'	19	31	–	(0.10–0.20)
('HS 110'×'A 1921')×'A 1921'	24	29	–	(0.50–0.70)
('P.R.'×'A 1921')×'A 1921'	20	30	–	(0.20–0.30)
('Pb.Chh.'×'A 1921')×'A 1921'	25	37	2	(0.10–0.20)

[a] A 1921 = (*L. pimpinellifolium* A 1921) = resistant parent

toms after 90 days of planting cause no loss of yield in field grown tomatoes. *L. pimpinellifolium* 'A1921' is a good donor for TLCV resistance as it is easily crossable with *L. esculentum* and possesses fewer undesirable morphological traits as compared to *L. hirsutum* f. *glabratum*. Furthermore, in the segregating population from the crosses of *L. pimpinellifolium* and *L. esculentum*, recombinants with a preponderance of traits from cultivated parents and TLCV resistance are easily obtained. *L. pimpinellifolium* was also found resistant to tomato yellow leaf curl virus (TYLCV) in Israel (Pilowsky and Cohen 1974).

Some accessions of *L. esculentum* were moderately susceptible. Among these, 'Acc. 99', a cultivated type, exhibited the minimum score of 20.65. In addition to having a low degree of susceptibility 'Acc. 99' has a determinate growth habit, is medium late, has medium or large red fleshy fruit and is high yielding. Thus, in the areas where there is a low incidende of TLCV, this variety can be grown. Under screenhouse conditions another cultivar, 'HS 101', also exhibited a low incidence of virus infection. This variety was developed at the Haryana Agricultural University and was selected for from autumn grown progenies when there was a high incidence of TLCV (Kalloo and Singh 1976). Other cultivated varieties showing a low rating of incidence were: 'AC 142', 'Kalyanpur Angurlata', 'Pan American', 'Ostenkinskiz', and 'VFN Bush'. These varieties can be grown in the autumn season without much loss to the yield.

Inheritance of resistance

The reactions of the parents, F_1, F_2 and backcross progenies to local strains of TLCV are presented in Table 4. All 52 plants of *L. pimpinellifolium* 'A1921' were resistant and the plants of 'HS 101', 'HS 102', 'HS 110', 'Pusa Ruby' and 'Punjab Chhuhara' were susceptible. Out of a total of 105 plants from the five crosses tested, 98 showed an intermediate reaction. Thus, resistance appeared to be incompletely dominant. The five plants which were classified as resistant were probably escapes and the two which were classified as susceptible may have been selfs.

The F_2 progenies segregated into three classes – resistant, intermediate and susceptible in the ratio of 1 : 2 : 1 respectively (Table 4). The P-value indicated a close fit for a 1 : 2 : 1 ratio. Thus, the F_2 data support the hypothesis that the inheritance of *L. pimpinellifolium* 'A1921' to the local strains of TLCV is controlled by a single incompletely dominant gene. This resistance gene may be designated as *Tlc*.

These results were confirmed from the analysis of backcross progenies. A total of 295 plants from five backcross progenies to the susceptible parents (Table 4) segregated into intermediate and susceptible classes in a 1:1 ratio. Three resistant plants amongst these progenies may have been escapees. Progenies from backcrosses to the resistant parent (*L. pimpinellifolium* 'A1921') segregated into a ratio of 1 resistant: 1 intermediate, and the P-values indicated a close fit to this ratio.

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