GENETIC CATALOGUING OF TOMATO GERMPLASM TOWARDS ISOLATION OF LINE(S) RESISTANT TO BACTERIAL WILT

BY

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THESIS

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DECLARATION

I hereby declare that the thesis entitled "Genetic cataloguing of tomato germplasm towards isolation of line(s) resistant to bacterial wilt" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellanikkara,
27th July, 1981.

CELINE, V.A.

CERTIFICATE

Certified that the thesis entitled "Genetic cataloguing of tomato germplasm towards isolation of line(s) resistant to bacterial wilt" is a record of research work done independently by Miss. Celine, V.A. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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CERTIFICATE

We, the undersigned members of the Advisory Committee of Miss. Celine, V.A. a candidate for the degree of Master of Science in Horticulture agree that the thesis entitled "Genetic cataloguing of tomato germplasm towards isolation of line(s) resistant to bacterial wilt" may be submitted by Miss. Celine, V.A. in partial fulfilment of the requirement for the degree.

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CELINE, V.A.

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INTRODUCTION

Tomato (*Lycopersicon lycopersicum* (L) Karst.) is one of the most important fruit vegetables grown both in tropics and subtropics. It is affected by a conglomeration of parasitic and non-parasitic diseases. Bacterial wilt, caused by *Pseudomonas solanacearum* (E.F.Smith), is the most serious disease which has made cultivation of tomato impossible in certain acidic soils of the tropics. The attempts on disease management and control have not made substantial impact, necessitating the development of resistant lines to bacterial wilt. Luckily, two basic sources of resistance and a large array of resistant lines have been reported. The reports on susceptibility of reportedly resistant lines elsewhere have complicated the attempts on breeding for disease resistance.

Genetic cataloguing is the key and vital step *a priori* to any disease resistance breeding programme. The information bank generated in tomato through the Reports of the Tomato Genetics Coöperative provide adequate bases for such attempts. Genetic cataloguing would also throw light on linkage/pleiotropism among mendelian characters and disease resistance. This would help in the screening and isolation of resistant lines both in the nursery and mainfield.

The reports on undesirable linkage between resistance and unfavoured marketable fruit characteristics present a gloomy picture to the breeders. This has necessitated detailed study on mendelian characters and their association, if any, with resistance.

Being a self pollinated crop, pureline selection is the ideal method to develop newer productive lines for characters essentially governed by additive gene action. Mass selection would help to cull out undesirable plant types. The efficiency of different methods of selection for economic characters in association with resistance needs to be investigated.

The present study was formulated with the following objectives

1. To catalogue the available tomato germplasm maintained in the department of Olericulture
2. To isolate, if any, line(s) resistant to bacterial wilt
3. To estimate realised selection response under pureline, mass and bulk methods of selection based on yield *per se* associated with resistance

REVIEW OF LITERATURE

REVIEW OF LITERATURE

A Genetic cataloguing

Genetic cataloguing would enable identification of line(s) based on distinct mprphological and mendelian characters. Identification of marker character(s) linked with/pleiotropic to disease resistance character would help in screening a large number of germplasm for source of resistance.

Reports of the Tomato Genetics Coöperative (1979, 1980) provide an uptodate information on genes, their reference and seed source in tomato. The information on mapped genetic loci of the crop has also been provided. The 81 characters thus listed were made use of to catalogue the present germplasm.

B Sources of resistance to bacterial wilt

Bacterial wilt remains the most important disease of tomato in warm humid tropics. The causal agent, Pseudomonas solanacearum, (a soil borne bacterium which prefer acidic soils) exists in several races. This has further complicated breeding for resistance to the bacterium. The Annual Report of the School of Agriculture, North Carolina State College (1950-'51) contains the first report on breeding for resistance to bacterial wilt in tomato. Lines with good field resistance to bacterial wilt have been developed. These lines had lesser fruit size resulting in low marketable returns. Greenhouse testing indicated higher susceptibility of young plants than old ones. Abeygunawardena and Siriwardena (1963) tested 49 hybrids and their parents for resistance to bacterial wilt. The North Carolina lines 1960 - 8, 1960 - 2a, 1962 - B2 and 1961 - 57 - 55 M and Masterglobe, Rahangala Selection II were obsérved more resistant. Los Banos strain which was reported resistent in Philippines was observed susceptible in Sri Lanka. This was the first indication of the presence of different races in _P. solanacearum_. Abeygunawardena and Siriwardena (1963) reported the efficiency of root inoculation studies to eliminate susceptible ones. The crosses involving the popular varieties of U.S.A., Manalucie and Floradel with a resistant stock from North Carolina resulted in the evolution of a few lines resistant to _P. solanacearum_ (University of Florida, 1967). The four F_7 lines from a cross UPR 199 x Floralou showed good tolerance to *P. solanacearum* (IRAT, 1970). The local line 2 ASS was observed tolerant to bacterial wilt (Serere Research Station, 1970-71). Henderson and Jenkins (1971) reported resistance in Venus and Saturn to bacterial wilt. Akiba *et al*. (1972) reported resistance in three strains of tomato viz., 65S2, 66 S52 and 68 S4. Daly (1973) confirmed the resistance in the North Carolina cultivars Venus and Saturn and in local lines III IRAT and OTB2. Chetia and Kakati (1973) reported some resistance to *P. solanacearum* in Oxheart under natural infection. Mew and Ho (1976) screened 43 varieties and lines. The line VC 8-1-2-1 was observed resistant regardless of inoculum density. Sunarjono *et al*. (1976) screened tomato varieties resulting in the isolation of AVRDC resistant lines 15, 22 and 33. New F_8 tomato lines FP - 1, FP -2 and FP - 5 were selected for tolerance to bacterial wilt (University of Malaya, 1977). Sonada and Augustine (1977) isolated Hawaian selection 7997 as resistant out of 72 tomato lines screened against bacterial wilt. Sonoda (1977) further evaluated 121 lines and cultivars and observed tolerance in Venus and Saturn. Graham *et al*. (1977) observed resistance in VC-4. Badekar (1977) reported the resistance in VC 9-1 UG and VC 11-1 UG.

The line VC 48-1 was observed resistant to bacterial wilt in Taiwan (AVRDC, 1978). Of the 25 lines reported as being resistant, only the lines L 3972, L 3987 and CL 8d - 0-7-1 were moderately resistant in Nigeria (IITA, 1978). Sonoda et al. (1979) reported moderate tolerance in tomato accessions 102, 106, 135-1, 135-2, 14 and 123-1 in Fort Pierce.

C Genetics of resistance

Two primary sources of resistance have been reported (Russell, 1978). Louisiana Pink, being the first source of resistance, has been studied in detail. The Louisiana Pink source of resistance, also called as North Carolina type of resistance, is inherited recessively and controlled by polygenes (Singh, 1961). Graham and Yap (1976) conducted detailed variance component analysis of the parents, F_1S, F_2S, B_1S and B_2S of Cross between resistant line, VC4, and susceptible line, Walter. This study indicated a narrow sense heritability of 42% and a broad sense heritability of 53% with a degree of dominance of 75% for wilt resistance. Inheritance of resistance was observed mainly due to additive gene action. They suggested repeated selfing and selection followed by intercrossing of resistant selections as the most efficient breeding procedure for wilt resistance. The polygenic resistance is modified by changes in temperature (Mew and Ho, 1977). Another factor which alters the resistance mechanism is the inoculum density of bacteria. Villareal and Lai (1978) supported the hypothesis of additive gene action in the inheritance of disease resistance.

A second type of resistance has been derived from the Eulycopersicon species Lycopersicon pimpinellifolium (PI 127805 A) (Acosta et al., 1964; Mohanakumaran et al., 1969 and Roddick, 1974). Acosta et al. (1964) presented evidence for partial dominance for resistance in F_1 in early stage of growth. In mature plants, resistance appeared to be controlled by recessive genes.

D Information on linkage

Acosta (1964) reported a possible linkage between sp^+, the factor for indeterminate growth habit and resistance to wilt caused by bacteria. Acosta et al. (1964) observed no association between the gene 'u' controlling uniform fruit colour and resistance to bacterial wilt. A few resistant selections had yellow gel round the seeds of ripening fruits. They could get no lines in resistant group with fruits of commercial quality. Scientists at University of West Indies (1968-'69) based on the investigations on resistance to *P. solanacearum* indicated close linkage between recessive genes for resistance and genes for poor fruit characteristics. Kanñ and Laterot (1977) reported pleiotropism rather than linkage between resistant factors against *P. solanacearum* and *Fusarium oxysporum.*

E Biochemical basis of resistance

α- tomatine content was more in resistant parents and hybrids than in susceptible ones (Mohanakumaran, *et al.*, 1969). A marked increase in α- tomatine content was observed in resistant lines following artificial inoculation than in susceptible ones. Roddick (1974) reported higher levels of the steroidal glycoalkaloid α- tomatine in the roots of *L. pimpinellifolium* cultivars resistant to *P. solanacearum.*

F Breeding methods

Continued selfing followed by selection and interplant hybridisation was suggested by Graham and Yap (1976) to develop resistant lines. Peter and Rai (1976) conducted detailed studies on genetic analysis of economic traits in tomato. Locule number and plant height were reported to be more important characters of divergence in tomato and obviously governed by additive gene action. Information on variability and association among polygenic characters were collected by a number of workers (Singh *et al.*, 1973; Peter and Rai, 1976; Prasad and Prasad, 1976; Singh *et al.*, 1977; Nandpuri *et al.*, 1977). Information on realised genetic response for different economic characters in association with resistance to bacterial wilt are rather limited.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present study was conducted at the Instructional Farm of the College of Horticulture, Kerala Agricultural University, Trichur, during April-August 1980, May-September 1980, September-December 1980 and February-May 1981. The farm is located at an altitude of 22.25 m. and at 10^{o} 32" N latitude and 76^{o} 10" E longitude. The soil of the experimental site is deep, well drained, moderately acidic (pH = 5.1), medium clay loam and fairly rich in organic matter. The area enjoys a typical warm humid tropical climate. The soil is highly infested with Pseudomonas solanacearum resulting in high rate of crop damage when solanaceous vegetables are grown.

A. Experimental materials

The tomato germplasm maintained in the Department of Olericulture formed the basic experimental material for cataloguing and screening under field conditions. The source, pedigree and morphological description of the tomato lines are given in Table 3.1.

B. Experimental methods

1. Cataloguing

The 78 tomato lines were sown in raised beds during September 1980 and the seedlings were studied for qualitative characters as suggested in the Report of the Tomato Genetics Cooperative, May, 1980 (Table 3.2). The seedlings were classified into five distinct groups based on the spread and intensity of purple pigmentation as indicated below:

a) completely free of anthocyanin
b) upper part of the hypocotyl free of anthocyanin
c) full hypocotyl region with anthocyanin
d) hypocotyl and epicotyl with anthocyanin and
e) hypocotyl, epicotyl, cotyledons and first leaves with anthocyanin

The seedlings were further classified into groups based on phyllotaxy as suggested by Bible (1976).

The seedlings were transplanted and they were observed for juvenile and adult plant characters as suggested in the Report of the Tomato Genetics Cooperative, May 1980 (Tables 3.3 and 3.4).

2. Estimation of response to selection

The line(s) showing resistance to bacterial wilt based on 'ooze test' was observed on individual plant basis and observations were recorded on plant height, primary branches per plant, days to first fruit set, days to first harvest, fruits per plant, marketable fruits per plant, locules per fruit, marketable fruit weight per plant and total fruit weight per plant. Elite plants were identified based on total fruit weight per plant and negligible or no incidence of cracking to generate progenies through mass selection (three plants out of 67), pureline (single elite plant) and the bulk. The progenies were later grown during February 1981 in a randomised block design with six replications. There were five rows of 12 plants per row in bulk and mass selected progenies and a single row for single plant selected progeny (pureline) in each replication. Every fifth row in each replication was planted with susceptible variety of tomato, Sioux, to study simultaneously the resistance/susceptibility of the above lines. Observations were recorded on plant height, primary branches per plant, days to first fruit set, days to first harvest, total fruits per plant, marketable fruits per plant, locules per fruit, percentage of small fruited plants (<20 g.), percentage of medium fruited plants

(20 to 40 g.) percentage of large fruited plants (>40 g.), percentage of plants without cracked fruits (zero per cent cracked fruits), percentage of plants with medium cracked fruits (>zero to 25 per cent cracked fruits), percentage of plants with highly cracked fruits (>25 per cent cracked fruits), marketable fruits per plant and total fruit weight per plant. The data were analysed as in randomised block design and later in completely randomised design as the variations due to replication were found to be non-significant.

Selection differential (S), selection response (R) and realised heritability (h^2) for each polygenic character was computed as given by Falconer (1960).

3. Evaluation of field tolerance

The trials were carried out in soils known for high inoculum density of Pseudomonas solanacearum. The cropping was done in the same plot where the previous crop was tomato or a solanaceous vegetable. The lines under screening were grown along with known susceptible line (Sioux) to prove the inoculum potential of the soil.

4. Artificial inoculation

1. The soil where diseased plants were observed was used for growing the line(s) under screening.
2. Artificial inoculation was done as suggested by Winstead and Kelman (1952).

Table 3.1 The source, name, pedigree and morphological description of lines under screening.

Accession number	Source	Cultivar name	Pedigree	Important traits
LE 5	I.A.R.I.	Pusa Ruby	Improved Meeruthi x Sioux	Indeterminate, spreading, moderately ribbed fruit surface
LE 18	Pantnagar	AC 238	-	Indeterminate, large fruited
LE 23	Pantnagar	AC 259	-	-
LE 34	Pantnagar	11-5-2-3-1	HS102 x AC 142	Determinate, medium fruited
LE 40	Pantnagar	AC 111	-	Indeterminate, large fruited, smooth fruited
LE 44	A.I.C.V.I.P.	King Kig	-	-
LE 47	Pantnagar	11-2-74-3-1	HS 102 x AC 142	-
LE 69	I.A.R.I.	Pusa Early Dwarf	-	Semideterminate, moderately ribbed fruit surface
LE 71	Pantnagar	11-5-2-0-1	HS 102 x AC 142	Determinate, medium fruited

Table 3.1 (Contd.)

Accession number	Source	Cultivar name	Pedigree	Important traits
LE 74	Pantnagar	-	-	-
LE 75	AVRDC, Taiwan	CL 8d-0-7-1 GS	VC 11-1-2-1B x Venus	Determinate, early bearing, heat tolerant, bacterial wilt resistant, nematode resistant
LE 78	AVRDC, Taiwan	CL 11d-0-2-2-0-3UG	VC 9-1-2-9B x Venus	Determinate, early bearing, heat tolerant, bacterial wilt resistant, nematode resistant
LE 79	AVRDC, Taiwan	CL 32d-0-1-19 GS	VC 9-1-2-3 x Venus	Indeterminate, early bearing, heat tolerant, bacterial wilt and nematode resistant
LE 82	AVRDC, Taiwan	CL 143-0-6-9 UG	VC 48-1 x Tamu Chico III	Determinate, early bearing, heat tolerant, bacterial wilt and nematode resistant
LE 84	AVRDC, Taiwan	LTGS	VC 48-1	Determinate, early bearing, heat tolerant, bacterial wilt and nematode resistant.

Table 3.1 (Contd.)

Accession number	Source	Cultivar name	Pedigree	Important traits
LE 87	N.B.P.G.R.	La Bonita	-	-
LE 88	T.N.A.U.	PKM - 1	-	-
LE 90	T.N.A.U.	Co-2	-	-
LE 93	IIHR.Bangalore	-	-	-
LE 94	Takii & Co. Ltd., Kyoho, Japan	Master No.1	-	-
LE 95	Takii & Co.Ltd., Kyoho, Japan	Hope No.1	-	-
LE 97	AVRDC, Taiwan	CL 9-0-0-1	VC 11-1-2-1 B x Venus	-
LE 98	AVRDC, Taiwan	CL 143-0-10-3	VC 48-1 x Tamu Chico III	-
LE 99	AVRDC, Taiwan	CL 123-2-4	ah TM - 2a x VC 8-1-2-1	-
LE 101	AVRDC, Taiwan	CL 1591-5-0-1-6	F 63 - 19 x CL 11-0-2-1-0-2	-
LE 105	AVRDC, Taiwan	L1	VC 48-1	-
LE 106	AVRDC, Taiwan	L 387	White skin	-
LE 107	-	Tropic	-	-

Table 3.1 (Contd.)

Accession number	Source	Cultivar name	Pedigree	Important traits
LE 108	Strocks Seed Ltd., Canada	New York Special	-	-
LE 111	Strocks Seed Ltd., Canada	Quinte	-	-
LE 114	Strocks Seed Ltd., Canada	Veepick VF 419 A	-	-
LE 117	Strocks Seed Ltd., Canada	Starshot 408	-	-
LE 118	Strocks Seed Ltd., Canada	Veepro 464 A	-	-
LE 119	Strocks Seed Ltd., Canada	Starfire	-	-
LE 121	Strocks Seed Ltd., Canada	Veeroma VF 418	-	-
LE 124	Strocks Seed Ltd., Canada	Basket Vee 326	-	-
LE 134	-	-	BWN 21 x HS 101	-
LE 158	Petro Seed Co. Inc.Calipso	-	-	-

Table 3.1 (Contd.)

Accession number	Source	Cultivar name	Pedigree	Important traits
LE 160	AVRDC, Taiwan	VC 98-1	-	-
LE 161	AVRDC, Taiwan	VC 48-1-1-2	-	-
LE 162	AVRDC, Taiwan	VC 8-1-2-1	-	-
LE 163	AVRDC, Taiwan	VC 9-1-UG	-	-
LE 164	AVRDC, Taiwan	VC 11-1 UG	-	-
LE 165	AVRDC, Taiwan	VC 2029	-	-
LE 166	AVRDC, Taiwan	VC 8-1-2-1	-	-
LE 167	AVRDC, Taiwan	VC 11-2-2-79	-	-
LE 168	AVRDC, Taiwan	(TR x VC 11-2)-2-1	-	-
LE 169	AVRDC, Taiwan	(TR x VC 48-1)-11-2	-	-
LE 170	AVRDC, Taiwan	Walter	-	-
LE 171	AVRDC, Taiwan	Florida MH	-	-
LE 172	AVRDC, Taiwan	Venus	Louisiana Pink x Beltsville 3814	Reported resistant to bacterial wilt
LE 173	AVRDC, Taiwan	Saturn	Louisiana Pink x Beltsville 3814	Reported resistant to bacterial wilt

Table 3.1 (Contd.)

Accession number	Source	Cultivar name	Pedigree	Important traits
LE 174	AVRDC, Taiwan	Galaxy	-	-
LE 175	AVRDC, Taiwan	Anahu	-	Reported resistant to nematodes
LE 176	AVRDC, Taiwan	Kewalo	-	-
LE 177	AVRDC, Taiwan	White skin	-	-
LE 178	AVRDC, Taiwan	Green Fruit	-	-
LE 179	AVRDC, Taiwan	Tropic	-	-
LE 180	AVRDC, Taiwan	Hotset	-	-
LE 181	Herbrew Univ. of Jeruselem-Israel	Hosen - Elion	-	-
LE 182	Herbrew Univ. of Jeruselem-Israel	Gamed	-	Indeterminate, oval fruited
LE 183	Holland	Mandel 502 VFNF - 1 - RS.	-	-
LE 184	Holland	Monprecos RS	-	-
LE 185	Holland	Bonset F-IRS	-	-
LE 186	Holland	Tobol (No.748) WFNF - IRS.	-	-

Table 3.1 (Contd.)

Accession number	Source	Cultivar name	Pedigree	Important traits
LE 187	Redwood City, Seed Co., California	Roma	-	Semideterminate, bushy, extrovert, deep yellow flowers, small smooth fruits, nipple tipped
LE 188	Redwood City Seed Co., California	Yellow Pear	-	-
LE 189	Redwood City Seed Co., California	Red Cherry	-	-
LE 190	Redwppd City Seed Co., California	Beefsteak	-	-
LE 191	Redwood City Seed Co., California	India River	-	-
LE 192	Redwood City Seed Co., California	Early Large Red	-	-
LE 193	NSC, New Delhi	Sioux	-	Indeterminate, large fruited
LE 194	Hissar	HS-110	-	Determinate, large fruited
LE 195	Yates Co., Australia	Red Cloud	-	-
LE 196	Yates Co., Australia	Grosse Lisse	-	-

Table 3.1 (Contd.)

Accession number	Source	Cultivar name	Pedigree	Important traits
LE 197	Yates Co., Australia	Rouge De Marmande	-	-
LE 198	Vellayani	Local	-	-
LE 199	Vellayani	Local	-	-

Table 3.2 Seedling characters

Gene	Name	Phenotype	Locus	
			Chromosome	Site
a	anthocyaninless	Completely anthocyaninless	11L	68
aw2	without anthocyanin[2]	Completely free of anthocyanin		
atv	atroviolacea	Intense anthocyanin pigmentation	7L	
dkv	dark veined leaf	seedling leaves yellow green, veins, always draker green		
Fw	Furrowed	plant stunted, cotyledons deeply furrowed		
hp-2		high pigment	11L	95
lg	light green	light green foliage colour	10S	18
lg_2	light $green_2$	cotyledons light yellow, leaves pale green		
lg_3	light $green_3$	cotyledins and leaves light green, cotyledons fade to yellow, mature plants pale green		
pg_2	pale $green_2$			
pg_3	pale $green_3$			
v	virescent	white seedlings turning to green		

L = long arm of chromosome

S = short arm of chromosome

Table 3.3 Juvenile characters

Gene	Name	Phenotype	Locus	
			Chromosome	Site
acu	accumbens	leaves and pinnae shortly stalked, leaf surface furrowed, older leaves strongly bend downwards		
aer	aerial roots	adventitious roots on the stem from soil level to considerable height above		
al	anthocyanin loser	pigmented only at nodes later	8L	67
are	authocyanin reduced	young leave of older plants pigmented	2L	58
au	aurea	bright yellow foliage	1S	32
aud	auroid	uniform yellow foliage	12S	
bi	bifurate	extreme stem fasciation	12L	97
bip	bipinnata	highly divided leaves	2L	68
br	brachytic	internodes shortened	1S	0
c	potate leaf	fewer leaf segments	6L	104
clau	clausa	leaves subdivided, segment tip acute	4S	0
cpt	compact	habit compact, exceedingly branched	8L	16
dp	drooping leaf	leaf drooping, elongate, dark, green stem weak, slender and prostrate		
e	entire	leaf segments few, mid vein distorted	4L	66
fy	field yellow	bright yellow green foliage in the field		
h	hair absent	large trichomes absent	10L	46

Table 3.3 (Contd.)

Gene	Name	Phenotype	Locus	
			Chromosome	Site
Hr	Hirsute	long hairs on adaxial leaf surface	8L	46
Hrt	Hirtum	increased density of larger trichomes	7L	
lg	light green	light green foliage colour	10S	18
ni	nitida	leaves long petioled, pinnae deeply cut	8L	45
Od	Odourless	herbage with little or no volatiles	3	
pg_2	palegreen-2			
pg_3	palegreen-3			
sf	solanifolia	pinnae entire, epiculate, concave	3L	111
tp	tripinnate	plant retarded; leaves tripinnately compound	8L	22
vi	villous	stem very hairy	10	
wd	wilty dwarf	plants stunted, leaves grey green, droop if drought stressed	9S	20
wt	wilty	leaf margins curl adaxially	5L	55
Wo	Woolly	all parts densely pubescent	2L	46
yg_2	yellow-green$_2$	foliage uniformly yellow green	12S	

Table 3.4 Adult plant characters

Gene	Name	Phenotype	Locus	
			Chromosome	Site
ap	apetalous	most or part of corolla lacking	11	114
at	apricot	fruit flesh colour	5	-
bk	beaked	fruit stylar end pointed	2L	38
bl	blind	stem terminate in first inflorescence	11 L	75
bs	brown seeds	endosperm brown	1S	17
bu	bushy	inflorescences and internodes fore-shortened	8L	18
ch	chartreuse	corolla greenish yellow	8L	28
ck	corky fruit	fruit wall splits	-	-
cl-2	cleistogamous-2	flowers open only slightly	6L	113
el	elongated fruits	-	-	-
ex	exserted	-	-	-
f	fasciated	fruits fasciated,many loculed	11L	95
f^D	fasciated	-	-	-
fl	fleshy calyx	-	-	-
Fs	Fruit stripe	broad distal stripe as in <u>Lycoperaicon</u> <u>hirsutum</u>	10S	11
g	grooved	-	-	-
gf	green fruit	chlorophyll persist in the fruit locules	8L	44
gs	green stripe	unripe fruit with radial green stripes	7S	5
hp	high pigment	fruit pigments intensified	12S	-
Ip	Intense pigmentation	dark pigmentation of the fruit both in ripe and unripe stages	-	-

Table 3.4 (Contd.)

Gene	Name	Phenotype	Locus	
			Chromosome	Site
j	jointless	pedicel jointless, inflorescence leafy	11S	28
lu	luteola	corolla light green	1	-
mc	macrocalyx	sepals and inflorescence leafy	5S	-
n	nipple tip	at stylar end of the fruit	5	-
nor	non ripening	fruit ripening greatly retarded	10S	-
Nr	Never ripe	fruit ripen slowly to dull orange	9	-
o	ovate	fruits elongate	2L	55
p	peach	fruit surface dull, more hairy	2L	67
pst	persistent style	developing into beak	7S	5
pat	parthenocarpic fruits	seedless fruits	-	-
rl	radial cracking resistance of fruits		-	-
r_2	yellow fruit flesh, lighter yellow flowers		-	-
rin	ripening inhibitor	fruits ripen very slowly to yellow	5S	0
s	Compound cluster	inflorescence strongly proliferated	2L	30
sp	selfpruning	determinate habit	6L	-
spf	superpuff	extremely puffy, hollow locals, and bell pepper shaped fruits	-	-
ss	spong seed	smooth, but spongy seed	-	-
u	uniform ripening	unripe fruits lack bicolour pigmentation	10S	14
yc	yellow calyx	when fruit ripens	-	-

RESULTS

EXPERIMENTAL RESULTS

The data collected were analysed and are presented under the following sub-heads

A Cataloguing

B Estimation of response to selection

C Evaluation for field tolerance to bacterial wilt

D Artificial inoculation for testing resistance

E Chemical analysis of resistant line

A Cataloguing

Seventyeight lines germinated and genetic cataloguing of the plants was done in the seedling stage (Table 4.1.a) and juvenile stage (Table 4.1.b). The line LE 79 was studied for adult plant characters (Table 4.1.c).

In the nursery, the seedlings were critically studied for intensity and spread of purple colour which varied greatly. The purple colour character was partitioned into five groups (Table 4.2). The lines LE 186 and LE 196 were observed completely free of anthocyanin. The line LE 79 had its hypocotyl, epicotyl, cotyledons and first leaf purple pigmented - when observation was taken 18 days after sowing.

The 78 lines were further classified into two groups - right and left - based on phyllotaxy (Table 4.3).

B. Estimation of response to selection

The line LE 79 survived the onslaught of bacterial wilt. The population was studied for nine polygenic characters - plant height, primary branches per plant, days to first fruit set, days to first harvest, fruits per plant, marketable fruits per plant, locules per fruit, marketable fruit weight per plant and total fruit weight per plant. The statistical properties of LE 79 population indicated that the population was a normal one for characters plant height, primary branches per plant, days to first fruitset, days to first fruit harvest, marketable fruits per plant and locules per fruit (Table 4.4). The averages - mean, median and mode - coincided for the above characters and thus justified the properties of normally distributed plant population.

The progenies derived from the population based on mass selection (intensity of selection 4.47%), single plant selection (pureline) and bulk selection were grown in a randomised block design with six replications. The data were analysed as per completely randomised design due to non-significance of the variation due to blocking(Table 4.5).

The progenies developed through the above three methods of selection were significantly different for plant height and days to first fruit set. No significant difference was observed among the progenies developed through the three methods of selection for primary branches per plant, days to first fruit harvest, total fruits per plant, marketable fruits per plant, locules per fruit, percentage of small fruited plants, medium fruited plants and large fruited plant, percentage of plants with no cracked fruits, medium cracked fruits and highly cracked fruits, marketable fruit weight, and total fruit weight.

Mean performances of the population selected plants and selected elite single plant and their respective progenies for 15 polygenic characters are presented in Table 4.6. The progenies derived through mass selection was superior to progenies through bulking for days to first fruit set, days to first harvest, fruits per plant, marketable fruits per plant and marketable fruit weight per plant. The progenies developed through pureline selection were superior to those developed through bulking for days to fruit set, days to first harvest, marketable fruit weight per plant, percentage of large fruited plants and percentage of plants with cracked fruits. The bulk progenies were superior to those developed by mass and pureline selection for higher locules per fruit, total percentage of medium fruited plants and total fruit weight.

The values of selection differential (S), selection response (R) and realised heritability (h^2) for 10 polygenic characters are presented in Table 4.7. The selection response through mass selection was positive for primary branches per plant and locules per fruit. The selection response through pureline selection was positive for primary branches per plant and locules per fruit. Selection response through bulk was positive for plant height and primary branches per plant. The realised heritability was very high (0.88) for days to first harvest indicating thereby the scope of going for selection to develop still earlier lines. The selection responses were obviously negative through bulk (-25.99), mass (-13.31) and pureline (-20.45) selection for days to first harvest.

C. Evaluation for field tolerance to bacterial wilt

Six independent trials were conducted to evaluate resistance of the line under field conditions (Table 4.8). Wilting, where ooze test was positive, was more in juvenile stage as compared to one observed in adult stage.

Percentage of plants wilted ranged from 1.11 per cent during February-May 1981 to 46.91 per cent in September-December 1980 observed during juvenile stage. Percentage wilting ranged from zero during September-December 1980 and February-May 1981 to 1.34 during April-August 1980 in the adult plant stage.

D Artificial inoculation for testing resistance

1. Screening using infected soil as potting mixture

Out of 30 seedlings of LE 79 transplanted in pots where the soil was taken from the diseased field, no seedlings wilted.

2. Screening for wilt resistance through artificial inoculation

All the ten plants of LE 79 wilted within one week after inoculation along with the susceptible line.

E Chemical analysis of the resistant line

The fruits of LE 79 collected from progenies developed through bulking, mass selection and pureline selection were analysed for total soluble solids, ascorbic acid and pH. Total soluble solid content as read by Brix ranged from 3 to 6 with an average of five in progeny developed through mass selection and ranged from 4 to 5 in progeny developed through pureline selection. Ascorbic acid content ranged from 16.45 to 29.61 mg/100 g in progeny developed through bulking, 18.06 to 40.20 mg/100g in progeny developed through mass selection and 18.38 to 33.03 mg/100 g in progeny developed through pureline selection. The pH of the fruits ranged from 5.8 to 6.0.

Table 4.1.a Seedling characters

LE 5	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+-, lg_3^+-, pg_2^+-, pg_3^+-, v^+-
LE 18	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+-, lg_3^+-, pg_2^+-, pg_3^+-, v^+-
LE 23	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+-, lg_3^+-, pg_2^+-, pg_3^+-, v^+-
LE 34	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+-, lg_3^+-, pg_2^+-, pg_3^+-, v^+-
LE 40	a^+-, atg^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+-, lg_3^+-, pg_2^+-, pg_3^+-, v^+-
LE 44	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+-, lg_3^+-, pg_2^+-, pg_3^+-, v^+-
LE 47	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+-, lg_3^+-, pg_2^+-, pg_3^+-, v^+-
LE 69	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+-, lg_3^+-, pg_2^+-, pg_3^+-, v^+-
LE 71	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+-, lg_3^+-, pg_2^+-, pg_3^+-, v^+-
LE 74	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+-, lg_3^+-, pg_2^+-, pg_3^+-, v^+-

Table 4.1.a (Contd.)

LE 75	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 78	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 79	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 82	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 84	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 87	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 88	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 90	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 93	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 94	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-

Table 4.1.a (Contd.)

LE 95	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 97	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 98	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 99	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 101	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 105	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 106	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 107	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+ -
LE 108	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+ -
LE 111	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+ -

Table 4.1.a (Contd.)

LE 114	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+ -
LE 117	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 118	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 119	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 121	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 124	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 134	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 158	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 160	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 161	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 162	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-

Table 4.1.a (Contd.)

LE 163	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 164	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 165	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 166	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 167	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 168	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 169	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 170	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 171	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 172	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-

Table 4.1.a (Contd.)

LE 173	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 174	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 175	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 176	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 177	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 178	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 179	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 180	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 181	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 182	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, $hp\text{-}2^+$-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-

Table 4.1.a (Contd.)

LE 183	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 184	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 185	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 186	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 187	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 188	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 189	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 190	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 191	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 192	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-

Table 4.1.a (Contd.)

LE 193	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 194	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 195	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 196	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 197	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 198	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-
LE 199	a^+-, atv^+-, aw^{2+}-, dkv^+-, Fw^+-, hp-2^+-, lg^+-, lg_2^+ -, lg_3^+ -, pg_2^+ -, pg_3^+ -, v^+-

Table 4.1.b Juvenile characters*

LE 5	acu$^+$-, aer$^+$-, al$^+$-, are$^+$-, au$^+$-, aud$^+$-, bi$^+$-, bip$^+$-, br$^+$-, c$^+$-, clau$^+$-, cpt$^+$-, dkv$^+$-, dp$^+$-, e$^+$-, fy$^+$-, h$^+$-, Hr$^+$-, Hrt$^+$-, lg$^+$-, ni$^+$-, Od$^+$-, pg$_2^+$ -, pg$_3^+$-, sf$^+$-, tp$^+$-, vi$^+$-, wd$^+$-, wt$^+$-, Wo$^+$-, yg$_2^+$ -
LE 18	acu$^+$-, aer$^+$-, al$^+$-, are$^+$-, au$^+$-, aud$^+$-, bi$^+$-, bip$^+$-, br$^+$-, c$^+$-, clau$^+$-, cpt$^+$-, dkv$^+$-, dp$^+$-, e$^+$-, fy$^+$-, h$^+$-, Hr$^+$-, Hrt$^+$-, lg$^+$-, bi$^+$-, Od$^+$-, pg$_2^+$ -, pg$_3^+$ -, sf$^+$-, tp$^+$-, vi$^+$-, wd$^+$-, wt$^+$-, Wo$^+$-, yg$_2^+$ -
LE 23	acu$^+$-, aer$^+$-, al$^+$-, are$^+$-, au$^+$-, aud$^+$-, bi$^+$-, bip bip, br$^+$-, c$^+$-, clau clau, cpt$^+$-, dkv$^+$-, dp$^+$-, e$^+$-, fy$^+$-, h$^+$-, Hr$^+$-, Hrt$^+$-, lg$^+$-, ni$^+$-, Od$^+$-, pg$_2^+$ -, pg$_3^+$ -, sf$^+$-, tp$^+$-, vi$^+$-, wd$^+$-, wt$^+$-, Wo$^+$-, yg$_2^+$ -
LE 34	acu$^+$-, aer$^+$-, al$^+$-, are$^+$-, au$^+$-, aud$^+$-, bi$^+$-, bip$^+$-, br$^+$-, c$^+$-, clau$^+$-, cpt$^+$-, dkv$^+$-, dp$^+$-, e$^+$-, fy$^+$-, h$^+$-, Hr$^+$-, Hrt$^+$-, lg$^+$-, ni$^+$-, Od$^+$-, pg$_2^+$ -, pg$_3^+$ -, sf$^+$-, tp$^+$-, vi$^+$-, wd$^+$-, wt$^+$-, Wo$^+$-, yg$_2^+$ -

* Observations were not recorded for the lines wilted very early.

Table 4.1.b (Contd.)

LE 40	acu$^+$-, aer$^+$-, al$^+$-, are$^+$-, au$^+$-, aud$^+$-, bi$^+$-, bip$^+$-, br$^+$-, c$^+$-, clau$^+$-, cpt$^+$-, dkv$^+$-, dp$^+$-, e$^+$-, fy$^+$-, h$^+$-, Hr$^+$-, Hrt$^+$-, lg$^+$-, ni$^+$-, Od$^+$-, pg$_2^+$ -, pg$_3^+$-, sf$^+$-, tp$^+$-, vi$^+$-, wd$^+$-, wt$^+$-, Wo$^+$-, yg$_2^+$ -
LE 44	acu$^+$-, aer$^+$-, al$^+$-, are$^+$-, au$^+$-, aud$^+$-, bi$^+$-, bip$^+$-, br$^+$-, c$^+$-, clau$^+$-, cpt$^+$-, dkv$^+$-, dp$^+$-, e$^+$-, fy$^+$-, h$^+$-, Hr$^+$-, Hrt$^+$-, lg$^+$-, ni$^+$-, Od$^+$-, pg$_2^+$ -, pg$_3^+$ -, sf$^+$-, tp$^+$-, vi$^+$-, wd$^+$-, wt$^+$-, Wo$^+$-, yg$_2^+$ -
LE 47	acu$^+$-, aer$^+$-, al$^+$-, are$^+$-, au$^+$-, aud$^+$-, bi$^+$-, bip$^+$-, br$^+$-, c$^+$-, clau$^+$-, cpt$^+$-, dkv$^+$-, dp$^+$-, e$^+$-, fy$^+$-, h$^+$-, Hr$^+$-, Hrt$^+$-, lg$^+$-, ni$^+$-, Od$^+$-, pg$_2^+$ -, pg$_3^+$ -, sf$^+$-, tp$^+$-, vi$^+$-, wd$^+$-, wt$^+$-, Wo$^+$-, yg$_2^+$ -
LE 74	acu$^+$-, aer aer, al$^+$-, are are, au$^+$-, aud$^+$-, bi$^+$-, bip$^+$-, br$^+$-, c$^+$-, clau$^+$-, dkv$^+$-, dp$^+$-, e$^+$-, fy$^+$-, h$^+$-, Hr$^+$-, Hrt$^+$-, lg$^+$-, ni$^+$-, Od$^+$-, pg$_2^+$ -, pg$_3^+$ -, sf$^+$-, tp$^+$-, vi$^+$-, wd$^+$-, wt$^+$-, Wo$^+$-, yg$_2^+$ -

Table 4.1.b (Contd.)

LE 75	acu^+-, aer^+-, al^+-, are^+-, au^+-, aud^+-, bi^+-, bip^+-, br^+-, c^+-, $clau^+-$, cpt^+-, dkv^+-, dp^+-, e^+-, fy^+-, h^+-, Hr^+-, Hrt^+-, lg^+-, ni^+-, Od^+-, $pg_2^+ -$, $pg_3^+ -$, sf^+-, tp^+-, vi^+-, wd^+-, wt^+-, Wo^+-, $yg_2^+ -$
LE 78	acu^+-, aer^+-, al^+-, are^+-, au^+-, aud^+-, bi^+-, bip^+-, br^+-, c^+-, $clau^+-$, cpt^+-, dkv^+-, dp^+-, e^+-, fy^+-, h^+-, Hr^+-, Hrt^+-, lg^+-, ni^+-, Od^+-, $pg_2^+ -$, $pg_3^+ -$, sf^+-, tp^+-, vi^+-, wd^+-, wt^+-, Wo^+-, $yg_2^+ -$
LE 79	acu^+-, aer aer, al^+-, au^+-, aud^+-, bi^+-, bip^+-, br^+-, c^+-, $clau^+-$, cpt^+-, dkv^+-, dp^+-, e^+-, fy^+-, h^+-, Hr^+-, Hrt^+-, lg^+-, ni^+-, Od^+-, $pg_2^+ -$, $pg_3^+ -$, sf^+-, tp^+-, vi^+-, wd^+-, wt^+-, Wo^+-, $yg_2^+ -$
LE 82	acu^+-, aer^+-, al^+-, are^+-, au^+-, aud^+-, bi^+-, bip^+-, br^+-, c^+-, $clau^+-$, cpt^+-, dkv^+-, dp^+-, e^+-, fy^+-, h^+-, Hr^+-, Hrt^+-, lg^+-, ni^+-, Od^+-, $pg_2^+ -$, $pg_3^+ -$, sf^+-, tp^+-, vi^+-, wd^+-, wt^+-, Wo^+-, $yg_2^+ -$

Table 4.1.b (Contd.)

LE 84	acu^{+}-, aer^{+}-, al^{+}-, are^{+}-, au^{+}-, aud^{+}-, bi^{+}-, bip^{+}-, br^{+}-, c^{+}-, clau^{+}-, cpt^{+}-, dkv^{+}-, dp^{+}-, e^{+}-, fy^{+}-, h^{+}-, Hr^{+}-, Hrt^{+}-, lg^{+}-, ni^{+}-, Od^{+}-, pg$_2^{+}$ -, pg$_3^{+}$ -, sf^{+}-, tp^{+}-, vi^{+}-, wd^{+}-, wt^{+}-, Wo^{+}-, yg$_2^{+}$ -
LE 87	acu^{+}-, aer^{+}-, al^{+}-, are^{+}-, au^{+}-, aud^{+}-, bi^{+}-, bip^{+}-, br^{+}-, c^{+}-, clau^{+}-, cpt^{+}-, dkv^{+}-, dp^{+}-, e^{+}-, fy^{+}-, h^{+}-, Hr^{+}-, Hrt^{+}-, lg^{+}-, ni^{+}-, Od^{+}-, pg$_2^{+}$ -, pg$_3^{+}$ -, sf^{+}-, tp^{+}-, vi^{+}-, wd^{+}-, wt^{+}-, Wo^{+}-, yg$_2^{+}$ -
LE 88	acu^{+}-, aer^{+}-, al^{+}-, are^{+}-, au^{+}-, aud^{+}-, bi^{+}-, bip^{+}-, br^{+}-, c^{+}-, clau^{+}-, cpt^{+}-, dkv^{+}-, dp^{+}-, e^{+}-, fy^{+}-, h^{+}-, Hr^{+}-, Hrt^{+}-, lg^{+}-, ni^{+}-, Od^{+}-, pg$_2^{+}$ -, pg$_3^{+}$ -, sf^{+}-, tp^{+}-, vi^{+}-, wd^{+}-, wt^{+}-, Wo^{+}-, yg$_2^{+}$ -
LE 90	acu^{+}-, aer^{+}-, al^{+}-, are^{+}-, au^{+}-, aud^{+}-, bi^{+}-, bip^{+}-, br^{+}-, c^{+}-, clau^{+}-, cpt^{+}-, dkv^{+}-, dp^{+}-, e^{+}-, fy*-, h^{+}-, Hr^{+}-, Hrt^{+}-, lg^{+}-, ni^{+}-, Od^{+}-, pg$_2^{+}$ -, pg$_3^{+}$ -, sf^{+}-, tp^{+} -, vi^{+} -, wd^{+}-, wt^{+}-, Wo^{+}-, yg$_2^{+}$ -

Table 4.1.b (Contd.)

LE 93	acu^+-, aer aer, al^+-, au^+-, aud^+-, bi^+-, bip^+-, br^+-, c^+-, $clau^+$-, cpt^+-, dkv^+-, dp^+-, e^+-, fy^+-, h^+-, Hr^+-, Hrt^+-, lg^+-, ni^+-, Od^+-, pg_2^+ -, pg_3^+ -, sf^+-, tp^+-, vi^+-, wd^+-, wt^+-, Wo^+-, yg_2^+ -
LE 94	acu^+-, aer^+-, al^+-, are^+-, au^+-, aud^+-, bi^+- bip^+-, br^+-, c^+-, $clau^+$-, cpt^+-, dkv^+-, dp^+-, e^+-, fy^+-, h^+-, Hr^+-, Hrt^+-, lg^+-, ni^+-, Od^+-, pg_2^+ -, pg_3^+ -, sf^+-, tp^+-, vi^+-, wd^+-, wt^+-, Wo^+-, yg_2^+ -
LE 95	acu^+-, aer^+-, al^+-, are^+-, au^+-, aud^+-, bi^+-, bip^+-, br^+-, c^+-, $clau^+$-, cpt^+-, dkv^+-, dp^+-, e^+-, fy^+-, h^+-, Hr^+-, Hrt^+-, lg^+-, ni^+-, Od^+-, pg_2^+ -, pg_3^+ -, sf^+-, tp^+-, vi^+-, wd^+-, wt^+-, Wo^+-, yg_2^+ -
LE 97	acu^+-, aer^+-, al^+-, are^+-, au^+-, aud^+-, bi^+-, bip^+-, br^+-, c^+-, $clau^+$-, cpt^+-, dkv^+-, dp^+-, e^+-, fy^+-, h^+-, Hr^+-, Hrt^+-, lg^+-, ni^+-, Od^+-, pg_2^+ -, pg_3^+ -, sf^+-, tp^+-, vi^+-, wd^+-, wt^+-, Wo^+-, yg_2^+ -

Table 4.1.b (Contd.)

LE 98	$acu^{+}-$, aer aer, $al^{+}-$, $au^{+}-$, $aud^{+}-$, $bi^{+}-$, $bip^{+}-$, $br^{+}-$, $c^{+}-$, $clau^{+}-$, $cpt^{+}-$, $dkv^{+}-$, $dp^{+}-$, $e^{+}-$, $fy^{+}-$, $h^{+}-$, $Hr^{+}-$, $Hrt^{+}-$, $lg^{+}-$, $ni^{+}-$, $Od^{+}-$, $pg_2^{+}-$, $pg_3^{+}-$, $sf^{+}-$, $tp^{+}-$, $vi^{+}-$, $wd^{+}-$, $wt^{+}-$, $Wo^{+}-$, $yg_2^{+}-$
LE 99	$acu^{+}-$, $aer^{+}-$, $al^{+}-$, $are^{+}-$, $au^{+}-$, $aud^{+}-$, $bi^{+}-$, $bip^{+}-$, $br^{+}-$, $c^{+}-$, $clau^{+}-$, $cpt^{+}-$, $dkv^{+}-$, $dp^{+}-$, $e^{+}-$, $fy^{+}-$, $h^{+}-$, $Hr^{+}-$, $Hrt^{+}-$, $lg^{+}-$, $ni^{+}-$, $Od^{+}-$, $pg_2^{+}-$, $pg_3^{+}-$, $sf^{+}-$, $tp^{+}-$, $vi^{+}-$, $wd^{+}-$, $wt^{+}-$, $Wo^{+}-$, $yg_2^{+}-$
LE 101	$acu^{+}-$, $aer^{+}-$, $al^{+}-$, $are^{+}-$, $au^{+}-$, $aud^{+}-$, $bi^{+}-$, $bip^{+}-$, $br^{+}-$, $c^{+}-$, $clau^{+}-$, $cpt^{+}-$, $dkv^{+}-$, $dp^{+}-$, $e^{+}-$, $fy^{+}-$, $h^{+}-$, $Hr^{+}-$, $Hrt^{+}-$, $lg^{+}-$, $ni^{+}-$, $Od^{+}-$, $pg_2^{+}-$, $pg_3^{+}-$, $sf^{+}-$, $tp^{+}-$, $vi^{+}-$, $wd^{+}-$, $wt^{+}-$, $Wo^{+}-$, $yg_2^{+}-$
LE 105	$acu^{+}-$, $aer^{+}-$, $al^{+}-$, $are^{+}-$, $au^{+}-$, $aud^{+}-$, $bi^{+}-$, $bip^{+}-$, $br^{+}-$, $c^{+}-$, $clau^{+}-$, $cpt^{+}-$, $dkv^{+}-$, $dp^{+}-$, $e^{+}-$, $fy^{+}-$, $h^{+}-$, $Hr^{+}-$, $Hrt^{+}-$, $lg^{+}-$, $ni^{+}-$, $Od^{+}-$, $pg_2^{+}-$, $pg_3^{+}-$, $sf^{+}-$, $tp^{+}-$, $vi^{+}-$, $wd^{+}-$, $wt^{+}-$, $Wo^{+}-$, $yg_2^{+}-$

Table 4.1. b (Contd.)

LE 106	acu^{+}-, aer^{+}-, al^{+}-, are^{+}-, au^{+}-, aud^{+}-, bi^{+}-, bip^{+}-, br^{+}-, c^{+}-, $clau^{+}$-, cpt^{+}-, dkv^{+}-, dp^{+}-, e^{+}-, fy^{+}-, h^{+}-, Hr^{+}-, Hrt^{+}-, lg^{+}-, ni^{+}-, Od^{+}-, pg_2^{+} -, pg_3^{+} -, sf^{+}-, tp^{+}-, vi^{+}-, wd^{+}-, wt^{+}-, Wo^{+}-, yg_2^{+} -
LE 107	acu^{+}-, aer^{+}-, al^{+}-, are^{+}-, au^{+}-, aud^{+}-, bi^{+}-, bip^{+}-, br^{+}-, c^{+}-, $clau^{+}$-, cpt^{+}-, dkv^{+}-, dp^{+}-, e^{+}-, fy^{+}-, h^{*}-, Hr^{+}-, Hrt^{+}-, lg^{+}-, ni^{+}-, Od^{+}-, pg_2^{+} -, pg_3^{+} -, sf^{+}-, tp^{+}-, vi^{+}-, wd^{+}-, wt^{+}-, Wo^{+}-, yg_2^{+} -
LE 108	acu^{+}-, aer^{+}-, al^{+}-, are^{+}-, au^{+}-, aud^{+}-, bi^{+}-, bip^{+}-, br^{+}-, c^{+}-, $clau^{+}$-, cpt^{+}-, dkv^{+}-, dp^{+}-, e^{+}-, fy^{+}-, h^{+}-, Hr^{+}-, Hrt^{+}-, lg^{+}-, ni^{+}-, Od^{+}-, pg_2^{+} -, pg_3^{+} -, sf^{+}-, tp^{+}-, vi^{+}-, wd^{+}-, wt^{+}-, Wo^{+}-, yg_2^{+} -
LE 121	acu^{+}-, aer^{+}-, al^{+}-, are^{+}-, au^{+}-, aud^{+}-, bi^{+}-, bip^{+}-, br br, c c, $clau^{+}$-, cpt^{+}-, dkv^{+}-, dp^{+}-, e e, fy^{+}-, h h, Hr^{+}-, Hrt^{+}-, lg^{+}-, ni^{+}-, Od^{+}-, pg_2^{+} -, pg_3^{+} - sf sf, tp^{+}-, vi^{+}-, wd^{+}-, wt^{+}-, Wo^{+}-, yg_2^{+} -

Table 4.1. b (contd.)

LE 160	acu^{+}-, aer aer, al^{+}-, au^{+}-, aud^{+}-, bi^{+}-, bip^{+}-, br^{+}-, c^{+}-, clau^{+}-, cpt^{+}-, dkv^{+}-, dp^{+}-, e^{+}-, fy^{+}-, h^{+}-, Hr^{+}-, Hrt^{+}-, lg^{+}-, ni^{+}-, Od^{+}-, pg$_{2}^{+}$ -, pg$_{3}^{+}$ -, sf^{+}-, tp^{+}-, vi^{+}-, wd^{+}-, wt^{+}-, Wo^{+}-, yg$_{2}^{+}$ -
LE 161	acu^{+}-, aer^{+}-, al^{+}-, are^{+}-, au^{+}-, aud^{+}-, bi^{+}-, bip^{+}-, br^{+}-, c^{+}-, clau^{+}-, cpt^{+}-, dkv^{+}-, dp^{+} -, e^{+}-, fy^{+}-, h^{+}-, Hr^{+}-, Hrt^{+}-, lg^{+}-, ni^{+}-, Od^{+}-, pg$_{2}^{+}$ -, pg$_{3}^{+}$ -, sf^{+}-, tp^{+}-, vi^{+}-, wd^{+}-, wt^{+}-, Wo^{+}-, yg$_{2}^{+}$ -
LE 162	acu^{+}-, aer^{+}-, al^{+}-, are^{+}-, au^{+}-, aud^{+}-, bi^{+}-, bip^{+}-, br^{+}-, c^{+}-, clau^{+}-, cpt^{+}-, dkv^{+}-, dp^{+}-, e^{+}-, fy^{+}-, h^{+}-, Hr^{+}-, Hrt^{+}-, lg^{+}-, ni^{+}-, Od^{+}-, pg$_{2}^{+}$ -, pg$_{3}^{+}$ -, sf^{+}-, tp^{+}-, vi^{+}-, wd^{+}-, wt^{+}-, Wo^{+}-, yg$_{2}^{+}$ -
LE 163	acu^{+}-, aer^{+}-, al^{+}-, are^{+}-, au^{+}-, aud^{+}-, bi^{+}-, bip^{+}-, br^{+}-, c^{+}-, clau^{+}-, cpt^{+}-, dp^{+}-, dkv^{+}-, e^{+}-, fy^{+}-, h^{+}-, Hr^{+}-, lg^{+}-, ni ni, Od^{+}-, pg$_{2}^{+}$ -, pg$_{3}^{+}$ -, sf^{+}-, tp^{+}-, vi^{+}-, wd^{+}-, wt $^{+}$-, Wo^{+}-, yg$_{2}^{+}$ -

Table 4.1.b (Contd.)

LE 164	acu$^+$-, aer aer, al$^+$-, au$^+$-, aud$^+$-, bi$^+$-, bip$^+$-, br$^+$-, c$^+$-, clau$^+$-, cpt$^+$-, dkv$^+$-, dp$^+$-, e$^+$-, fy$^+$-, h$^+$-, Hr$^+$-, Hrt$^+$-, lg$^+$-, ni$^+$-, Od$^+$-, pg_2^+ -, pg_3^+ -, sf$^+$-, tp$^+$-, vi$^+$-, wd$^+$-, wt$^+$-, Wo$^+$-, yg_2^+ -
LE 165	acu$^+$-, aer$^+$-, al$^+$-, are$^+$-, au$^+$-, aud$^+$-, bi$^+$-, bip$^+$-, br$^+$-, c$^+$-, clau$^+$-, cpt$^+$-, dkv$^+$-, dp$^+$-, e$^+$-, fy$^+$-, h$^+$-, Hr$^+$-, Hrt$^+$-, lg$^+$-, ni$^+$-, Od$^+$-, pg_2^+ -, pg_3^+ -, sf$^+$-, tp$^+$-, vi$^+$-, wd$^+$-, wt$^+$-, Wo$^+$-, yg_2^+ -
LE 166	acu$^+$-, aer$^+$-, al$^+$-, are$^+$-, au$^+$-, aud$^+$-, bi$^+$-, bip$^+$-, br$^+$-, c$^+$-, clau$^+$-, cpt$^+$-, dkv$^+$-, dp$^+$-, e$^+$-, fy$^+$-, h$^+$-, Hr$^+$-, Hrt$^+$-, lg$^+$-, ni$^+$-, Od$^+$-, pg_2^+ -, pg_3^+ -, sf$^+$-, tp$^+$-, vi$^+$-, wd$^+$-, wt$^+$-, Wo$^+$-, yg_2^+ -
LE 167	acu$^+$-, aer$^+$-, al$^+$-, are$^+$-, au$^+$-, aud$^+$-, bi$^+$-, bip$^+$-, br$^+$-, c$^+$-, clau$^+$-, cpt$^+$-, dkv$^+$-, dp$^+$-, e$^+$-, fy$^+$-, h$^+$-, Hr$^+$-, Hrt$^+$-, lg$^+$-, ni$^+$-, Od$^+$-, pg_2^+ -, pg_3^+ -, sf$^+$-, tp$^+$-, vi$^+$-, wd$^+$-, wt$^+$-, Wo$^+$-, yg_2^+ -

Table 4.1.b (Contd.)

LE 168	acu^+-, aer^+-, al^+-, are^+-, au^+-, aud^+-, bi^+-, bip^+-, br^+-, c^+-, $clau^+-$, cpt^+-, dkv^+-, dp^+-, e^+-, fy^+-, h^+-, Hr^+-, Hrt^+-, lg^+-, ni^+-, Od^+-, $pg_2^+ -$, $pg_3^+ -$, sf^+-, tp^+-, vi^+-, wd^+-, wt^+-, Wo^+-, $yg_2^+ -$
LE 170	acu^+-, aer^+-, al^+-, are^+-, au^+-, aud^+-, bi^+-, bip^+-, br^+-, c^+-, $clau^+-$, cpt^+-, dkv^+-, dp^+-, e^+-, fy^+-, h^+-, Hr^+-, Hrt^+-, lg^+-, ni^+-, Od^+-, $pg_2^+ -$, $pg_3^+ -$, sf^+-, tp^+-, vi^+-, wd^+-, wt^+-, Wo^+-, $yg_2^+ -$
LE 182	acu^+-, aer^+-, al^+-, are^+-, au^+-, aud^+-, bi^+-, bip^+-, br^+-, c^+-, $clau^+-$, cpt^+-, dkv^+-, dp^+-, e^+-, fy^+-, h^+-, Hr^+-, Hrt^+-, lg^+-, ni^+-, Od^+-, $pg_2^+ -$, $pg_3^+ -$, sf^+-, tp^+-, vi^+-, wd^+-, wt^+-, Wo^+-, $yg_2^+ -$
LE 184	acu^+-, aer^+-, al^+-, are^+-, au^+-, aud^+-, bi^+-, bip^+-, br^+-, c^+-,$clau^+-$, cpt^+-, dkv^+-, dp^+-, e^+-, fy^+-, h^+-, Hr^+-, Hrt^+-, lg^+-, ni^+-, Od^+-, $pg_2^+ -$, $pg_3^+ -$, sf^+-, tp^+-, vi^+-, wd^+-, wt^+-, Wo^+-, $yg_2^+ -$

Table 4.1.b (Contd.)

LE 186	acu^+-, aer aer, al^+-, au^+-, aud^+-, bi^+-, bip^+-, br^+-, c^+-, $clau^+-$, cpt^+-, dkv^+-, dp^+-, e^+-, fy^+-, h^+-, Hr^+-, Hrt^+-, lg^+-, ni^+-, Od^+-, pg_2^+-, pg_3^+-, sf^+-, tp^+-, vi^+-, wd^+-, wt^+-, Wo^+-, yg_2^+-

Table 4.1.c Adult plant characters

LE 79	ap$^+$-, at$^+$-, bk$^+$-, bl$^+$-, bs$^+$-, bu$^+$-, ch$^+$-, ck ck, cl-2$^+$-, el$^+$-, ex ex, f$^+$-, f^{D+}-, fl$^+$-, Fs$^+$-, g$^+$-, gf$^+$-, gs$^+$-, hp$^+$-, Ip$^+$-, j$^+$-, lu lu, mc$^+$-, n$^+$-, nor$^+$-, Nr$^+$-, o$^+$-, p$^+$-, pst$^+$-, pat$^+$-, rl$^+$-, r_2^+ -, rin$^+$-, s$^+$-, sp$^+$-, spf$^+$-, ss$^+$-, u$^+$-, ye$^+$-

Table 4.2 Classification of tomato lines based on intensity and spread of anthocyanin pigment in seedling stage

Classes*				
1	2	3	4	5
LE 186	LE 69	LE 34	LE 5	LE 23
LE 196	LE 95	LE 40	LE 18	LE 78
	LE 107	LE 44	LE 71	LE 79
	LE 119	LE 47	LE 74	LE 165
	LE 160	LE 82	LE 75	LE 174
	LE 185	LE 93	LE 84	LE 175
	LE 193	LE 97	LE 87	LE 177
	LE 194	LE 101	LE 88	LE 178
	LE 199	LE 106	LE 90	LE 180
		LE 118	LE 94	
		LE 164	LE 98	
		LE 166	LE 99	
		LE 167	LE 105	
		LE 172	LE 108	

* 1 Seedlings completely free of anthocyanin
2 Seedlings with upper part of the hypocotyl region free of anthocyanin
3 Seedlings with full hypocotyl region with anthocyanin
4 Seedlings with hypocotyl and epicotyl region with anthocyanin
5 Seedlings with hypocotyl, epicotyl, cotyledons and first leaf with anthocyanin

Table 4.2 (Contd.)

Classes				
1	2	3	4	5
		LE 179	LE 114	
		LE 181	LE 117	
		LE 183	LE 111	
		LE 184	LE 121	
		LE 188	LE 124	
		LE 189	LE 158	
		LE 190	LE 161	
		LE 192	LE 162	
		LE 195	LE 163	
		LE 197	LE 168	
		LE 198	LE 169	
			LE 170	
			LE 171	
			LE 173	
			LE 176	
			LE 182	
			LE 185	
			LE 187	
			LE 191	

Table 4.3 Classification of tomato seedlings based on phyllotaxy

Classes	
Left	Right
LE 18	LE 5
LE 23	LE 44
LE 34	LE 47
LE 40	LE 69
LE 71	LE 74
LE 75	LE 79
LE 78	LE 84
LE 82	LE 90
LE 87	LE 93
LE 88	LE 97
LE 94	LE 99
LE 95	LE 101
LE 98	LE 105
LE 106	LE 107
LE 111	LE 108
LE 121	LE 114
LE 124	LE 117
LE 158	LE 118
LE 162	LE 119
LE 163	LE 160
LE 165	LE 161
LE 166	LE 164
LE 167	LE 168
LE 169	LE 170
LE 173	LE 171
LE 174	LE 172
LE 176	LE 175
LE 177	LE 178
LE 179	LE 180
LE 182	LE 181
LE 183	LE 185
LE 184	LE 186
LE 188	LE 187
LE 189	LE 188
LE 191	LE 190
LE 192	LE 195
LE 193	LE 196
LEE 194	LE 197
LE 199	LE 198

Table 4.4 Statistical properties of the base population of LE 79

Characters	Range	Mean	Median	Mode	Standard deviation	Coefficient of variation
Plant height (cm)	50-125	70.74 ± 2.23	71	71	17.00	24.04
Primary branches per plant	1-8	3.97 ± 0.19	4	4	1.43	35.96
Days to first fruit set	34-82	58.82 ± 1.43	58	50	11.52	19.58
Days to first fruit harvest	66-113	94.36 ± 1.53	94	94	10.94	11.59
Fruits per plant	2-53	17.02 ± 2.07	14	3	14.37	84.43
Marketable fruits per plant	1-48	14.25 ± 1.86	9	7	12.88	90.43
Locules per fruit	2-6	3.69 ± 0.10	4	4	0.69	18.71
Marketable fruit weight per plant (g)	39-1541	517.79 ± 58.52	440	79	405.43	78.30
Total fruit weight per plant (g)	39-1485	445.53 ± 54.58	351	-	378.13	84.87

Table 4.5 General analysis of variance

Sources of variation	df	Mean squares: Plant height (cm)	Primary branches per plant	Days to first fruit set	Days to first fruit harvest	Total fruits per plant	Market-able fruits per plant	Locules per fruit	Small fruited plants (%)
Methods of selection	2	223.18*	0.29	23.35*	13.10	52.77	23.46	0.08	345.23
Error	12	49.59	0.25	2.19	6.40	18.64	17.21	0.03	92.70

Sources of variation	df	Mean squares: Medium fruited plants (%)	Large fruited plants (%)	Plants with no cracked fruits (%)	Plants with medium cracked fruits (%)	Plants with highly cracked fruits (%)	Marketa-ble fruit weight per plant (g)	Total fruit weight per plant (g)
Methods of selection	2	19.49	214.77	0.86	38.71	609.79	4438.91	1719.88
Error	12	96.74	131.60	52.25	72.41	181.07	31495.78	34140.21

* P = 0.05

Table 4.6 Mean performance of base population, selected plants, single plant and their respective progenies

Characters	Mean			CD (P=0.05)
	Bulk	Mass	Pureline	
Plant height (cm)	72.00 (70.74)	62.48 (73.00)	59.12 (74.00)	9.70
Primary branches per plant	4.46 (3.97)	4.68 (4.67)	4.20 (4.00)	-
Days to first fruit set	37.20 (58.86)	36.10 (48.00)	33.60 (56.00)	2.04
Days to first fruit harvest	68.37 (94.36)	65.99 (76.00)	66.55 (87.00)	-
Fruits per plant	16.32 (17.02)	19.51 (44.00)	12.99 (53.00)	-
Marketable fruits per plant	13.01 (14.25)	15.98 (39.67)	11.77 (48.00)	-
Locules per fruit	3.65 (3.69)	3.63 (3.33)	3.42 (3.00)	-
Small fruited plants[1] (%)	8.35 (12.50)	22.73 (0.00)	5.00 (0.00)	-
Medium fruited plants[2] (%)	74.94 (68.75)	73.15 (100.00)	71.00 (100.00)	-
Large fruits plants[3] (%)	16.90 (18.75)	4.27 (0.00)	24.00 (0.00)	-

Data in parentheses indicate the mean performance of population, selected plants and single plant

1 Plants with average fruit weight less than 20 g

2 Plants with average fruit weight of 20 - 40 g

3 Plants with average fruit weight more than 40 g

Table 4.6 (Contd.)

Characters	Mean			CD (P = 0.05)
	Bulk	Mass	Pureline	
Plants without cracked fruits[4] (%)	43.45 (50.00)	43.85 (33.33)	43.85 (0.00)	-
Plants with medium cracked fruits[5] (%)	34.39 (29.17)	35.49 (66.67)	37.58 (100.00)	-
Plants with highly cracked fruits[6] (%)	28.73 (20.83)	27.06 (0.00)	22.14 (0.00)	
Marketable fruit weight per plant (g)	375.51 (445.54)	391.87 (1156.67)	433.50 (1118.00	-
Total fruit weight per plant (g)	507.00 (517.79)	485.27 (1296.33)	470.10 (1325.00)	

4 Plants with zero per cent cracked fruits

5 Plants with >0 - 25 per cent cracked fruits

6 Plants with more than 25 per cent cracked fruits

Table 4.7 Values of selection differential (S), selection response (R) and realised heritability (h2)

Characters		S	R	h^{2*}
Plant height (cm)	B		1.26	
	M	2.26	-10.52	-
	P	3.26	-14.88	-
CD (P = 0.05)			9.70	
Primary branches per plant	B		0.50	
	M	0.70	0.01	0.10
	P	0.04	0.36	
CD (P = 0.05)			-	
Days to first fruit set	B		-21.60	
	M	-10.80	-11.90	-
	P	- 2.80	-22.40	-
CD (P = 0.05)			2.49	
Days to first fruit harvest	B		-25.99	
	M	-15.05	-13.99	0.88
	P	- 7.36	-20.45	
CD (P = 0.05)			3.62	

* Negative values and values exceeding one are omitted

B = Bulk

M = Mass

P = Pureline

Table 4.7 (Contd.)

Characters		S	R	h^{2*}
Total fruits per plant	B		-0.70	
	M	26.98	-24.49	
	P	35.98	-40.01	-
CD (P = 0.05)			7.71	
Marketable fruits per plant	B		-1.24	-
	M	25.42	-23.68	-
	P	33.75	-36.23	
CD (P = 0.05)			4.57	
Locules per fruit	B		-0.04	
	M	-0.36	0.30	-
	P	-0.69	0.42	-
CD (P = 0.05)			0.22	
Marketable fruit weight per plant (g)	B		-69.96	
	M	771.13	-764. 79	-
	P	672.40	-684.60	-
CD (P = 0.05)			440.19	
Total fruit weight per plant (g)	B		-10.79	
	M	778.54	-811.05	-
	P	807.21	-854.90	-
CD (P = 0.05)			53.65	

Table 4.8 Resistance of IE 79 under field conditions

Population	Number of plants	Juvenile stage		Adult stage	
		plants wilted	% of plants wilted	Plants wilted	% of plants wilted
Base population[1]	81	38	46.91	0	0
Progenies[2]					
Mass	360	5	1.38	0	0
Bulk	360	4	1.11	0	0
Pureline	72	2	2.77	0	0
Bulk[3]	1185	45	3.79	13	1.14
Bulk[4]	1781	143	8.02	22	1.34
Bulk[5]	306	52	16.99	0	0
Bulk[6]	541	-	-	4	0.73

1 September - December 1980
2 February - May 1981
3 April - August 1980
4 April - August 1980
5 September - December 1980
6 May - September 1980

DISCUSSION

DISCUSSION

Bacterial wilt caused by <u>Pseudomonas solanacearum</u> is the most serious disease of tomato in the acidic soils of Kerala. The cultivation of the crop has become impossible due to the incidence of this ~~highly appreciated~~ disease. Any attempt to evolve a line tolerant/resistant to this disease would be highly appreciated. The present investigation was carried out to identify a line (s) tolerant/resistant to bacterial wilt. An effective breeding programme for wilt resistance essentially consists of collection of germplasm, cataloguing of the lines thus collected, screening for resistance, improving the line thus isolated through appropriate breeding methods and finally evaluating its yield potential for the economic cultivation of the crop.

Germplasm collection

Tomato lines reported tolerant/resistant to bacterial wilt were collected from AVRDC, Taiwan. The lines were CL 8d-0-7-1 GS, CL 11d-0-2-2-0-3 UG, CL 32d-0-1-19 GS, CL 143-0-6-9 UG, L 1 GS, Venus and

Saturn. La Bonita an introduction made by N.B.P.G.R., New Delhi showing tolerance to wilt was also included. Lines whose tolerance/resistance were not previously evaluated also formed the germplasm evaluated.

Genetic cataloguing

The Report of the Tomato Genetics Cooperative, 1980 provides an exhaustive list of genes which could be used for cataloguing the germplasm. This might reveal marker character(s) associated with tolerance/resistance to bacterial wilt. The marker character thus identified could be used in screening in seedling stage, juvenile stage or even in adult plant stage of the crop. Acosta (1964) reported that the resistant lines to bacterial wilt are all indeterminate, indicating a possible relation between sp^+- the gene for indeterminate growth habit and resistance to wilt. He noticed yellow gel around the seeds in a few of the resistant lines. The present study could identify the line LE 79 (CL 32 d-0-1-19 GS) with tolerance to bacterial wilt. The detailed genetic cataloguing of the line revealed high content of anthocyanin in the seedling stage, indeterminate growth habit, yellow gel around the seed, green shouldered and non-uniform coloured fruits. The above observation concurs with the findings of Acosta (1964) and further points out the possibility of a relationship between resistance and high content of anthocyanin in the seedling stage, green shouldered and non-uniform coloured fruits. If there exists a relationship between resistance and green shouldered and non-uniform coloured fruits, there remains need for an effective breeding programme to delink the characters. Green shouldered and non-uniform coloured fruits are undesirable characters during marketing.

Genetic improvement of the tolerant/resistant line

Scientists at University of West Indies (1968-'69) reported close linkage between recessive genes for resistance and genes for poor fruit characteristics. The line LE 79 isolated for field tolerance had also poor fruit characteristics like small fruit size (average fruit weight 30.42 g) which needs to be further improved. This is in conformation with the results reported from University of West Indies (1968-'69) and University of Hawaii (1951). Being a self-pollinated crop conventional breeding methods like pureline selection and mass selection were initially done to upgrade the fruit size of the line, keeping resistance intact. The efficiency of different methods of selection was compared with progressing the generation through bulking. Significant differences due to the three methods of selection were observed only for plant height and days to first fruitset. The initial criteria of selection both in pureline and mass selection methods were fruit yield and absence of cracking. Selection based exclusively on fruit yield and absence of cracking may have been responsible for nonsignificant differences due to different methods of selection with respect to other polygenic characters. A trait-wise selection making use of discriminant function equations would have been more appropriate in such situations. The Realised heritability was higher (0.88) for days to fruit harvest indicating considerable scope for selection of early line(s) in the tolerant/resistant line identified.

Evaluation for field tolerance/resistance of the line

The line LE 79 observed "not affected from" bacterial wilt in the initial evaluation trial was grown separately in diseased plots in six independent trials. These trials indicated field tolerance of the line. To confirm the tolerance under artificial conditions, the seedlings were transplanted in pots filled with earth from known and confirmed diseased plots. Here again, the seedlings withstood the test of tolerance. The artificial inoculation technique as suggested by Winstead and Kelman (1952) caused susceptible reaction in the line under test. Mew and Ho (1976) found that certain tomatoes showed an uncertain degree of susceptibility to bacterial wilt when they were exposed to high inoculum densities; differences in inoculum density may, therefore, explain the differences in the expression of resistance. The resistance of bacterial wilt can vary with the temperature as reported by Krausz and Thurston (1975). Therefore, the susceptibility of the resistant line, LE 79, under artificial inoculation may be attributed to the fact that the inoculum density and temperature can alter the disease resistance.

SUMMARY

SUMMARY

1. One hundred and sixtyfive lines of tomato collected from different sources were sown during September 1980 to isolate line(s) resistant/tolerant to bacterial wilt. Genetic cataloguing of available lines was also attempted.

2. Seventyeight lines germinated were critically examined for seedling characters as given in the Report of the Tomato Genetics Cooperative, 1980. The line LE 79 had its hypocotyl, epicotyl, cotyledons and the first leaf purple pigmented, as observed 18 days after sowing.

3. The line LE 79 survived the onslaught of bacterial wilt. The statistical properties of LE 79 population indicated that the population was a normal one for plant height, primary branches per plant, days to first fruit set, days to first fruit harvest, marketable fruits per plant and locules per fruit.

4. An attempts was made to improve the fruit size and productivity of the line (LE 79) through pureline selection and mass selection. A comparison of the effectiveness of the above methods with bulking was also

made. The progeny developed through pureline selection were superior to those developed through bulking for days to fruit set, days to first fruit harvest, marketable fruit weight per plant, percentage of large fruited plants and percentage of plants with cracked fruits. The selection response obtained through mass selection was positive for primary branches/plant and locules/fruit. The realised heritability was very high (0.88) for days to first fruit harvest indicating thereby the scope of going for selection to develop still earlier lines.

5. The tolerance/resistance of the line LE 79 was further evaluated in six independent trials. The percentage of plants susceptible ranged from zero to 1.34 per cent (adult plant stage) indicating a case of tolerance.

6. Under artificial inoculation as proposed by Winstead and Kelman (1952), the line LE 79 became susceptible as any other susceptible line. This may possibly be due to high inoculam density in artificial inoculation.

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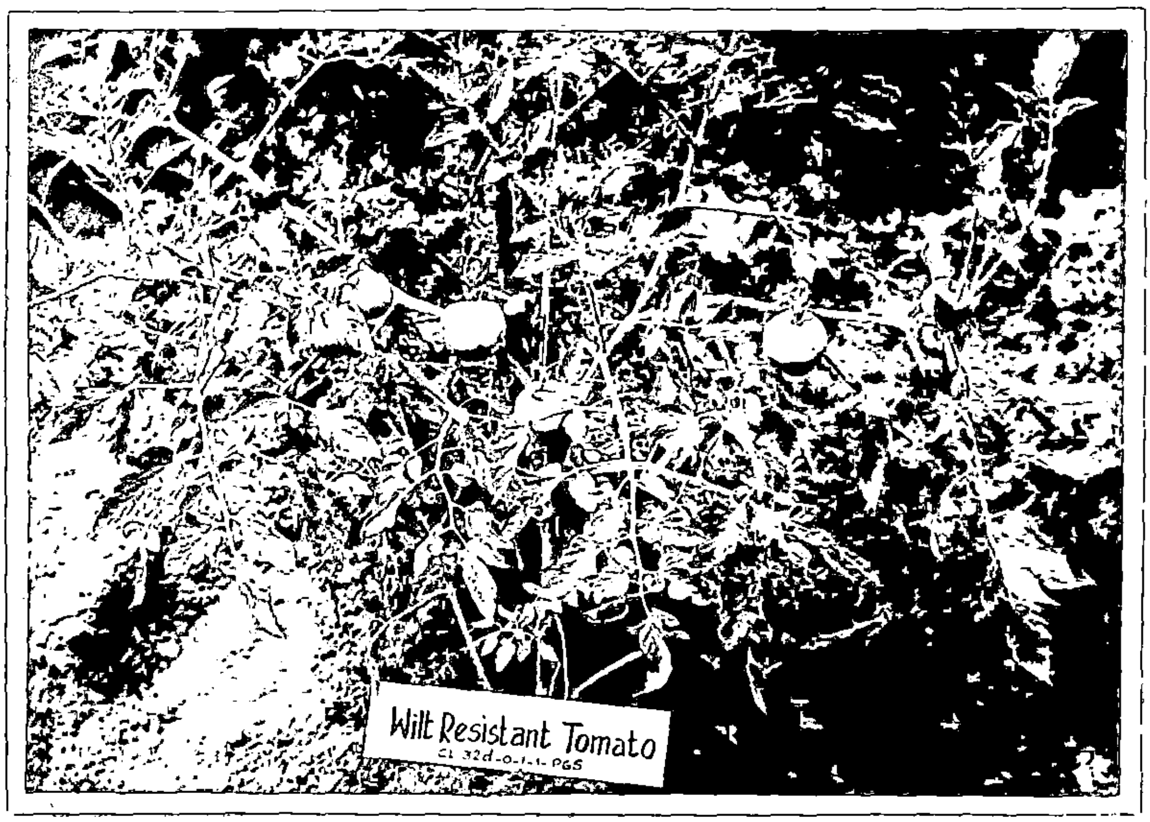
APPENDIX


Wilt Resistant Tomato
CL 32d-0-1-1-PGS

GENETIC CATALOGUING OF TOMATO GERMPLASM TOWARDS ISOLATION OF LINE(S) RESISTANT TO BACTERIAL WILT

BY

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ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement
for the degree of

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ABSTRACT

Bacterial wilt caused by Pseudomonas solanacearum is the single disease causing the greatest damage in tomato grown in the acidic soils of Kerala. Isolation of a line(s) tolerant/resistant would be a worthwhile attempt which would have considerable impact on tomato production in Kerala. An experiment was planned and carried out during 1980-'81 in the College of Horticulture, Vellanikkara to isolate tolerant/resistant line to bacterial wilt.

Seventy eight lines collected from different sources where genetically catalogued as per the Reports of the Tomato Genetics Cooperative, 1980. Field screening indicated the tolerance of one line, LE 79 (CL 8X-32d-0-1-19 GS) received from AVRDC, Taiwan. This line had indeterminate growth habit, green shouldered and medium sized fruits and the seeds covered by yellow gel.

The line was grown in the field continuously for six seasons to confirm the tolerance/resistance. The susceptibility ranged from zero per cent to 1.34 per cent in the adult plant stage.

Breeding methods like pureline and mass selection were adopted to improve the fruit size and other characters

of the resistant line. Genetic information like realised heritability were gathered for plant height, primary branches per plant, days to first fruit set, days to first fruit harvest, fruits per plant, marketable fruits per plant, locules per fruit, marketable fruit weight per plant and total fruit weight per plant.

The tolerance/resistance was tested using soils from susceptible plots. Here again, LE 79 showed freedom from disease infection. The artificial inoculation proposed by Winstead and Kelman (1952) caused susceptibility in the resistant line. This may probably be due to high inoculum density which alter the disease resistance.