

STUDIES ON RESISTANCE IN TOMATO TO BACTERIAL WILT

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INTRODUCTION

BACTERIAL WILT disease caused by *Pseudomonas solanacearum* E. F. Sm. is one of the main pathological problems in tomato culture in Ceylon. The disease is widely prevalent in the wet zone and in Hewaheta, Hangurenketha and Udukinda tomato-growing areas. The pathogen is chiefly soil-borne and its control by soil treatment with chemicals or by agricultural practices such as crop rotation, elimination of the sources of infection, and eradication of alternate host plants is commercially impractical. The most effective and economic method of control of the disease, therefore, is by breeding and selection of varieties with a high level of field resistance to the locally prevalent strains of *P. solanacearum*. Besides, an evaluation of the natural resistance of tomato varieties by artificial inoculation and by making field plantings in contaminated soils, a comparison is made in the present paper, of the relative resistance determined by the two methods. Furthermore, the yield potential of wilt-resistant tomato lines and of commercial varieties have been examined in some detail.

The search for a source of genetic resistance to bacterial wilt of tomato has been pursued in several tropical countries but many workers reported negative results or inadequate levels of resistance in the varieties tested. In Ceylon, Park and Fernando (1938) ascertained the relative resistance of eight tomato varieties and concluded that Marvana, Red Marhio 2 and Marglobe were significantly superior in resistance to Pritchard, Red Marhio 1 and Break O'Day. None of the varieties tested had adequate resistance of commercial value. Park (1941a, b) reported that five single plant selections of the local tomato strain "Talatuoya" were significantly superior in their character for wilt resistance to the commercial varieties Burwood Wonder, Excelsior and Early Dwarf Red. In his trials, he determined the bacterial wilt percentages of Marglobe and "Talatuoya" as 81.5 and 47.0 percent. respectively. In comparing two North

Carolina selections with Marglobe and Ponderosa, Peiris (1962) demonstrated the former as superior in resistance to the two commercial varieties. Abeygunawardena (1962) compared the resistance of local tomato selections with varieties such as Roma and Moscow. In these studies he demonstrated that the Rahangala selection II (*Lycopersicon esculentum* var *cerasiforme*) had a superior quality for wilt resistance but that this variety was small-fruited and had undesirable agronomic characteristics. In trials conducted in infested soils in growers holdings at Hangurenketha and Pata Hewaheta, Abeygunawardena (1963) compared the wilt resistance of the two North Carolina selections 1960-2a and 1960-8 with the local variety grown in these areas. He concluded that the two North Carolina selections had a superior resistance to the local variety extensively cultivated by the growers.

Varietal studies in the U. S. A., the Philippines, Australia and Africa have also been designed to find possible sources of resistance to bacterial wilt disease in tomato. Sherbakoff (1919) working in Florida evaluated 60 commercial varieties of tomato and concluded that none had an adequate level of resistance to disease. In North Carolina, Schmidt (1937) observed some resistance in the commercial variety Louisiana Pink but the resistance of progeny from crosses involving this variety was inconsistent. Nevertheless, in 1950, several promising lines were selected and hybridisation pursued to combine wilt resistance with high fruit quality. Negative results in the search for wilt resistance in tomato have been reported by Labrousse (1932) in France, by Mendiola and Ocfemia (1926) and Empig *et al* (1962) in the Philippines and by Burnett (1949) in Malaya. Nolla (1931) demonstrated that all the Puerto Rican lines were highly susceptible while the variety Marglobe had the highest resistance. In Australia, Aberdeen (1946b, 1949) showed that the selections from the variety Sensation had the highest resistance but they lacked desired agronomic characteristics and fruit quality. Wager (1944 a) working in South Africa compared the resistance of several tomato varieties and concluded that the small wild-current tomato types while having some resistance were inadequate for hybridisation.

MATERIALS AND METHODS

In the past, evaluations of resistance in tomato were based mainly on field plantings. Winstead and Kelman (1952) in a comparative study on the inoculation techniques for evaluating resistance concluded that the greatest differentiation between resistant and

susceptible plants was attained by a root inoculation method. The method used in the greenhouse evaluations was in many respects similar to the root inoculation technique.

Seeds of tomato varieties and selections were sown in a sterilized medium containing a mixture of soil and cattle manure. When the seedlings had developed two or more true leaves they were transplanted in pots containing the same sterile soil-cattle manure mixture. Due to rapid loss of virulence of *P. solanacearum* in laboratory culture media, a standard inoculum of bacterial suspension was prepared from naturally infected potato and tomato stems. The infected potato tubers were chopped into 2-4 mm. slices, covered with sterile water and incubated for 24 hours at room temperature. The bacterial exudate that appeared as fine milky droplets from the cut ends of vascular bundles was collected by a platinum loop. Similarly, the inoculum from tomato was obtained by incubation of pieces of infected stems. The stems were chopped diagonally into 2 inch pieces and placed in a beaker containing one inch sterile distilled water. When the test plants were 6 weeks old a sterile scalpel was passed close to the stem along one side of the plant to a depth of 4-6 cm. to cause sufficient injury to secondary roots. Four drops of the standard bacterial suspension were poured over the wounded roots. The inoculation was repeated 24 hours later on the opposite side of the stem and a high soil moisture level maintained thereafter by frequent watering, particularly in dry weather.

Disease ratings were made once in 3 days, seedling infection being evaluated according to the following numerical grades; 0 = no symptom of wilt, 1 = one leaf partially wilted, 2 = one to two leaves wilted, 3 = all leaves except 2-3 uppermost leaves wilted, 4 = all leaves including uppermost leaves wilted and 5 = death of the whole plant.

The disease ratings, interpreted as the bacterial wilt index of each test variety, was calculated using the following formula:—

$$BWI = \frac{C \times S}{N}$$

where BWI refers to the bacterial wilt index, C to disease index class, S to number of seedlings to each class and N to the number of seedlings inoculated.

EXPERIMENTAL RESULTS AND DISCUSSION

1. *Greenhouse Tests.*—49 introduced and local tomato varieties and selections were subjected to root inoculation with standard bacterial suspensions. Six weeks old plants grown on sterile soil/cattle

manure medium were inoculated and disease ratings made once in 3 days. The relative resistance of the test varieties interpreted as the bacterial wilt index is given in Table 1.

TABLE 1

The Resistance in Tomato in to *P. Solanaceatum* transformed as the Bacterial Wilt Index

<i>Variety</i>	<i>Mean Bacterial Wilt Index</i>			
North Carolina line 1960-8	..	..	..	3.05
North Carolina line 1960-2a	..	..	..	3.72
North Carolina line 1962-B2	..	..	..	6.94
North Carolina line 1961-57-55M	..	..	..	9.75
Master Marglobe	..	..	..	12.80
Rahangala Selection II	..	..	..	13.23
No. 146	..	..	..	14.08
K. Y. I.	..	..	..	16.05
France Marglobe	..	..	..	16.43
North Carolina line 1960-2a (mixed)	..	..	..	16.84
American Variety	..	..	..	17.61
Marglobe Supreme	..	..	..	19.83
Japanese Variety	..	..	..	20.23
Sperls Zukunht	..	..	..	21.18
Sioux	..	..	..	21.60
Moscow	..	..	..	21.67
Burpee Big Bay Hybrid	..	..	..	21.95
Heinz Special	..	..	..	22.10
Professor Rudolf	..	..	..	22.68
Marglobe B	..	..	..	22.88
Lintora Princess	..	..	..	23.27
South Australian Dwarf	..	..	..	23.44
Pritchard	..	..	..	24.70
Roma	..	..	..	24.78
Burpee Certify Marglobe	..	..	..	25.23
Burpee Hybrid	..	..	..	26.15
Manalucie	..	..	..	26.38
Los Banos strain	..	..	..	26.53
Hoffmans Rent	..	..	..	26.77
M. D. Marches	..	..	..	27.10
Datura Dwarf	..	..	..	28.50

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<i>Variety</i>					<i>Mean Bacterial Wilt Index</i>
Burpee Calcross	..	..	..	..	28.60
Burpee Big Early hybrid		..	..	..	28.86
Burpee Early Hybrid	..	..	..	..	29.40
Ford Hook Hybrid	..	..	..	..	30.01
Grosse Lesse	..	..	..	..	30.01
Ace	..	..	..	..	30.10
Super Marmende	..	..	..	..	30.51
Fire Steel	..	..	..	..	30.60
Hoffman's Jubilium	..	..	..	..	31.01
Burpee Sunny Brook	..	..	..	..	31.51
Mendoza	..	..	..	..	31.76
Indian River	..	..	..	..	32.10
Roma	..	..	..	..	32.48
Early Pac	..	..	..	..	32.57
Globe Master hybrid	..	..	..	..	32.77
Tomato Clinton hybrid	..	..	..	..	33.40
Saint Peirre	..	..	..	..	33.48
College Challenger		..	..	..	35.53

Significant Difference at $P = .05$ is 7.78

Wilt symptoms first appeared 5 days after the second inoculation in highly susceptible varieties such as College Challenger, Saint Pierre and Tomato Clinton Hybrid. For instance, the entire seedling population of College Challenger was diseased in 2 weeks while only 10 per cent of the plants remained unaffected in the variety Saint Pierre. The varieties which emerged resistant, namely, the Rahangala Selection II and the North Carolina lines 1960-8, 1960-2a, 1962-B2 and 1961-57-55M all showed symptoms of wilt disease considerably later. Among them, the North Carolina Line 1960-8 and Rahangala Selection II had less than 25 and 50 per cent disease respectively in two weeks from inoculation. The North Carolina lines 1960-8 and 1960-2a with their mean disease indices of 3.05 and 3.72 respectively were highly resistant to the disease. They had a significantly superior resistance to all other test varieties except the North Carolina Lines 1962-B2 and 1961-51-55M. The Rahangala Selection II with a mean disease index of 13.23 was superior in resistance to most commercially grown varieties such as Moscow, Roma and Marglobe. Nevertheless, it has certain undesirable agronomic features such as profuse vege-

tative growth resulting in prostate habit and the presence of commercially unacceptable small-sized fruits. Empig *et al* (1962) have shown that the Los Banos strain was the most resistant to wilt disease in the Philippines. This variety with a mean disease index of 26.53 has shown a different reaction under Ceylon conditions. While being susceptible to disease, it has proved to be significantly inferior to the Rahangala Selection and all North Carolina lines. The results of differential resistance observed in the Los Banos variety clearly show the existence of pathogenic strains of *P. solanacearum* with varying virulence in different parts of the world.

2. *Field Test in Naturally Infected Soil.*—To determine the relationship of the bacterial wilt index and the appearance of disease in the field a replicated trial was established on naturally infected soil at the Central Research Station, Peradeniya. The seed of 13 tomato varieties was sown in sterile soil/cattle manure medium and seedlings with 2-3 true leaves transplanted in the experimental plots. Biweekly stand counts of the transplants were made until maturity. In Table 2 the mean per cent. disease of the test varieties and their bacterial wilt indices are summarised.

TABLE 2

Comparison of mean per cent. disease in field plantings and bacterial wilt indices of tomato varieties

Variety		Mean % disease	Mean bacterial wilt index
North Carolina line 1961-57-55M	..	2.60	9.75
North Carolina 1962-B2	..	9.80	6.94
North Carolina line 1960-8	..	10.00	3.05
North Carolina line 1960-2a	..	10.00	3.72
Los Banos Strain..	..	18.52	26.53
Rahangala Selection II	..	18.57	13.23
No 146	..	19.20	14.08
Master Marglobe	..	20.20	12.80
Moscow	..	21.74	21.67
Roma	..	25.00	24.78
Burpee Certify Marglobe	..	26.56	25.23
France Marglobe	..	30.56	16.43
Marglobe Supreme	..	32.00	19.83

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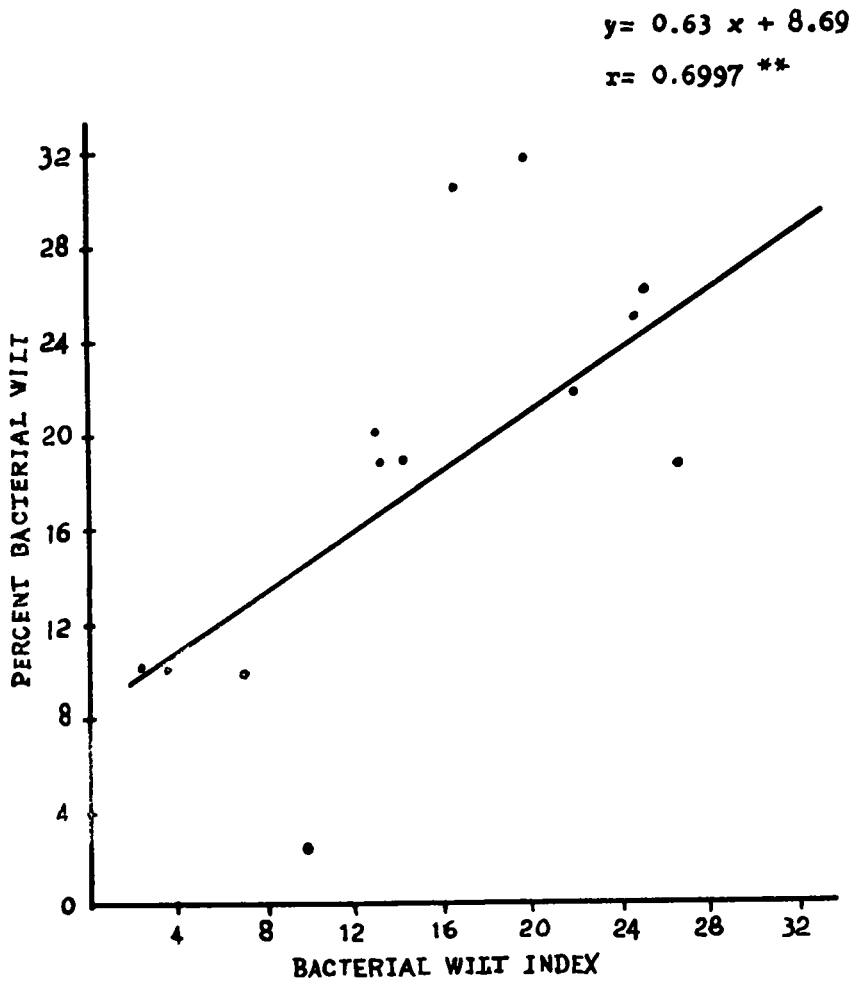


Fig. 1. Relation between Bacterial Wilt Index and the percentage of plants developing the wilt disease

Statistical analysis of the results revealed a significant correlation between disease index and field reaction to wilt in the tomato varieties tested. A correlation coefficient of 0.6997 which is statistically valid at $P = 0.01$ was determined. The equation connecting the field per cent disease (y) and mean bacterial wilt index (x) reads as $y = 0.63x + 8.69$. The relation between the bacterial wilt index and field resistance of the test varieties is shown graphically in Fig. 1. The results clearly show that a rapid screening test like the root inoculation method is adequate for preliminary disease resistance studies involving large populations of hybrid lines, and therefore, could be valuable for the elimination of unpromising progeny lines in breeding for bacterial wilt resistance in tomato.

3. *Tests in Infected Growers Holdings.*—In a second field test, the more promising North Carolina lines 1960-8, 1960-2a, 1962-B2 and 1961-57-55M were evaluated in growers holdings in the Pata Hewaheta tomato-growing area where the soils are naturally infected with bacterial wilt. The plots were distributed in Weligammade, Medagama, Uduwela-Pallegama, Puliyadde, Nahiniwela, and Kandegama. The test varieties, including the local strain of tomato grown in the area, were established in the different plots. Fertilization, weed control and other agricultural practices adopted for these trials were similar to those of the main crop grown in each test area. The mean wilt counts taken at biweekly intervals have been transformed to inverse sine scale and are presented in Table 3. Analysis revealed that the North Carolina line 1960-8 was significantly superior to all other lines tested except 1961-57-55M and 1962-B2. The local variety grown extensively in the area had the minimum resistance to disease.

TABLE 3

The Incidence of Bacterial Wilt in Resistant Lines and Local Variety in Growers Holdings

Variety	Mean Equivalent Angle
North Carolina line 1960-8	12.54
North Carolina Line 1961-57-55M	17.40
North Carolina Line 1962-B2	20.77
North Carolina Line 1960-2a	23.64
Local Strain	57.67
Significant Difference at $P = 0.05$ is 10.62.	

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4. *The Yield Potential of Wilt Resistant Tomato Varieties.*—The yield potential of tomato varieties and hybrid lines determined resistant to bacterial wilt was compared with that of some commonly grown varieties such as Moscow, Marglobe Supreme and Pearson. A randomised trial consisting of 4 replicates, was established at Kunda-sale in the Yala 1963 cropping season. Each plot measured 12' × 18' and carried a population of 50 plants. The seedlings of the test varieties were raised in bacterial wilt-free seedbeds and transplanted in the experimental area also located in uninfested soil of an abandoned rice field. Application of artificial fertilizers was considered unnecessary owing to the observed high soil fertility in the experimental area. The plots received, nevertheless, a basal dressing of cattle manure at 10 tons per acre. The yield results expressed in cwt. per acre and the percentage weight of fruits categorised large, medium and small are presented in Table 4.

TABLE 4

Comparative Yield Potential of Wilt Resistant and Some Commercial Tomato Varieties

Variety	Per cent. Weight of Fruits						Yield in cwt/acre	
	Large (5 cm. in diameter)	Medium (3-5 cm. in diameter)	Small (1 cm. in diameter)					
North Carolina line 1961-57-55M	..	3	..	28	..	69	..	119.12
North Carolina line 1960-8	..	12	..	48	..	40	..	117.50
Rahangala Selection II	..	0	..	0	..	100	..	93.00
Moscow	..	5	..	94	..	3	..	92.64
Pearson	..	22	..	71	..	3	..	64.09
Marglobe Supreme	..	10	..	84	..	4	..	55.20
North Carolina Line 1962-B2	..	45	..	54	..	1	..	51.19
North Carolina Line 1960-2a	..	24	..	75	..	1	..	44.95
No ; 146	..	50	..	47	..	3	..	43.92

Significant difference at $P = 0.05$ is 28.56.

The wilt resistant North Carolina line 1961-57-55M with the highest yield of 119.12 cwt./acre significantly outyielded all other test varieties except the North Carolina Line 1960-8, Rahangala Selection II and Moscow. In the character for wilt resistance determined by greenhouse tests and field plantings this tomato line was not significantly inferior to those having the highest resistance to disease. The line



1961-57-55M has the disadvantage that it is open pollinated and may therefore show tendency to segregate. The tomato varieties with a high yield potential produced an appreciable proportion of small sized fruits, measuring less than 3 cm in diameter. Among them, the Rahangala Selection II yielded only small-sized fruits while the North Carolina Lines 1961-57-55M and 1960-8 had 69 per cent. and 40 per cent. respectively of fruits of the same grade. All other varieties including the resistant lines 1962-B2 and 1960-2a produced less than 5 per cent of small-sized fruits but were distinctly inferior in their yield potential to the other disease resistant lines. The line 1962-B2 while having a high level of resistance had an improved fruit size, yielding 45 per cent of large-sized fruits. The total yield of this line, however, has been poor under Kundasale conditions.

SUMMARY

Forty-nine tomato varieties and hybrid lines were evaluated for resistance to wilt disease caused by *P. solanacearum* and the results transformed into bacterial wilt indices. The North Carolina lines showed an outstanding resistant reaction when inoculated with bacterial suspensions. Master Marglobe and the Rahangala Selection II also had an appreciable resistance to wilt. The Los Banos strain reputed to be resistant in the Philippines, however, emerged susceptible under local conditions. This clearly shows the existence of pathogenic strains of the wilt organism with varying virulence in different parts of the world. It can be concluded, therefore, that the resistance in tomato to bacterial wilt depends largely on the virulence of the strain or strains of the bacterium encountered in each country.

A comparison of the bacterial wilt indices and the field reaction to disease showed a significant correlation. A correlation coefficient of 0.6997 which is statistically valid at $P = 0.01$ was determined. The general conclusion from these data is that the root inoculation method is sufficient for preliminary studies involving large populations of hybrid lines and could, therefore, serve as a means of elimination of unpromising progeny lines when breeding for bacterial wilt resistance.

Tests in growers holdings in a major tomato growing area revealed that the North Carolina lines were superior in the character for wilt resistance to the cultivated local strains of tomato. These trials, further confirmed the observed resistant reaction of the North Carolina lines to bacterial wilt organism prevalent in Ceylon.

A comparative study of the yield potential revealed that among the wilt resistant types, the North Carolina lines 1961-57-55M and 1960-8, and the Rahangala Selection II outyielded the commercial varieties Marglobe and Pearson. However, they produced an appreciable proportion of small-sized fruits.

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