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Incompatible Reactions between Some Plants and Pathogenic Bacteria

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ABSTRACT. Incompatible combinations of plant and plant bacteria produce an incompatible reaction at different rates, producing, besides the typical hypersensitive reaction, also darkening, yellowing, and fading. Plants differ in their responsiveness to plant bacteria in terms of reaction rate. Study of incompatible reactions may differentiate the species and strains of plant bacteria if properly explored.

Bacteria of different biological nature behave differently when introduced in a plant. While a pathogen compatible with the plant (host) produces a disease reaction an incompatible pathogen produces a hypersensitive reaction (HR) and a saprophyte produces no reaction (Klement and Goodman 1967*a*,*b*). This was found to hold in the case of pseudomonads on tobacco (Klement 1968, 1972). Many attempts to elucidate the incompatible reactions including HR were made (Ward 1902; Thiers and Lester 1949; Muller 1959; Goodman 1965, 1967; Lovrekovich and Farkas 1965; Goodman and Plurad 1971; Solymosy 1970; Klement *et al.* 1964; Sule and Klement 1971).

The present work was designed to test the possibility of utilizing the incompatible reaction (IR) for locating plant bacterial pathogens in general and for assessing its universality in different plant systems. The ability of IR to differentiate between species, different host-specific strains of the same species of plant bacteria and different virulence grades of isolates of same host species of plant bacteria have also been examined.

MATERIALS AND METHODS

Leaves of 15 different plants from 9 families were injected with equal volumes of bacterial suspensions of 10^8 cells per ml prepared from 2 d-old nutrient agar cultures of 8 different bacterial species, *e.g. Xanthomonas oryzae* (Uyeda et Ishiyama) Dowson, *X. vesicatoria* (Doidge) Dowson, *X. citri* (Hasse) Dowson, *X. campestris* (Pammel) Dowson, *X. translucens* f. *oryzicola* (Fang *et al.*) Bradbury, *X. phaseoli*, *X. vignicola* Burk, and *Pseudomonas solanacearum* Smith amongst the plant pathogens, *Bacillus polymyxa* (a storage tissue rotting bacterium) and *Escherichia coli* (a human pathogenic bacterium). Three host-specific races of *P. solanacearum* from brinjal, potato and tomato and 8 isolates of different virulence grades of *X. oryzae* were also included. All the cultures except the first 7 isolates of *X. oryzae* and *E. coli* were isolated in the present laboratory from diseased specimens. The whole work comprised:

TABLE I. Overall reactions of different bacteria towards different hosts on infiltration[a]

Host plant	Bacteria		
	X. oryzae	*B. polymyxa*	*E. coli*
Citrus	no typical necrosis, only yellowing[b] (Y)	0	0
Rose	0	0	
Brinjal	necrosis[b] (HR)	0	paleness[b] (no HR)
Canna	0	0	0
Tomato	necrosis[b] (HR)	deep brown spots[b] (HR)	0
Potato	necrosis[b] (HR)	two small necrotic patches[b] (HR)	0
Tobacco	slightly yellowish green[b] (Y)	necrosis of a small portion[b] (HR)	paleness[b] (no HR)

[a] Yellowing (incomparible reaction), HR hypersensitive reaction (necrosis or deep-brown spots).
[b] Of the infiltrated zone.

a) *Overall reaction study.* A group of 7 different plants were injected with 3 bacteria, *X. oryzae*, *B. polymyxa* and *E. coli*, and incubated at 27—31 °C for 7 d and the reactions were recorded.

b) *Detailed reaction study.* The detailed, time-lapse study of the reaction of 15 different plants of 8 families to injected bacteria, *X. oryzae* (normal host is rice) and *X. vesicatoria* (normal hosts are chilli and tomato) were studied, making observations every 24 h up to 7 d.

c) *Reaction of plants to various strains of plant bacteria.* The plant reaction to 5 different species of the same bacterial genus, *e.g. Xanthomonas*, to 3 host-specific strains (brinjal, potato and tomato) of the same bacterial species, *e.g. P. solanacearum* and to 8 different isolates (of different virulence grades) of the same species of bacteria, *e.g. X. oryzae*, were studied, making observations up to 7 d.

RESULTS AND DISCUSSION

Results of the overall reaction study (Table I) show that *X. oryzae* caused IR in all the hosts, the typical HR sympton being discernible on 5 out of 7, while *E. coli* generally could not react with the plants. *B. polymyxa* produced IR in the shape of HR on 3 solanaceous plants (tobacco, tomato and potato).

In the detailed reaction study (Table II) two plant bacteria produced different reactions, such as disease, HR, yellowing (Y), slight darkening (D), slight fading (F) and finally no visible reaction on the plants. While *X. oryzae* produced IR (HR, D, F and Y) on all its non-host plants, except canna and rose, *X. vesicatoria* produced the disease on its host plants, *e.g.* chili and tomato, IR (HR, D, F and Y) on all except canna, rose. China rose and wheat. Thus solanaceous plants appear to be

TABLE II. Reactions of plant leaves on infiltration by *X. vesicatoria* and *X. oryzae*[a]

Family	Plant	Days after infiltration[b,c]							
		1		3		5		7	
		XV	XO	XV	XO	XV	XO	XV	XO
Solanaceae	tomato	0	D	0	D	Dis	HR	Dis	HR
	brinjal	0	0	F	HR	HR	HR	HR	HR
	chilli	0	0	0	D	Dis	HR	Dis	HR
	tobacco	D	0	HR	F	HR	Y	HR	Y
	potato	0	0	HR	HR	HR	HR	HR	HR
Leguminosae	pea	0	0	F	Y	HR	HR	HR	HR
	bean	D	D	HR	HR	HR	HR	HR	HR
Rutaceae	citrus	0	0	0	0	0	Y	D	Y
Cruciferae	cabbage	0	0	HR	HR	HR	HR	HR	HR
	cauliflower	0	0	HR	HR	HR	HR	HR	HR
Malvaceae	China rose	0	0	0	D	0	HR	0	HR
Graminae	wheat	0	0	0	0	0	0	0	Y
	barley	0	0	0	0	D	Y	Y	Y

[a] No reaction with rose (Rosaceae) and canna (Cannaceae).
[b] XO. *oryzae*, XV *X. vesicatoria*.
[c] D slight darkening, L slight fading, Y yellowing, HR hypersensitive reaction, Dis disease.

most responsive while Rosaceae and Cannaceae are non-responsive and Graminae and Malvaceae are less responsive. Plants of the same family differed in the responsiveness quantitatively. The time taken for reaching the HR stage in an incompatible reaction varied from 2 to 6 d between different plant—bacteria combinations.

TABLE III. Reactions of tomato and citrus to different species of genus *Xanthomonas* on infiltration[a]

Xanthomonads	Tomato	Citrus
X. citri	necrosis and curling[b] (HR)	typical symptom of canker disease (Dis)
X. campestris	necrosis[b] (HR)	necrotic spots and yellowing[b] (HR)
X. vesicatoria	disease symptom, appearing late (Dis)	slight darkening after 7 d (SR)
X. translucens f. *oryzicola*	lower surface of the infiltrated zone water soaked (SR)	0
X. oryzae	necrosis, curling[b] (HR)	yellowish green[b] (SR)

[a] HR, hypersensitive reaction, SR slow reaction, Dis disease.
[b] Of the infiltrated zone.

TABLE IV. Reactions of leaves of tomato and potato infiltration with strains of *P. solanacearum*[a]

P. solanacearum strain of	Leaves of	
	tomato	potato
Tomato	0	whole infiltrated zone dried, loss of turgor (HR)
Potato	0	dry greyish-white patch surrounded by dark-brownish margin, dark-brown spots in the remaining yellow portion of the infiltrated zone (HR)
Brinjal	small blackish spots, adjacent area slightly faded (HR)	dark-brown spots within the infiltrated zone, a small portion dry, one edge with dark-brown margin (HR)

[a] HR hypersensitive reaction.

The results of reaction studies for different species of a genus (Table III), strains of a species (Table IV) and isolates of a species (Table V) show that on the responsive plant (tomato) 3 out of 4 incompatible combinations produce IR and in the fourth the reaction is unusually slow, while on the less-responsive host (citrus) one combination (*X. campestris*) could produce IR and two more (*X. vesicatoria* and *X. oryzae*) were slow in the process (Table III). Whether plants of different responsiveness may distinguish species of a bacterial genus on the time scale for IR production needs an elaborate examination.

TABLE V. Reaction of tomato and citrus towards different isolates of *X. oryzae* on infiltration[a]

Area of *X. oryzae* isolates	Tomato	Citrus
Orissa, Bhubaneswar	HR, larger area	0
Uttar Pradesh	HR, curling, small area	HR
Delhi	HR, different color	0
Tamil Nadu	slow HR, curling	pale yellow (Y)
Andhra Pradesh	HR, different color	fadded green or yellow (Y)
Orissa, Cuttack	HR, curling	0
Bihar	HR, curling	yellowing (Y)
West Bengal	HR, large area	yellowish green (Y)

[a] Y yellowing (incompatible reaction); HR hypersensitive reaction.

Leaves of one responsive plant (potato) with all the strains (tomato, brinjal and potato) of *P. solanacearum*, the xylem invader, produced HR, while tomato did so only in the case of the brinjal bacterium (Table IV). The failure of tomato with tomato and potato strains is not understood.

Tomato has produced HR with all the strains of *X. oryzae* though associated with different kinds of symptoms, *e.g.*, different area of necrosis, curling and colour difference for different strains while on citrus HR was produced rapidly with some strains, slowly with some others and not at all with the rest (Table V). The earlier claim (Klement and Goodman 1967*a*,*b*) that plant bacterial pathogens on incompatible hosts produce IR while saprophytes fail to do so has not only been confirmed but extended for xanthomonads. Besides production of typical HR symptoms of point necrosis surrounded by halo, other types of IR, such as slight darkening, yellowing or fading and association of curling *etc.* with them are also common symptoms. Although most of the plants can react in this manner with incompatible bacterium, some of them appear to be more responsive than others while a few are nearly non-responsive. The response of plants, however, differed generally in terms of rate of progress of the reaction and it is not understood whether non-responsive plants are actually excessively slowly reacting.

There are elements of difference in the details of reaction types in the case of different species of a genus towards different plants.

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