

Distribution of Races of *Xanthomonas vesicatoria* Pathogenic on Pepper

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ABSTRACT

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Cultures of *Xanthomonas vesicatoria* isolated from naturally infected peppers and tomatoes in Argentina, Australia, Brazil, El Salvador, Guadeloupe, Hungary, India, Italy, New Zealand, and the United States were identified to pathotype. All cultures pathogenic on pepper were categorized as pepper strain, race 1, except one culture (identified as pepper strain, race 2) from Guadeloupe and cultures collected in Florida that represented both pepper pathotypes. Race 2 has been widely distributed on pepper in Florida during the past 19 years, which, with the reported occurrence of the same race in Brazil, serves to confuse etiologic information concerning the original pepper pathotype. Sources of resistance to both pepper pathotypes have been identified and the problems of adding these characters to horticulturally desirable types defined.

Bacterial spot of pepper (*Capsicum annuum* L.), incited by *Xanthomonas vesicatoria* (Doidge) Dowson (XV), can cause significant reduction in yield and quality of fruit. Frequent rains in Florida are conducive to development of this warm weather disease and complicate successful use of foliar sprays for control. These considerations prompted a search for genetic resistance to this disease in pepper. Hypersensitive resistance was identified in accession PI 163192 and determined to result from a single, dominant factor (8). Early field plantings of a breeding line homozygous for this resistance factor led to discovery of a second, previously indistinguishable pathotype of the bacterium (4) that was infectious on plants with the resistance factor. A third pathotype of the bacterium also has been identified (1), but it is infectious only on tomato (*Lycopersicon esculentum*).

The pepper cultivar Florida VR 2 (VR)—noted for multiple virus resistance (3) but also homozygous for the single factor, dominant resistance to one pathotype of XV—was reported susceptible to bacterial spot in experimental plantings in Queensland, Australia (A. M. Hibberd, *personal correspondence*). To determine whether the causal bacterium as it occurs in Australia and elsewhere could be placed in the proposed classification scheme for isolates from Florida, cultures of XV obtained from naturally infected pepper

and tomato plants in Queensland were identified to pathotype. Six additional cultures were provided by A. C. Hayward, Microbiology Department, University of Queensland, St. Lucia. Isolates originally from pepper and maintained in a world collection of bacterial cultures by J. M. Young and D. W. Dye, Department of Scientific and Industrial Research, Mt. Albert Station, Auckland, New Zealand, were also identified to pathotype.

Cultures of XV collected in Florida since 1961 from infected plants grown in the state and elsewhere have been used primarily for general inoculations and teaching purposes but were only recently classified according to race on pepper. Isolates of the causal bacterium were obtained recently from Grover Sowell, Jr., Southern Regional Plant Introduction Station, Experiment, GA, and Lowell Black, Louisiana State University, Baton Rouge, LA. The combined results of these studies provide preliminary evidence of the worldwide distribution of races of the bacterium pathogenic on pepper and permit some evolutionary speculation.

MATERIALS AND METHODS

Inoculum was prepared from nutrient broth, shake cultures held at ca. 30 C for 18 hr. Bacterial cells collected by centrifugation for 5 min at ca. 1,000 g were resuspended in sterilized tap water (approximately 10^8 cells per milliliter) and injected into leaves of test plants using the infiltration technique described by Klement (7). Inoculated plants were incubated in a glasshouse where temperatures ranged from 22 to 38 C.

Isolates of XV that induced susceptible responses in both VR and Early Calwonder (EC) leaves were classified as pepper strain, race 1, of the bacterium; isolates that induced a hypersensitive response (HR) in VR and a susceptible

response in EC were classified as pepper strain, race 2. Isolates that caused nonconfluent HR within 24 hr after inoculation in leaves of both VR and EC pepper cultivars were categorized as the tomato strain of the bacterium. Each of the three bacterial pathotypes produced susceptible symptoms in tomato leaves, whereas all of the pathotypes induced hypersensitive responses in leaves of tobacco (*Nicotiana tabacum*).

RESULTS

Twenty-six cultures of XV were obtained from infected pepper and tomato plants grown in southeastern Queensland, Australia, during late 1979 and early 1980. Six isolates came from A. C. Hayward and four from Melda Moffett, Plant Pathology Branch, Department of Primary Industries. All 22 isolates from pepper and one isolate originally from tomato, obtained from A. C. Hayward, were identified as pepper strain, race 1 (Table 1). The three remaining cultures were identified as tomato strain.

Fifteen cultures of XV from the collection of Young and Dye, all from naturally infected pepper, included cultures that came originally from Hungary, India, Italy, Tonga, and the United States (Florida and New York). Of the ten isolates that produced recognizable symptoms on test plants, seven were classified as pepper strain, race 1. A single isolate, originally from Florida but of indefinite duration in the Dye collection, was identified as pepper strain, race 2. The remaining two isolates, originally from Italy, caused HR on both VR and EC and were classified as tomato strain.

Another 64 cultures of XV, collected by the junior author since 1961, were assayed to establish pathotype on pepper. Twenty-nine of 46 cultures collected from diseased plants grown in Florida were identified as race 2, and the remaining 17 cultures were race 1. Sixteen other cultures were isolated originally from infected plants grown outside Florida and included cultures from Argentina, Brazil, El Salvador, Guadeloupe, Israel, Georgia, Hawaii, Louisiana, and New York. Only the single culture from infected pepper grown in Guadeloupe in 1970 was found to be pepper strain, race 2, whereas the remainder were identified as race 1.

DISCUSSION

Bacterial spot of pepper occurs throughout the world. Isolates used in

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Table 1. *Xanthomonas vesicatoria* cultures identified to pathotype

Country of origin	Source plant	Number of cultures	Pathotype
Argentina	Tomato	3	Pepper 1
Australia	Pepper	22	Pepper 1
	Tomato	1	Pepper 1
	Tomato	3	Tomato
Brazil	Pepper	1	Pepper 1
	Tomato	1	Pepper 1
El Salvador	Pepper	2	Pepper 1
Guadeloupe	Pepper	1	Pepper 2
Hungary	Tomato	2	Pepper 1
India	?	1	Pepper 1
Israel	Tomato	1	Pepper 1
Italy	?	1	Pepper 1
New Zealand	Pepper	2	Pepper 1
United States			
Florida	Pepper	15	Pepper 1
	Pepper	14	Pepper 2
	Tomato	2	Pepper 1
	Tomato	15	Pepper 2
Georgia	Pepper	3	Pepper 1
Hawaii	Pepper	1	Pepper 1
Louisiana	Pepper	2	Pepper 1
New York	Pepper	3	Pepper 1

this study originated from Asia, Australia, Europe, New Zealand, South America, and the United States, but no isolates from Africa or numerous other localized areas where peppers are grown were included. With two geographic exceptions, all of the cultures from pepper identified to pathotype were classified as pepper strain, race 1. Race 2, as well as race 1, has been reported previously, however, to occur in Brazil (6). Despite these acknowledged exceptions, the results reported constitute preliminary evidence that a single pathotype of the bacterium predominates throughout the world as far as pepper disease is concerned.

It could be speculated that race 2, pepper strain, originated as a mutant form of the more widely disseminated race 1, particularly because the mutation rate for pathotype change in XV has been found to be relatively high (5). Absence of race 2 from areas other than Florida and Guadeloupe represented in this study and persistence of this pathotype in Florida for at least 19 yr are presumptive evidence

that race 2 is better adapted epidemiologically in Florida than elsewhere. There have been insufficient numbers of cultures from Guadeloupe and Brazil upon which to draw conclusions.

This study has revealed the unique status of the state of Florida, which is the only location noted to date, except Brazil, in which three pathotypes of XV have been identified. It was determined from isolates collected during the last 19 yr in Florida that pepper strain, race 1, has been found consistently only in the Delray Beach-Vero Beach-Ft. Lauderdale area, and, on one occasion only, in the Sanford area. However, pepper strain, race 2, has been isolated repeatedly from infected plants grown in areas represented by Gainesville, Sanford, Ft. Myers, Belle Glade, and Delray Beach. The tomato pathotype also has been found in the last three named areas, in addition to the Miami area, where peppers are not grown. Thus, in Florida as opposed to several other locations in the world, pepper strain, race 2, is much more widely

distributed than race 1. This information is all that has been found in opposition to the assumption that race 1 represents, etiologically, the original pepper pathotype.

Hypersensitive resistance to race 2 (pepper strain) of the bacterium has been available for several years; one commercially available cultivar (VR) is homozygous for this single factor, dominant resistance. Apparent hypersensitive resistance to race 1 has been identified in a cultivar of *C. chacoense* (2), whereas other sources of resistance in *C. frutescens* and *C. annuum* are now under investigation. None of the resistant cultivars is horticulturally useful in its present state. Interspecific genetic incompatibility and partial to complete sterility of early progeny plants have been encountered in attempts to transfer resistance from *C. chacoense* to *C. annuum* types. However, these problems do not now appear to be insurmountable, and there is considerable promise of resistant varieties for the future.

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