HortScience 19(2):277–278. 1984.

Indian Hot Peppers as New Sources of Resistance to Bacterial Wilt, *Phytophthora* Root Rot, and Root-Knot Nematode

K.V. Peter[1]
Kerala Agricultural University, Vellanikkara, India 680651

R.W. Goth and R.E. Webb
Horticultural Science Institute, ARS-BARC, U.S. Department of Agriculture, Beltsville, MD 20705

Additional index words. *Capsicum annuum*, *Capsicum frutescens*, *Pseudomonas solanacearum*, *Phytophthora capsici*, *Meloidogyne incognita*, multiple disease resistance, vegetable breeding

Abstract. **The 4 hot peppers from India 'Pant C-1', 'KAU Cluster' (*Capsicum annuum* L.), 'White Khandari', and 'Chuna' (*C. frutescens* L.) were evaluated along with 6 United States cultivars for their reaction to *Pseudomonas solanacearum* E.F. Smith (races 1 and 2), *Phytophthora capsici* Leonian, and root-knot nematode *Meloidogyne incognita* Chitwood. The Indian 'Pant C-1' was resistant to 4 *Pseudomonas solanacearum* isolates and moderately resistant to *Phytophthora* root rot and root-knot nematode. The breeding line 'White Khandari' was resistant to 3 isolates of the bacterium and root-knot nematode and moderately resistant to *Phytophthora* root rot. These Indian pepper lines could be an additional source in multiple disease-resistant breeding programs. Multiple disease resistance and good horticultural characteristics make 'Pant C-1' an excellent source of these resistances.**

Bacterial wilt caused by *Pseudomonas solanacearum*, root rot caused by *Phytophthora capsici*, and the root-knot nematode *Meloidogyne incognita*, are persistent problems affecting pepper production in the tropical and subtropical areas of the world (1, 3, 4, 7, 9, 11, 12, 14). Since 1975, selections of *Capsicum annuum* and *C. frutescens* that were highly resistant to infection by these organisms have been made under field conditions in the tropical and subtropical areas of India (8). These selections, although not immune to infection, have produced marketable yields under extreme disease pressure (6). The cultivar 'Pant C-1', included in the set of lines under study, is grown now throughout India where bacterial wilt and root disease problems exist. The selections 'KAU Cluster', 'White Khandari', and 'Chuna' also yield well under extreme disease pressure. Because these selections have good combining abilities, they have been used in other studies and breeding programs (2, 8). In the present study, we have differentiated the response of this pepper germplasm to different isolates of the 3 pathogens for breeding purposes. This knowledge is needed to develop multiple disease-resistant lines with desirable horticultural attributes. This enhanced germplasm will be useful in expanding the genetic base for both disease-resistance and horticultural characteristics. A portion of this research has been published (2).

Four hot pepper lines (*C. annuum* cvs. Pant C-1 and KAU Cluster and *C. frutescens* cvs. White Khandari and Chuna) selected for growing in areas of known disease infestation in India were used in this study. The U.S. *C. annuum* cultivars were 'Yolo Wonder Improved', 'Hybrid Pepper Bell Boy', 'Cubanelle 78V2866', '672 Hungarian Wax', 'Early California Wonder', and 'Sweet Red Cherry Pickling'. Seedlings were raised in Jiffy mix and transplanted to 10-cm plastic pots containing 400 ml of 50:50 Jiffy mix and sandy loam soil that was steam sterilized for 4 hr.

Pseudomonas solanacearum. Nine isolates of *P. solanacearum* (races 1 and 2) collected from diverse, geographical locations were used to evaluate these pepper lines for their bacterial wilt reactions (Table 1). Kelman's medium (5) was used to select virulent isolates. Inoculum was grown on the same medium, but without tetrazolium salt, for 2 days at 30° ± 2°C. Inoculations of the Petri dishes were made with a wire loop containing 0.01 ml of inoculum. Stems of 21-day-old plants were inoculated by using a sterile hypodermic needle to inject 0.2 ml of a bacterial suspension containing 2×10^{10} cells per ml into the axil of the 2nd fully expanded leaf from the bottom (13). Disease indices were determined as symptoms appeared and scored as resistant (<25%), moderately resistant (>25% <50%), susceptible (>50% <75%), and highly susceptible (>75%). The experiment was repeated 6 times with 20 plants per treatment.

No pepper lines tested were resistant to all 9 isolates of *P. solanacearum* and only isolate A 21 was pathogenic to all the pepper lines. The most resistant line was 'Pant C-1', a line derived as an advanced generation selection from a cross between 'NP46A' and 'Khandari'. It was susceptible only to Florida isolates A21, TFP12, TFP13, and 126408-1 (Table 2). 'KAU Cluster' was resistant to 5 isolates. 'White Khandari' was resistant to 3 Florida tomato isolates; moderately resistant to 2 isolates; susceptible to 2 isolates; and highly susceptible to 2 isolates. The breeding line 'Chuna' was resistant to 4 isolates and highly susceptible to 2 isolates. All the U.S. cultivars were highly susceptible to all except the Philippine eggplant isolate.

Phytophthora capsici. Three of the 4 Indian hot peppers, 'Pant C-1', 'KAU Cluster', and 'White Khandari' and 6 U.S. cultivars, 'Yolo Wonder Improved', 'Hybrid Pepper Bell Boy', 'Cubanelle 78V2866', '672 Hungarian Wax', 'Early California Wonder', and 'Sweet Red Cherry Pickling' were evaluated for their susceptibility to *P. capsici*. All plants used in this study were tested in 10-cm plastic pots containing 400 ml of fumigated soil mixture. Saucers were placed beneath each pot and irrigated to facilitate moisture retention and to help restrict splash spread of fungi. Five, 15-day-old seedlings were transplanted to each pot and were inoculated with inoculum containing 10^6 zoospores of *P. capsici* (10). The roots were dipped in the zoospore suspension before transplanting and then inoculated with 1 ml of zoospore suspension placed on the surface of the soil. The pot was covered by a polyethylene bag to prevent desiccation. Disease indices were determined 15 days after inoculation as symptoms appeared and scored as resistant (<25%), moderately resistant (>25% <50%), and susceptible (>50%).

Of the 9 cultivars and breeding lines evaluated for resistance to *P. capsici*, only 'KAU Cluster' was resistant (<25% infection). Moderately resistant lines with were 'Pant C-

Table 1. Origin of isolates of *Pseudomonas solanacearum*.

Isolates	Origin	Race
K 60	North Carolina (tobacco)	1
W 82	Colombia (potato)	2
W 295	Republic of Philippines (eggplant)	1
FF	Florida (weed)	1
A 21	Florida (tomato)	1
TFP 12	Florida (tomato)	1
TFP 13	Florida (tomato)	1
126408-1	Florida (tomato)	1
Tifton 80-1	Georgia (tomato)	1

Received for publication 25 June 1983. We acknowledge with appreciation R.H. Zimmerman and M.G. Benedict for their critical review and R.M. Sayre for the supply of nematodes. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

[1]On 1-year study grant from the government of India; Vegetable Laboratory, BARC, Beltsville, MD 20705.

Table 2. Disease indices of peppers to 9 isolates of *Pseudomonas solanacearum* from diverse geographical areas.

Pepper lines	Disease indices (%)								
	Pseudomonas solanacearum isolates								
	K 60	W 82	W 295	FF	A 21	TFP 12	TFP 13	126408-1	Tifton 80-1
Pant C-1	R(0)	R(0)	R(0)	R(0)	S(50)	S(50)	S(50)	S(50)	MR(36)
KAU Cluster	R(18)	R(10)	R(6)	R(0)	HS(100)	S(67)	HS(100)	HS(100)	R(0)
White Khandari	MR(33)	MR(40)	S(54)	R(0)	HS(100)	R(0)	HS(100)	R(0)	S(63)
Chuna	HS(100)	R(0)	R(0)	R(0)	NT	R(0)	NT	NT	HS(100)
Cubanelle	HS(100)	HS(83)	MR(33)	HS(100)	HS(100)	HS(100)	R(0)	HS(100)	HS(100)
Early Calo-Wonder	HS(100)	HS(100)	R(0)	HS(100)	HS(100)	HS(100)	HS(100)	HS(100)	HS(100)

R = resistant; MR = moderately resistant; S = susceptible; HS = highly susceptible; and NT = not tested.

1' (53%), 'White Khandari' (64%), and 'Cubanelle 78V2866' (67%). The susceptible cultivars were 'Yolo Wonder Improved' (94%), 'Hybrid Pepper Bell Boy' (78%), '672 Hungarian Wax' (80%), 'Early California Wonder' (100%), and 'Sweet Red Cherry Pickling' (100%).

Meloidogyne incognita. Four Indian pepper lines, 'Chuna', 'KAU Cluster', 'Pant C-1', and 'White Khandari', 4 U.S. cultivars, 'Early California Wonder', 'Hybrid Pepper Bell Boy', '672 Hungarian Wax', and 'Sweet Red Cherry Pickling', and three F_1 hybrids developed by using 'KAU Cluster' as the pollen parent were evaluated for their susceptibility to root-knot nematode infestations. Larvae were collected from the roots of susceptible pepper plants. The roots were washed to remove soil, chopped into pieces 3 to 4 cm, and shaken in a solution of 20% sodium hypochlorite for 4 min. The dislodged eggs were poured through nested screens of 60, 100, and 500 mesh per 2.5 cm and washed with a large volume of water. The eggs were washed again from the 500-mesh screen and allowed to hatch. Larvae were added at a rate of 100 larvae per 400 ml of the soil mixture of steamed soil and 50:50 Jiffy mix into 10-cm pots containing pepper seedlings. The plants were grown in a greenhouse with an ambient temperature of 30° ± 2°C and the soil was kept moist by irrigation every 12 hr. The infection indices were determined 60 days after treatment as: susceptible = more than 5 root-knots per seedling; moderately resistant = less than 5 root-knots per seedling; and resistant = no root-knots. Each test contained 25 plants per treatment each replicated 3 times.

The pepper lines 'Chuna', 'KAU Cluster', and 'White Khandari' were resistant to infection by *M. incognita*. The cultivar 'Pant C-1' was moderately resistant with less than 2 knots per seedling. The U.S. cultivars 'Hybrid Pepper Bell Boy', 'Sweet Red Cherry Pickling', '672 Hungarian Wax', 'California Wonder', and F_1 hybrids involving 'KAU Cluster' as a pollen parent were all severely diseased.

Conclusions. Combining resistances present in the lines 'Pant C-1', 'White Khandari', 'Chuna', and 'KAU Cluster' should develop a widely adapted, multiple pest resistance, horticulturally acceptable pepper germplasm. Of the 4 lines, 'Pant C-1', which is resistant to 4 isolates of *P. solanacearum* and moderately resistant to *P. capsici* and *M. incognita*, is presently one of the most widely grown hot pepper cultivars in the tropical and subtropical areas of India. The unique clustering and erect fruit habit of the breeding line 'KAU Cluster' coupled with its disease resistance make this selection desirable for developing germplasm suitable for a once-over harvest. 'White Khandari' and 'Chuna' collected from the Western Ghats of India possess a perennial fruiting habit associated with a multigenic resistance to bacterial wilt, *Phytophthora* root rot, and *M. incognita*. Thus, these lines could be additional sources of genes (pool) in a multiple disease- and nematode-resistant breeding program. The susceptibility of F_1 hybrids involving resistant 'KAU Cluster' as a pollen parent to *Meloidogyne incognita* indicates a recessive gene action which could be used readily to study the nature of root-knot nematode resistance in peppers.

Literature Cited

1. Conti, M. 1976. Breeding for resistance in Capsicum: viruses and other important pathogens. Genet. Agraria 30:91–93.
2. Goth, R.W., K.V. Peter, and R.E. Webb. 1983. Bacterial wilt *Pseudomonas solanacearum* resistance in pepper and eggplant lines. Phytopathology 75:808. (Abstr.)
3. Hsu, S.T. and J.Y. Chen. 1977. Physiological variation among isolates of *Pseudomonas solanacearum* from Taiwan. Plant Protect. Bul. (Taiwan) 19:124–132.
4. Kelman, A. 1953. The bacterial wilt caused by *Pseudomonas solanacearum*. A literature review and bibliography. N.C. Agr. Expt. Sta. Tech. Bul. 99:194.
5. Kelman, A. 1954. The relationship of pathogenicity in *Pseudomonas solanacearum* to colony appearance on a tetrazolium medium. Phytopathology 44:693–695.
6. Mathai, P.J., G.S. Dubey, K.V. Peter, V.D. Saklani, and N.P. Singh. 1977. Pant C-1 and Pant C-2 two new promising selections of chili (*Capsicum annuum*). S. Indian Hort. 24:123–125.
7. Peacock, F.C. 1976. Nematodes and crop diseases. Outlook Agr. 8:328–334.
8. Peter, K.V. 1975. Pant C-1, a promising chili variety. Indian Farmers Dig. 1975(March):3–5.
9. Raj, S. and P.N. Patel. 1977. Studies on resistance to bacterial diseases in India. Indian Phytopath. 30:207–212.
10. Schlub, R.L. 1983. Epidemiology of *Phytophthora capsici* on bell peppers. J. Agr. Sci. 100:7–13.
11. Smith, P.G., K.A. Kimble, R.G. Grogen, and A.N. Millett. 1967. Inheritance of resistance in peppers to *Phytophthora* root rot. Phytopathology 57:377–379.
12. U.S. Department of Agriculture. 1968. Market diseases of tomatoes, peppers and eggplants. Agriculture Handbook No. 28. Agr. Res. Serv., USDA, Washington, D.C.
13. Winstead, N.N. and A. Kelman. 1952. Inoculation techniques for evaluating resistance to *Pseudomonas solanacearum*. Phytopathology 42:628–634.
14. Yamakawa, K. 1976. Breeding for disease resistance of vegetable crops in Japan. Solanaceae. J. Agr. Res. Quart. 10:187–192.