Resistance in Pepper (*Capsicum annuum* L.) to Western Flower Thrips [*Frankliniella occidentalis* (Pergande)]

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Additional index words. insect resistance, insect tolerance, vegetable breeding

Abstract. A replicated greenhouse study was conducted to confirm the availability of resistance to western flower thrips in pepper germplasm. Host-plant resistance ratings confirmed earlier observations that there is a considerable amount of variability within pepper germplasm for reaction to *F. occidentalis*. Plants of 'Keystone Resistant Giant', 'Yolo Wonder L', 'Mississippi Nemaheart', 'Sweet Banana', and 'California Wonder' were resistant to the insect and exhibited only mild symptoms of damage. Plants of 'Carolina Cayenne', 'Santaka', and 'Bohemian Chili', however, exhibited the symptoms of severe thrips damage, i.e., poorly expanded, deformed, and distorted leaves; greatly shortened internodes; and severe chlorosis. The resistance to *F. occidentalis* in pepper appears to be due to tolerance mechanisms, not antixenosis (nonpreference) or antibiosis mechanisms. Thrips-resistant cultivars could be used as a cornerstone in an integrated pest management program for greenhouse pepper production.

Western flower thrips are tiny insects that can cause severe losses to a wide range of crops (Mantel, 1989). The insect is considered to be one of the most serious greenhouse pests of ornamental and vegetable crops in Europe (vanLenteren and Wardlow, 1989). Mantel (1989) noted that chemical control of *F. occidentalis* is difficult; the insect is quite resistant to most insecticides and difficult to target with directed insecticide applications because it lives inside flowers, buds, and young unfolded leaves. Mantel (1989) observed that the need to use insecticides in greenhouse crop culture to control *F. occidentalis* seriously limits the opportunities for using biological control methods against mites and other insect pests. Efforts are underway to find suitable biological control measures for *F. occidentalis*, but progress to date has been disappointing (Wardlow, 1989).

F. occidentalis can be responsible for severe damage to greenhouse plantings of pepper. Thrips-damaged plants exhibit poorly expanded, deformed, and distorted leaves;

shortened internodes; and chlorosis. The damage is often most severe in the seedling stage. Although we are not aware of any published reports of resistance in pepper to *F. occidentalis*, our observations of several greenhouse infestations suggest that there is a considerable amount of variability within pepper germplasm for reaction to this pest. The objectives of this study were to confirm the existence of resistance to *F. occidentalis* in pepper germplasm and to characterize the nature of the resistance.

The data reported here are from a greenhouse experiment conducted at the U.S. Vegetable Laboratory, Charleston, S.C., using the cultivars Bohemian Chili, California Wonder, Carolina Cayenne, Keystone Resistant Giant, Mississippi Nemaheart, Santaka, Sweet Banana, and Yolo Wonder L. Our previous observations indicated that 'Keystone Resistant Giant', 'Mississippi Ne-

maheart', and 'Yolo Wonder L' are thrips resistant, and that 'Bohemian Chili' and 'Santaka' are susceptible. The design of the experiment was a randomized complete block with six replications. Each plot consisted of a single row of five single-plant pots (0.5 liter) spaced 25 cm apart across a greenhouse bench; the rows were 20 cm apart. The plots were direct seeded on 11 Jan. 1990, and the entire planting was exposed to a colony of *F. occidentalis* on 6 Feb. 1990 by placing pots containing infested *Cucurbita pepo* L. cv. Early Prolific plants near the eight plots of each replicate. All plants were fertilized weekly with a nutrient solution. The greenhouse air was maintained between 24 and 32°C.

The test was terminated on 27 Feb. 1990. Symptoms of *F. occidentalis* damage (poorly expanded, deformed, distorted leaves and stunted internodes) were used to classify each host plant into one of five resistance classes (1 = no or minimal symptoms; 5 = severe symptoms). The extent of leaf tissue collapse caused by the piercing/sucking action of feeding thrips (tan, white, or silvery wound tissue on the underside of leaves) was visually rated for each plant on a scale of 1 to 5 (1 = no or minimal feeding; 5 = extensive feeding). The number of thrips adults and of thrips larvae on each plant were estimated using a timed (30-sec) count. The height of each plant was determined by measuring from the soil surface to the terminal bud. Shoot fresh weight was determined for each plot by harvesting and weighing all above-soil plant tissue.

Conditions for plant growth and development of a heavy *F. occidentalis* infestation were favorable throughout the 3-week exposure. Host-plant resistance ratings for the eight pepper cultivars confirmed our earlier general observations of variability within pepper germplasm for reaction to *F. occidentalis* (Table 1). 'Keystone Resistant Giant', 'Yolo Wonder L', 'Mississippi Nemaheart', 'Sweet Banana', and 'California Wonder' plants were resistant, exhibiting only mild symptoms of thrips damage. 'Carolina Cay-

Table 1. Host-plant resistance ratings, leaf feeding ratings, larval and adult insect counts, plant heights, and shoot fresh weights of plants of pepper cultivars infested by western flower thrips (WFT).¹

Cultivar	Western flower thrips					Shoot fresh wt (g)
	Host-plant resistance (rating) ²	Leaf feeding (rating) ³	Larvae/plant ⁴ (no.)	Adults/plant ⁴ (no.)	Plant ht (cm)	
Keystone Resistant Giant	2.0 c	2.7 b	3.4 bc	3.0 abc	13.1 bc	58.4 a
Yolo Wonder L	2.1 c	2.9 ab	4.0 b	3.6 a	13.0 bc	57.6 a
Mississippi Nemaheart	2.2 c	2.0 c	3.0 bc	1.9 bc	12.2 c	44.6 b
Sweet Banana	2.2 c	3.1 a	7.4 a	3.4 ab	16.0 a	58.5 a
California Wonder	2.3 c	2.8 ab	6.1 a	2.8 abc	14.5 b	57.3 a
Carolina Cayenne	4.0 b	2.3 c	3.6 bc	1.9 bc	13.3 bc	36.0 bc
Santaka	4.7 a	2.1 c	2.9 bc	1.8 c	12.8 c	32.8 c
Bohemian Chili	4.9 a	2.0 c	1.6 c	1.7 c	12.9 c	30.9 c

¹Mean separation in columns by Duncan's multiple range test, $P = 0.05$.

²Severity of the symptoms of thrips damage (poorly expanded, deformed, distorted leaves and stunted internodes) rated on a scale of 1 to 5; 1 = no or minimal symptoms and 5 = severe symptoms.

³Extent of leaf tissue collapse caused by the piercing/sucking action of feeding thrips (tan, white, or silvery wound tissue on the underside of leaves) rated on a scale of 1 to 5; 1 = no or minimal feeding and 5 = extensive feeding.

⁴The number of WFT larvae and adults on each plant were estimated using a timed (30-sec) count.

Received for publication 20 Aug. 1990. We acknowledge M.A. Lacey and S. Nakahara, Systematic Entomology Laboratory, Beltsville Agricultural Research Center, Agr. Res. Serv./U.S. Dept. Agr. ARS/USDA) Beltsville, Md., for the identification of *Frankliniella occidentalis*; and P.D. Dukes, ARS/USDA, Charleston, S.C., and C.W. Kuhn, Dept. of Plant Pathology, Univ. of Georgia, Athens, for evaluating *F. occidentalis* -damaged pepper plants for presence of viruses. The assistance of agricultural research technicians F.P. Maguire, R.B. Cuthbert, II, B.W. Davis, and J.E. Day is also gratefully acknowledged. 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.

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enne', 'Santaka', and 'Bohemian Chili' plants, however, were susceptible; these plants were chlorotic and badly stunted, and the leaves were poorly expanded, deformed, and distorted.

All of the resistant cultivars supported larval and adult thrips populations that were at least as large as those on the susceptible cultivars, suggesting that *F. occidentalis* was just as attracted to resistant as to susceptible cultivars. Additionally, the thrips fed at least as much on the leaf tissue of resistant cultivars as they did on that of susceptible cultivars; this similarity suggests that the resistant plants did not have adverse effects on the insect's biology. These results indicate that the thrips resistance exhibited by the cultivars used in this study was largely due to tolerance, not antixenosis (nonpreference) or antibiosis (Horber, 1980; Kogan and Ortman, 1978). Horber (1980) defined tolerance as "all plant responses resulting in the ability to withstand infestation and to support insect populations that would severely damage susceptible plants."

The density of *F. occidentalis* populations was related to plant size and indirectly related to the amount of leaf tissue damaged by the insect's feeding activity. For example, the correlation between plant weight and the number of adult insects per plant was highly significant ($r = 0.919$, $P = 0.01$), as was the correlation between number of adult insects per plant and leaf feeding ratings ($r = 0.926$, $P = 0.01$). These relationships should be considered when choosing criteria for evaluating pepper germplasm for resistance to *F. occidentalis*. The selection of "number of adult insects per plant" as a criterion for antixenosis, for example, might not be appropriate because of possible confounding effects with such plant traits as plant size and plant habit.

The pepper cultivars we identified have sufficiently high levels of resistance to justify the initiation of breeding efforts to transfer *F. occidentalis* resistance into susceptible greenhouse cultivars. Resistant cultivars could be a cornerstone in an integrated pest management program for greenhouse peppers. The availability of such cultivars may reduce the need to use either chemical or biological controls for *F. occidentalis* (Wardlow, 1989). Also, the use of tolerant cultivars would not adversely affect the biology of the insect, which would eliminate much of the selection pressure for the development of new biotypes. Finally, it should be noted that the resistances identified by us were found without resorting to detailed or extensive evaluation of germplasm collections. Significantly higher levels of resistances, and possibly different types of resistances, might be found in the large pepper germplasm collections that are available for evaluation (International Board for Plant Genetic Resources, 1983).

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