Role of the Shrub *Tamarix nilotica* in Dissemination of *Fusarium oxysporum* f. sp. *radicis-lycopersici*

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ABSTRACT

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The saltcedar shrub *Tamarix nilotica* grows as a weed in the Arava region of Israel. This weed is commonly found in cultivated fields naturally infested with *Fusarium oxysporum* f. sp. *radicis-lycopersici*, the causal agent of tomato crown and root rot. Young bushes, 20 to 40 cm tall, were randomly uprooted from different fields. The roots were cut into segments which were placed on *Fusarium*-selective medium. Although the plants did not show any symptoms of disease, the roots of the shrub were colonized by the pathogen. The incidence of infected saltcedar plants and level of root colonization by *F. oxysporum* f. sp. *radicis-lycopersici* decreased with increasing distance of the sampling location from a tomato field infected with crown and root rot. *F. oxysporum* f. sp. *radicis-lycopersici* was also isolated from chaff of inflorescence samples taken from mature *T. nilotica* shrubs. Identity of the pathogen isolates obtained from *T. nilotica* roots and chaff samples was verified by pathogenicity and vegetative compatibility tests. Roots of *T. nilotica* plants sown under greenhouse conditions in soil naturally infested with *F. oxysporum* f. sp. *radicis-lycopersici* became colonized by the pathogen. Uprooting and removing saltcedar plants throughout the season from fields not cultivated with tomatoes lowered the inoculum density of *F. oxysporum* f. sp. *radicis-lycopersici* in the soil from 611 to 6 and from 176 to 10 CFU/g of soil in the 1998-99 and 1999-2000 growing seasons, respectively. These results demonstrate that *T. nilotica* may contribute to the buildup of the pathogen populations in the absence of a susceptible host. Colonization of saltcedar by *F. oxysporum* f. sp. *radicis-lycopersici* is an additional mechanism for survival of this pathogen in the fields and for dissemination through the spread of infested seed or chaff of *T. nilotica*.

Additional keywords: nonsusceptible host, susceptible host, symptomless carrier

Many formae speciales of *Fusarium oxysporum* persist in the soil for long periods in the absence of a host crop (1,23). One of the mechanisms of survival of these fungi is colonization of the tissues of nonsusceptible hosts, consequently reproducing and increasing the pathogen populations (1,6,11,12,17). Symptomless association of wilt Fusaria with plants other than their susceptible hosts has been demonstrated in several studies (1,3,11,12). Such associations may compensate for the decline of pathogen populations in the absence of susceptible hosts.

Fusarium crown and root rot of tomato, caused by *F. oxysporum* Schlechtend.:Fr. f. sp. *radicis-lycopersici* W. R. Jarvis & Shoemaker, is a severe disease worldwide.

The widespread occurrence of the disease in fields planted with tomatoes for the first time (Y. Rekah and J. Katan, unpublished data) suggests that the pathogen may have been present and established in the fields at the time of planting. The broad host range of *F. oxysporum* f. sp. *radicis-lycopersici* includes cultivated plants in the *Solanaceae*, *Cucurbitaceae*, *Cruciferae*, *Leguminosae*, *Umbelliferae*, *Liliaceae*, and *Chenopodiaceae* families (17,21). This raises the question of whether this pathogen may form associations with wild plant species that would allow it to survive in soils in the absence of the tomato host.

The saltcedar shrubs *Tamarix nilotica* (Ehrenb.) Bge. and *T. aphylla* (L.) Karst. grow naturally in the Arava and Negev regions in the southern desert of Israel (4,24). Both species have become very common weeds in cultivated fields as a result of germination of seeds located close to the drip outlets of irrigation systems (Fig. 1). These weeds disturb the growth and development of the cultivated crop. Mature saltcedar plants are very common in noncultivated lands and produce large numbers of seeds disseminated by winds. The role of weed seeds in the dissemination

of pathogens received little investigation (2). However, macroconidia of *F. oxysporum* f. sp. *radicis-lycopersici* are dispersed via the air (20,22) at the same time that *T. nilotica* is in flower, so *T. nilotica* seeds may become infested with *F. oxysporum* f. sp. *radicis-lycopersici* and serve as a vehicle for dissemination and establishment of the pathogen.

The objectives of this study were to investigate the possibility of *T. nilotica* and *T. aphylla* serving as nonsusceptible hosts for *F. oxysporum* f. sp. *radicis-lycopersici* and to determine the potential role of these weeds in the survival and dissemination of *F. oxysporum* f. sp. *radicis-lycopersici* under field conditions.

MATERIALS AND METHODS

Media. Modified peptone-pentachloronitrobenzene *Fusarium*-selective medium (8) was used to isolate *Fusarium* spp. from plants and seeds of *T. nilotica* and *T. aphylla* and from tomato plants. Czapek-Dox medium (contained, per liter, 1 g of K₂HPO₄, 2 g of NaNO₃, 0.5 g of KCl, 0.5 g of MgSO₄·7H₂O, 0.01 g of FeSO₄, 30 g of sucrose, and 0.25 g of chloramphenicol) was used to grow inoculum for pathogenicity testing. Puhalla's minimal medium containing sucrose-salt and nitrate as the nitrogen source was used to recognize nitrate nonutilizing (*nit*) mutants and for complementation (heterokaryon) tests (14). Chlorate medium, based on potato dextrose agar (PDA) amended with potassium chlorate, was used to select *nit* mutants (14).

Colonization of roots of *T. nilotica* and *T. aphylla* by *F. oxysporum* f. sp. *radicis-lycopersici* under field conditions. The level of colonization of *T. nilotica* roots by *F. oxysporum* f. sp. *radicis-lycopersici* was assessed for 327 plants collected from various fields during four tomato-growing seasons: 1996-97, 1997-98, 1998-99, and 1999-2000. Sampling was done during February to April each year. Plants of *T. nilotica* were sampled from fields located at the 'En Tamar experimental station near to the Dead Sea, in the southeastern desert of Israel. The collected *T. nilotica* plants were 20 to 40 cm tall. Preliminary tests revealed that, in smaller plants, the pathogen could hardly be detected on roots, probably because its invasion and establishment to and in roots was not completed. Sixty-four *T. nilotica* plants were

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collected from eight tomato fields infected with *F. oxysporum* f. sp. *radicis-lycopersici*, in which tomato plants exhibited typical crown and root rot symptoms. In addition, 128 *T. nilotica* plants were collected from five melon fields, 95 plants from pepper fields, and 40 plants from one watermelon greenhouse. The melon, pepper, and watermelon fields were located about 20, 100, and 1,000 m from the tomato fields, respectively. The fields that were cultivated with crops other than tomato were fumigated with methyl-bromide annually and had never been cultivated with tomato.

Colonization of *T. nilotica* by *F. oxysporum* f. sp. *radicis-lycopersici* was determined by isolations. The crown and the whole root system were examined for presence of the pathogen. The root system of *T. nilotica* plants consists mainly of a taproot and some lateral roots. Roots and crowns were washed with tap water and the entire root system was cut into 1-cm segments. The segments were surface sterilized with NaOCl (1%) for 1 min, rinsed twice with sterile water, and incubated on *Fusarium*-selective medium at 27°C for 5 days in the dark. Colonies exhibiting morphology similar to that of *F. oxysporum* were subcultured for pathogenicity tests to determine the identity of the isolates. The level of root colonization was defined as the percentage of root segments colonized by *F. oxysporum* f. sp. *radicis-lycopersici*

from the total number of root segments for each *T. nilotica* plant. Records of individual plants were averaged, yielding an estimate of the level of root colonization for each field. Incidence of plants infected by *F. oxysporum* f. sp. *radicis-lycopersici* was calculated as the percentage of plants infected by the pathogen from the total number of *T. nilotica* plants sampled from that field. Colonization by the pathogen of roots of 20 melon plants and 15 pepper plants also was examined. Pathogenicity tests were conducted as previously described (14) using 16-day-old tomato seedlings (cv. Rehovot 13). Inoculated seedlings were kept in a greenhouse at 22 to 25°C for 14 days after inoculation and the isolates were identified as *F. oxysporum* f. sp. *radicis-lycopersici* if at least three out of five seedlings in each pot showed typical disease symptoms and collapsed. Noninoculated tomato seedlings maintained under the same conditions served as controls. Pathogenicity tests were performed for approximately 95% of the *F. oxysporum* colonies isolated from roots of *T. nilotica* plants (one colony per *T. nilotica* plant, approximately 150 total isolates). Vegetative compatibility group (VCG) tests were carried out with 25 randomly chosen isolates from *T. nilotica* roots that were identified by pathogenicity tests as *F. oxysporum* f. sp. *radicis-lycopersici*, and with 32 isolates of *F. oxysporum* f. sp.

radicis-lycopersici originating from infected tomato roots grown in the fields.

In 1999, plants of *T. aphylla* also were sampled from a tomato field in which plants were infected by *F. oxysporum* f. sp. *radicis-lycopersici*. The field was located in 'En Habsor, the Negev desert region in southwestern of Israel. *T. aphylla* is not a common weed in cultivated fields in that region, but roots of 43 plants were examined for colonization by *F. oxysporum* f. sp. *radicis-lycopersici* as described for *T. nilotica*.

Infection of *T. nilotica* plants under greenhouse conditions. Seeds of *T. nilotica* were sown in eight 10-liter pots in the greenhouse and maintained at 22 to 25°C. The pots were filled with naturally infested soil obtained from a crown and root rot-infected tomato field. Initial inoculum density was determined by spreading 0.2-ml aliquots of a 1:10 soil dilution with 0.1% water agar on each of five petri dishes containing *Fusarium*-selective medium (8). The pots were watered by drip irrigation three times a day to maintain high soil moisture. Seeds that served as controls were sown in pots containing pathogen-free Rehovot sandy soil (3.8% clay, 0.0% silt, 96.2% sand, and 0.4% organic matter). This soil was defined as pathogen-free because control plants that were grown on it did not show any disease symptoms and no pathogens could be isolated from their roots. Forty-three plants (three to eight plants per pot), 20 to 25 cm tall, randomly chosen from all the pots, were removed after 96 days and tested for root colonization by *F. oxysporum* f. sp. *radicis-lycopersici*. The whole root system of each plant was examined for the presence of the pathogen as described above. Representative colonies of *F. oxysporum* (40 isolates in all) were randomly chosen for pathogenicity tests. The level of root colonization was determined as the percentage of root segments colonized by *F. oxysporum* f. sp. *radicis-lycopersici* from the total number of root segments tested for each *T. nilotica* plant. The incidence of infection was calculated as the percentage of infected plants of the total number of plants examined.

Effect of removal of *T. nilotica* plants on inoculum density of *F. oxysporum* f. sp. *radicis-lycopersici* in soil. A commercial melon field (c.v. Arava, in an area of 3,000 m²), which was fumigated annually with methyl-bromide and in which tomato had not previously been grown, was used to examine the effect of removing *T. nilotica* plants on the inoculum density of *F. oxysporum* f. sp. *radicis-lycopersici*. Seed of *T. nilotica* from nearby plants had spread naturally to this field, germinated, and produced plants. Samples were taken from two rows of the melon field. In each row, the *T. nilotica* seedlings were routinely (every 2 weeks) uprooted from 10 randomly chosen melon growing sites but

Fig. 1. Young plants of *Tamarix nilotica* at 'En Tamar experimental station. The plants grow close to the drip-irrigation system in cultivated fields prior to planting.

were left untouched in other 10 randomly chosen sites. When the *T. nilotica* plants that were left in the field were 30 to 40 cm tall, they were removed and the roots were examined for colonization by *F. oxysporum* f. sp. *radicis-lycopersici* as described above. A soil sample (approximately 100 g) was collected from a depth of 10 cm from all 40 planting sites described above. Inoculum density of *F. oxysporum* f. sp. *radicis-lycopersici* in soil samples was determined using the soil-dilution method (7). Results were expressed as the number of CFU of *F. oxysporum* f. sp. *radicis-lycopersici* per gram of soil, based on dilution counts and results of pathogenicity tests performed for representative colonies from each sample. The tests were performed in the 1998–99 and 1999–2000 growing seasons.

Isolation of *F. oxysporum* f. sp. *radicis-lycopersici* from seeds and chaff of *T. nilotica*. The inflorescence of *T. nilotica* contains pink flowers and small scale-like leaves that form a cluster of chaff-containing seeds. The seeds (about 0.4 to 0.6 mm in diameter) are connected to sessile apical pappi of unicellular hairs and are disseminated by winds (24). Chaff was collected in bulk from four different *T. nilotica* plants growing at the edge of the experimental station. Chaff (3 mg) was plated without surface sterilization on each of 50 petri dishes containing *Fusarium*-selective medium. This chaff (3 mg) contained about seven seeds, seven bracts, and 72 sessile apical pappi of unicellular hairs. The number of colonies of *F. oxysporum* was determined for each plate after incubation for 5 days in dark at 27°C. The inoculum density was calculated as the average ($\pm$ standard error) of 50 samples containing 3 mg each, adjusted to 1 g content. The developing colonies were subcultured for pathogenicity tests, as described above, to determine the forma specialis. VCG tests were carried out with all 31 isolates identified as *F. oxysporum* f. sp. *radicis-lycopersici* by pathogenicity tests. For comparison, the VCGs of 32 isolates from *F. oxysporum* f. sp. *radicis-lycopersici* that infected tomato roots also were determined. These isolates were obtained from randomly collected roots of diseased tomato plants grown in different tomato fields over the 1998–99 and 1999–2000 seasons.

Vegetative compatibility tests. Isolation of *nit* mutants, complementation tests, and assignment to VCGs were done as previously described (14), using the testers 0-1090 1 and 0-1090 B for VCG 0090I; II E and II D for VCG 0090II; c696A 3 and c710A 62 for VCG 0090III; c544 and c758 for VCG 0091I; c69E 3 and FA222 for VCG 0091II; and CRNK-676 and CRNK-678 for VCG 0092. The VCG testers were obtained from the international collection of Talma Katan at the Volcani Center, Bet Dagan. A detailed description of the testers is given elsewhere (13).

RESULTS

Colonization of roots of *T. nilotica* and *T. aphylla* by *F. oxysporum* f. sp. *radicis-lycopersici* under field conditions. *F. oxysporum* f. sp. *radicis-lycopersici* was detected in 71% (ranging from 25 to 100%) of the *T. nilotica* plants growing in fields with diseased tomato plants; 38% (ranging from 10 to 71%) of the root segments of these plants were colonized by the pathogen (Table 1). The incidence of *T. nilotica* plants infected by *F. oxysporum* f. sp. *radicis-lycopersici* in an adjacent melon field was 77% (ranging from 50 to 93%). However, the level of root colonization of *T. nilotica* plants sampled from this melon field was 20% (ranging from 12 to 27%). The pathogen was also detected at a lower incidence (ranging from 0 to 40%) from *T. nilotica* plants sampled from a pepper field located 100 m from the tomato field; the level of root colonization was 9% (ranging from 0 to 29%). The incidence of colonization of *T. nilotica* plants by *F. oxysporum* f. sp. *radicis-lycopersici* sampled from a watermelon greenhouse located about 1,000 m from the infested tomato field was 8% and the level of root colonization of these plants was 5% (ranging from 0 to 10%). In comparison, isolations from diseased tomato roots revealed that 100% of the roots and crowns were colonized by *F. oxysporum* f. sp. *radicis-lycopersici*. Identity of the fungi isolated from *T. nilotica* plants was confirmed by pathogenicity tests to be *F. oxysporum* f. sp. *radicis-lycopersici*.

F. oxysporum f. sp. *radicis-lycopersici* colonized only the taproot of *T. nilotica* plants and not the lateral roots or the crowns. No disease symptoms were observed on any plant tissues. Attempts to isolate *F. oxysporum* f. sp. *radicis-lycopersici* on *Fusarium*-selective medium from root segments of melon and pepper plants growing in infested soil were unsuccessful.

Although no disease symptoms could be detected on the root samples of *T. aphylla*, 34 of 43 plants (79%) were infected by *F. oxysporum* f. sp. *radicis-lycopersici*. The

level of root colonization was $30 \pm 4.0\%$ (ranging from 0 to 86%).

Infection of *T. nilotica* under greenhouse conditions. *T. nilotica* was sown in naturally infested soil in which inoculum density of *F. oxysporum* f. sp. *radicis-lycopersici* averaged 6,000 CFU/g of soil. Ninety-six days after sowing, 40 of 43 plants of *T. nilotica* (93%) were colonized by the pathogen and the mean level of root colonization in these plants averaged 45% (ranging from 11 to 100%). The plants did not exhibit any disease symptoms. None of the plants grown in noninfested soil (control pots) were colonized by *F. oxysporum* f. sp. *radicis-lycopersici*.

Effect of removal of *T. nilotica* on the inoculum density of *F. oxysporum* f. sp. *radicis-lycopersici* in the soil. Continuous removal of *T. nilotica* plants from the melon field reduced the inoculum density of *F. oxysporum* f. sp. *radicis-lycopersici* in soil. The inoculum density in soil sampled from sites where *T. nilotica* plants were not removed was 611.3 ± 505.0 and 443.8 ± 238.6 CFU/g of soil for the 1998–99 and 1999–2000 seasons, respectively. In these sites, 83 to 93% of the *T. nilotica* plants (for the 1998–99 and 1999–2000 seasons, respectively) were colonized by the pathogen, and the level of root colonization was 25 to 27% for both years. The inoculum density of *F. oxysporum* f. sp. *radicis-lycopersici* in soil sampled from the root zone of melon plants grown in sites from which *T. nilotica* seedlings were continuously removed was 5.5 ± 2.8 and 9.9 ± 1.2 CFU/g of soil for the 1998–99 and 1999–2000 seasons, respectively.

Isolation of *F. oxysporum* f. sp. *radicis-lycopersici* from chaff samples of *T. nilotica*. *F. oxysporum* f. sp. *radicis-lycopersici* was detected in 15 of 50 samples of *T. nilotica* chaff collected from many inflorescences from different *T. nilotica* plants. The inoculum density of the pathogen in the inflorescence chaff, which contains seeds, bracts, and sessile apical pappus hairs, averaged 21.3 ± 6.3 CFU/g. All isolates obtained from the

Table 1. Colonization of roots of *Tamarix nilotica* by *Fusarium oxysporum* f. sp. *radicis-lycopersici* from plant samples collected from 22 plots located at various distances from tomato fields naturally infected with *F. oxysporum* f. sp. *radicis-lycopersici* at 'En Tamar experiment station^a

Previous crop	No. of sampled plots	Proximity (m) ^b	No. of sampled plants	Incidence of colonized plants (%) ^c	Root colonization per plant (%) ^d
Tomato	8	0	64	71.4 $\pm$ 10.3	37.9 $\pm$ 12.1
Melon	5	20	128	77.2 $\pm$ 8.1	19.5 $\pm$ 3.5
Pepper	8	100	95	13.4 $\pm$ 5.0	9.0 $\pm$ 3.5
Watermelon ^e	1	1,000	40	7.5	5.4 $\pm$ 1.5

^a Samples were collected during four growing seasons: 1996–97, 1997–98, 1998–99, and 1999–2000.

^b Distance in meters from infected tomato field.

^c The incidence of colonized plants is the percentage of infected plants out of the total number of *T. nilotica* plants examined.

^d Root colonization is the percentage root segments colonized by *F. oxysporum* f. sp. *radicis-lycopersici* out of the total number of root segments for each *T. nilotica* plant.

^e Watermelons were grown in a greenhouse. Plots were sampled in the 1999–2000 growing season only.

chaff samples were identified by pathogenicity tests as *F. oxysporum* f. sp. *radicis-lycopersici*.

VCG tests. The identity of *F. oxysporum* f. sp. *radicis-lycopersici* isolates from roots and chaff samples of *T. nilotica* was confirmed by VCG tests (Table 2). VCG 0091 was the most prevalent VCG regardless of the host plant, although a somewhat higher frequency was observed in isolates recovered from *T. nilotica* chaff samples. VCG 0092 was the least prevalent VCG for isolates of *F. oxysporum* f. sp. *radicis-lycopersici* from tomato roots and from *T. nilotica* root and chaff samples.

DISCUSSION

T. nilotica and *T. aphylla* grow abundantly in noncultivated areas in the southern part of Israel and have become common weeds in cultivated fields. In prior studies, *F. oxysporum* f. sp. *radicis-lycopersici* was shown to colonize roots of many cultivated plants (except tomato) and even cause mild symptoms in a few of these hosts (17,21). In this study, we recovered *F. oxysporum* f. sp. *radicis-lycopersici* from root and chaff samples (collected from mature inflorescence) of *T. nilotica* and from roots of *T. aphylla*. *T. nilotica* and *T. aphylla* plants infected by *F. oxysporum* f. sp. *radicis-lycopersici* showed no external or internal symptoms of disease. Therefore, they should be considered to be nonsusceptible hosts of *F. oxysporum* f. sp. *radicis-lycopersici*, denoting a commensal relationship between the host and fungus (12,15). The level of colonization of *T. nilotica* roots was lower than the level of colonization observed in tomato roots infected with *F. oxysporum* f. sp. *radicis-lycopersici*. This is in agreement with other studies that showed a greater colonization level of the pathogen on susceptible diseased hosts than on nonsusceptible hosts (6,12). Thus, saltcedar was considered a nonsusceptible host of *F. oxysporum* f. sp. *radicis-lycopersici*. Only the taproot of *T. nilotica* plants was colonized by the pathogen. Taproots represent the most massive and heavily lignified portion of a plant's

root system and can enhance the longevity of inoculum produced on a nonsusceptible host crop (10). *F. oxysporum* f. sp. *radicis-lycopersici* appears to have a broad nonsusceptible host range but a limited susceptible host range. A similar phenomenon has been reported for several other vascular and nonvascular formae speciales of *F. oxysporum* (3,10–12,15,23).

Nonsusceptible host plants can bridge the temporal discontinuity of annual susceptible host plants (1,3,6,9,11,12,17). Appropriate crop rotations are expected to slow down inoculum buildup, but the presence of nonsusceptible hosts may obstruct this potentially beneficial practice. Weed removal from cultivated fields is a recommended sanitation measure (23). In this study, we demonstrated that continuous removal of saltcedar plants from cultivated fields markedly reduces the inoculum density of *F. oxysporum* f. sp. *radicis-lycopersici*.

F. oxysporum f. sp. *radicis-lycopersici* may be transmitted in tomato seeds (16). Therefore, tomato seedlings may be the source of initial inoculum in fields planted with tomato for the first time. However, the level of tomato seed contamination is typically very low (0.01 to 0.1%) (16). Another source of inoculum of *F. oxysporum* f. sp. *radicis-lycopersici* in such fields may be airborne macroconidia (20,22) or conidia carried on seeds of nonsusceptible hosts such as saltcedar. We isolated *F. oxysporum* f. sp. *radicis-lycopersici* from chaff of the mature inflorescence of *T. nilotica* containing seeds, bracts, and hairy apical pappi. Seed production and dissemination by saltcedar usually starts in February (24), concomitant with the production of macroconidia of *F. oxysporum* f. sp. *radicis-lycopersici* on infected tomato plants, and continues through the summer and autumn until November. A mature *T. nilotica* plant may produce up to 500,000 seeds. Based on the incidence of the pathogen isolated from the *T. nilotica* inflorescence in this study, seeds originated from one saltcedar shrub may carry up to 10,000 propagules of *F. oxy-*

sporum f. sp. *radicis-lycopersici*. The propagules carried on saltcedar seeds might be better protected from adverse environmental conditions than airborne conidia. Moreover, propagules located in or on the seed are in the immediate vicinity of the infection court of their host (the roots). Thus, upon seed germination, propagules of *F. oxysporum* f. sp. *radicis-lycopersici* have a better chance of surviving the adverse conditions and infecting the host than propagules that are dispersed by wind. The dissemination of *F. oxysporum* f. sp. *radicis-lycopersici* via saltcedar seeds, which are equipped for aerial dissemination over long distances, has severe consequences. The infested seeds may contaminate fields that have never been cultivated to tomato or those that were treated against soilborne pathogens (e.g., fumigation, solarization). The spread of the pathogen by weed seeds adds another epidemiological factor to be considered in the management of Fusarium crown and root rot.

The VCG tests of the isolates of *F. oxysporum* f. sp. *radicis-lycopersici* obtained from the roots and chaff of *T. nilotica* confirmed the identity of the isolates. The majority of the isolates from *T. nilotica* and tomato belonged to VCG 0091. These results concur with previous reports for VCGs of isolates of *F. oxysporum* f. sp. *radicis-lycopersici* from tomato plants (5,13,14). The results suggest that all of the common VCGs of the pathogen have the ability to colonize *T. nilotica* roots and can be carried by the seeds disseminated in the air, and that this is not a unique phenomenon that characterizes only one VCG.

The mechanism of aerial dissemination of *F. oxysporum* f. sp. *radicis-lycopersici* by chaff of *T. nilotica* is consistent with our observations that Fusarium crown and root rot was occasionally detected at significant levels in fields in the Arava and Negev deserts in southern Israel with no prior history of tomato cropping. In these areas, *Tamarix* spp. grow abundantly in cultivated fields and in noncultivated areas. Severe outbreaks of Fusarium crown and root rot in southern Israel may be related to the widespread presence of *T. nilotica* and *T. aphylla* in these regions. Other nonsusceptible weed hosts of this fungus may be present but not yet verified. The existence of a variety of mechanisms of dissemination and survival of *F. oxysporum* f. sp. *radicis-lycopersici* requires an integrated approach to disease management that includes weed control as well as other sanitation practices (18,19).

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Table 2. Vegetative compatibility groups (VCGs) of isolates of *Fusarium oxysporum* f. sp. *radicis-lycopersici* obtained from tomato roots and from roots and chaff samples of *Tamarix nilotica*

Source of isolates	No. of isolates	Incidence of VCGs (%) ^a		
		VCG 0090	VCG 0091	VCG 0092
Tomato roots ^b	32	37.5 (12)	56.3 (18)	6.2 (2)
<i>T. nilotica</i> roots ^c	25	36.0 (9)	64.0 (16)	0.0 (0)
<i>T. nilotica</i> chaff ^d	31	25.8 (8)	71.0 (22)	3.2 (1)

^a Testers used were 0-1090 1 and 0-1090 B for VCG 0090I; II E and II D for VCG 0090II; c696A 3 and c710A 62 for VCG 0090III; c544 and c758 for VCG 0091I; c69E 3 and FA222 for VCG 0091II; CRNK-676 and CRNK-678 for VCG 0092. The VCG testers were obtained from the international collection of Talma Katan at the Volcani Center, Bet Dagan (13). Numbers in parentheses indicate the numbers of isolates.

^b Isolates were obtained from randomly chosen diseased tomato roots grown in infected fields.

^c Isolates originated from roots of 25 randomly chosen *T. nilotica* plants which were also identified by pathogenicity tests as *F. oxysporum* f. sp. *radicis-lycopersici*.

^d Isolates originated from chaff samples which were also identified by pathogenicity tests as *F. oxysporum* f. sp. *radicis-lycopersici*.

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