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Tomato Pathology in Turkey

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ABSTRACT

Turkey ranks 4th in the world after China, India and USA for vegetable production with 25.6 million tones and has a 3.1% share. Tomato, melon and watermelon are the most common vegetables with a large cultivation area in Turkey. Tomato is an important crop species in Turkey and total tomato production was 9,440,000 t in an area of 255,000 ha. Major fresh market tomato production takes place in the Aegean, Mediterranean and Marmara regions. Tomato is an important fresh fruit in Turkey's export, and ranks third after citrus and stone fruits with a 14% share. Some pests and diseases cause important yield loses in greenhouses and field grown tomatoes. Important fungal diseases of tomato in Turkey are Fusarium wilt (*Fusarium oxysporum* f.sp. *lycopersici*), Fusarium crown and root rot (*Fusarium oxysporum* f.sp. *radicis-lycopersici*), late blight (*Phytophthora infestans*), gray mold (*Botrytis cinerea*), early blight (*Alternaria solani*), leaf mold (*Cladosporium fulvum*), white mold (*Sclerotinia sclerotiorum*), damping-off (*Pythium* spp., *Rhizoctonia solani*, *Fusarium* spp.), corky root rot (*Pyrenochaeta lycopersici*). Reported viral diseases are: Alfalfa mosaic, Cucumber mosaic, Potato leaf roll, Tomato mosaic and Tobacco mosaic, Tomato spotted wilt, Tomato yellow leaf curl, Tobacco etch, Potato virus X, tomato black ring, tomato ringspot, Potato Y and stolbur disease as MLO. The bacterial diseases include bacterial canker (*Clavibacter michiganensis* subsp. *michiganensis*), bacterial speck (*Pseudomonas syringae* pv. *tomat*o), bacterial stem rot (*Erwinia* spp.) and tomato pith necrosis (*Pseudomonas* spp.). Soil disinfestation prior to planting in the case of greenhouse tomato production has become an important issue in Turkey because of the continuous plantation of the same crops. In greenhouse tomato production solarization alone and/or in combination with low dosage fumigant applications are being widely used in the Mediterranean region, which accounts for 90% of greenhouse tomato production in Turkey. Training studies are being conducted for farmers on Integrated Pest Management (IPM) strategies after planting.

Keywords: bacteria, diseases, fungi, virus

CONTENTS

INTRODUCTION

Tomato is one of the most important crop species among vegetables when cultivation, production and demand are considered. It is consumed as fresh and also has a great economical value as frozen food, fruit juice, canned products, paste, ketchup, pickles, etc. The tomato industry is based on many products using fresh and frozen tomatoes as raw materials.

Leading the world fresh tomato producing countries are EU, China, USA and Turkey with a 14%, 23.4%, 11.1% and 8.9% share, respectively. Italy, Spain and Greece are the main tomato producers within the EU whose production is increasing (Anonymous 2004).

Turkey, Spain, Mexico, Holland, Morocco, USA and Jordan are the leading tomato export countries in the world. Suitability of climatic conditions makes Turkey the most important tomato-producing country. In Turkey, tomato is cultivated mainly in the Marmara, Aegean and Mediterranean regions. Most of the tomato processing industry plants takes place in the Marmara and Aegean regions, while fresh production is mainly located in the Mediterranean region. Total tomato production in Turkey has reached 10 million t in 2005, and the yield was 4 t/day; of

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Invited Review

this production, 2.9 million t was used for tomato paste and 7.1 million t were consumed as table tomatoes (Anonymous 2005). Tomatoes grown in the Marmara region are used for paste production, while those of the Aegean and Mediterranean regions are consumed fresh.

There are some organic tomato farms in Turkey, but they are scarce. There is no extensive production in such farms. Tomato production in the Mediterranean region is being done in the controlled greenhouses in soilless cultures. In such greenhouses fertilization is done by *Bombus* bees.

Tomato is also grown under plastic and glasshouses in Turkey. Protected tomato production in 2005 was 2.02 million t, and main production came from the Mediterranean and Aegean regions. The important tomato producing provinces are İzmir, Muğla, Manisa (Aegean region), Bursa and Çanakkale (Marmara region). Antalya, Hatay, Icel and Adana are the main tomato producing provinces cited for the Mediterranean region. A total of 56-61% tomato production of Turkey takes place in these provinces (Anonymous 2005).

Tomatoes are grown as one or two crops in greenhouses in Turkey. When they are cultivated as one crop they are planted during the September-June season. In the case of double cropping, the first season is during August-January, followed by a late January-June plantation. Field plantations are usually done after 15 March.

Drip irrigation is usually applied in the greenhouse grown tomatoes, and in open fields, either drip irrigation or furrow irrigation systems are used.

Soil types in greenhouses in which tomatoes grown in Turkey are usually sandy-clay-loamy in places near the seaside, and clay-loamy type heavy soils in costal areas. Generally speaking, in most greenhouses in Turkey, monoculture plant cultivation practices are applied. This continued plantation causes soil-borne pathogens and nematode problems in such greenhouses. As mentioned previously tomatoes are also grown in the plastic houses in Turkey, and air-borne fungal pathogens become more serious than soil-borne pathogens in these areas.

Turkey has greatly improved its cultivation practices and processing industry from small family enterprises to modernized and controlled companies and firms. Such establishments have modernized machineries and tools for packing, pest-disease management and transportation. Use of resistant rootstock grafted seedlings to avoid soil-borne pathogens is becoming widespread in eggplants, tomatoes and watermelons.

As a matter of fact, variable soil and air-borne diseases are recorded in Turkey and some of them had caused important economic losses despite chemical control measures (Engindeniz 2006). This review deals with tomato disease reports in Turkey on the basis of the origin of the causal agent and on related research.

FUNGAL DISEASES OF TOMATO

Soil-borne pathogens

Fusarium wilt caused by *Fusarium oxysporum* f.sp. *lycopersici* (FOL) (**Fig. 1A**) and root and crown rot of tomato *F. oxysporum* f.sp. *radicis-lycopersici* (FORL) (**Fig. 1B**) were reported in Turkey (Bremer 1948, 1954; Yücel 1989; Can *et al*. 2004). Extensive research has been conducted on the diagnosis and control of FOL infections of field and greenhouse grown tomatoes in Aegean and Mediterranean regions (Filiz 1985; Yücel and Çınar 1989). In a study conducted by Yücel and Çınar (1989) and Yücel (1989), the effect of solarization on FOL was first tested in the Mediterranean climate, and solarization alone did not control the disease development. The disease incidence was lower when antagonist microorganisms (*Trichoderma harzianum* Rifai aggr.) and/or low dosage of soil fumigants were applied after solarization. Solarization in combination with soil fumigants in the Aegean, Marmara and Mediterranean regions have been successfully applied for controlling of FOL in greenhouse grown tomato. No report of FOL races has been published in Turkey.

In a study reported by Özgönen *et al*. (2001) salicylic acid and arbuscular mycorrhizal fungi, *Glomus etunicatum* were found to reduce FOL infection in greenhouse grown tomatoes in the Mediterranean region. Similarly *G. intraradices* and some rhizobacteria (*Pseudomonas fluorescens*, *P. putida*, *Enterobacter cloaca*e) were used for FOL control and reported to be effective (Akköprü and Demir 2005). FOL infection and the Fusarium wilt disease incidence in Turkey have recently been reduced by using resistant tomato cultivars (Yücel *et. al*. 2007).

FORL was first detected and reported in 2004 in Turkey, and since then started to spread to all tomato growing areas (Can *et al*. 2004; Erol and Tunalı 2007; Kabas *et al*. 2007). Due to the banning of Methyl Bromide (MeBr) in Turkey in 2008, exploring alternative methods for controlling soil-borne disease in tomato has been a major research area. Yücel *et al*. (2007) tested reduced amounts of Metham sodium and Dazomet in combination with solarization against FORL and root knot nematodes (*Meloidogyne javanica* and *M. incognita*), and reported that both of the pathogens were effectively controlled.

Bacillus subtilis (EU07) isolate was reported to be effective in pot experiments against FORL, and that this isolate was compared to that of commercial *B. subtilis* isolate (QTS 713) (Baysal *et al*. 2007a). EU07 exhibited difference from QTS 713 at the DNA level and had more colonization in tomato roots.

Baysal and Yeşilova (2007) used DL-β-Aminobutryric acid (BABA) to induce defense responses in tomato against FORL and reported increased resistance.

Tomato inbred lines produced by the West Mediterranean Agricultural Research Institute (BATEM) in Turkey were tested for their resistance to FORL and 9 tomato lines were found to be resistant, and they are currently being tested for further characterizations (Kabas *et al*. 2007).

Rhizoctonia solani Kühn, *Fusarium solani* (Mart.) Sacc., *Phythophthora capsici* Leon., *Sclerotinia sclerotiorum* (Lib.) de Bary, *Pyrenochaeta lycopersici*, *Macrophomina phaseolina* (Tassi) Goid. and *Pythium ultimum* Trow. var. *ultimum* were also reported in the field and greenhouse grown tomatoes in Turkey (Uslu and Yıldız 1995; Yıldız and Döken 2002; Kırbağ and Turan 2006; Soylu *et al*. 2007). These studies focused mainly on the characterization of the isolates, and their control in field and greenhouses.

R. solani isolates from Aegean, Central and Eastern Anatolia were characterized according to their anastomosis groups and were assigned to Ag-3, AG-4 and Ag-5, in which AG-4 being as the most common group (Tuncer and Erdiller 1990; Demirci and Döken 1995; Yildizz and Döken 2002).

S. sclerotiorum isolates from the Mediterranean region were characterized according to their mycelial compatibility, and 17 groups were determined out of 58 isolates examined. These groups were further divided into 6 pathogenic groups, in which the Samandağ district/Hatay province groups were classified as the most pathogenic (Tok and Kurt 2007).

Demirci *et al*. (2007) reported that *Pythium* spp., *R. solani* and *Fusarium* spp. are the main damping-off pathogens of tomato in the Ankara province of the Central Anatolia (**Fig. 1C**). In this study *Fusarium* spp. was the most widespread pathogen while *Pythium* spp. and *R. solani* were the most pathogenic.

Broccoli (*Brassica oleracea* var. *italica* Plenck) was used as soil amendments for controlling *Sclerotium rolfsii* and *S. sclerotiorum* in greenhouse-grown tomatoes (Irshad and Önoğur 2001). Effective control over these pathogens was obtained and it was suggested that broccoli cultivation should be included within the crop design and that the leftovers could then be mixed to soil as cultural control practice. They have also suggested that chemical usage could be decreased and *Sclerotium rolfsii* and *S. sclerotiorum* both in field and greenhouses could effectively be controlled.

Soylu *et al*. (2007) tested the antifungal activity of ore-

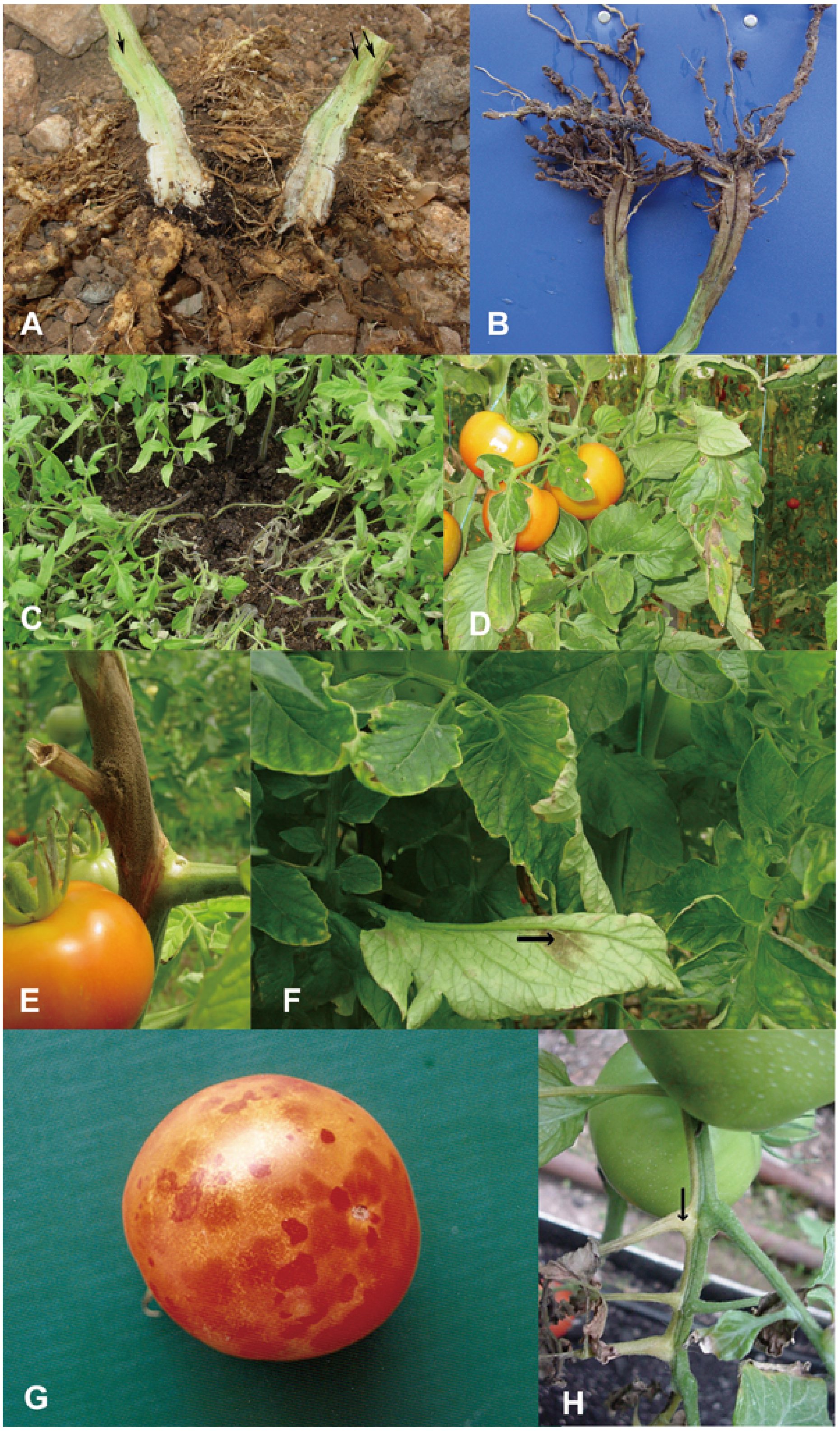

Fig. 1 (A) Fusarium wilt caused by *Fusarium oxysporum* f.sp. *lycopersici*. Arrows indicate vein discolorations. (**B**) Fusarium crown and root rot caused by *Fusarium oxysporum* f.sp. *radicis-lycopersici* in greenhouse grown tomatoes. Arrows indicate crown rots and fungus sporulation. (**C**) Damping off diseases caused by *Pythium* spp. in tomato seedlings. (**D**) Characteristic leaf symptoms of early blight disease caused by *Alternaria solani* in greenhouse grown tomatoes. (**E**) Gray mold caused by *Botrytis cinerea.* Arrow indicates massive sporulation on stem part. (**F**) Leaf mold caused by *Colletotrichum fulvum.* Arrow indicates sporulation site on the leaf. (**G**) Fruit symptom of TSWV. (**H**) One-sided wilting on tomato plant caused by *Clavibacter michiganensis* subsp. *michiganensis.* Wilting is indicated by an arrow.

gano (*Origanum syriacum* var. *bevanii*) and fennel (*Foeniculum vulgare*) against *S. sclerotiorum*, and the effect on mycelial growth was examined with electron microscope analyses. They reported that the both of the essential oils reduced *in vitro* hyphae growth and sclerotia germination in soil.

Verticillium wilt diseases caused by *Verticillium alboatrum* and *V. dahliae* have not been well documented in tomato, since these pathogens have not reached to economically important level in tomatoes in Turkey. *V. dahliae* was reported from eggplant in the Southeastern region of Turkey (Kırbağ and Turan 2006), and in general the Verticillium wilt pathogens effect olives and cotton plantations in Turkey. Physiological and pathological effect of *Verticillium albo-atrum* isolates on clover and tomato plants were invesitgated by Dikilitaş (1997, 2003).

Air-borne pathogens

Alternaria solani, *Botrytis cinerea*, *Phytophthora infestans* and *Cladosporium fulvum* are the main pathogens affecting the aerial part of tomatoes grown both in field and greenhouses in Turkey (**Figs. 1D-F**). The powdery mildew caused by *Oidium neolycopersici* has recently been reported in the Aegean region (Sın and Önoğur 2007). Some alternative chemicals ($NaHCO_3$, K_2SiO_3, KH_2PO_4, H_2O_2 plus Ag, sulphur and trifloxystrobin) were tested for their capacity to control the disease, and it was suggested that these applications alone or in combination could control powdery mildew in greenhouse grown tomatoes (Sın and Önoğur 2007).

Mildew disease of tomato caused by *Phytophthora infestans* Mont De Bary was previously reported in Turkey by Apaydın *et al*. (1999, 2000), who indicated that the disease becomes prevalent in moist regions with high rainfall. The disease is effectively controlled with chemical applications, and effect on yield and early warning criteria were explored (Apaydın *et al*. 1999, 2000). Öztürk (2000) examined the effect of high dosage of Metalaxyl that is used for controlling tomato mildew, and reported stomatal anomalies and mesophyll cell deformation.

The first report of A1 and A2 Mating types of *P. infestans* of tomato in Turkey was reported by Tosun *et al*. (2002, 2007).

Chemical control measures were explored against *A. solani*, *B. cinerea* and *P. infestans* by Yiğit and Poyraz (2003) and 14 different formulations were tested in plastic houses. *P. infestans* was effectively controlled but the chemical applications were not as effective for *A. solani* and *B. cinerea* with a disease incidence of 6.25% and 0.18%, respectively.

Delen *et al*. (1996) tested Flusilazole susceptibility of *A. solani* isolates in laboratory and field conditions. They reported that Flusilazole continued its effect for over 2 years but pointed put that repeated applications should be carefully examined for *A. solani* resistance against this fungicide.

Biological control of *B. cinerea* with five different *Pseudomonas fluorescens* was tested by Yildiz (2000) who reported that 10 days after inoculation, the infected plant ratio was reduced to 77.56-92.0%.

Soylu *et al*. (2006) tested antifungal activities of essential oils of oregano (*Origanum syriacum* var. *bevanii*), thyme (*Thymbra spicata* subsp. *spicata*), lavender (*Lavandula stoechas* subsp. *stoechas*), rosemary (*Rosmarinus officinalis*), fennel (*Foeniculum vulgare*), and laurel (*Laurus nobilis*) against *P. infestans* pathogenic to tomato. They reported that all the essential oils tested inhibited the growth of *P. infestans* in a dose-dependent manner. Light and scanning electron microscopic (SEM) observation revealed that the pathogen hyphae exposed to both volatile and contact phase of oil exhibited considerable morphological alterations such as cytoplasmic coagulation, vacuolations, hyphal shriveling and protoplast leakage.

Tosun *et al*. (2007) reported forecasting systems for prediction of late blight disease (*P. infestans*) and critical periods for chemical applications were determined. They reported that five fungicide applications instead of eight would be enough to control the late blight.

Surveys were conducted to find out fungal diseases of vegetables grown in greenhouses and their prevalence in Antalya and Mersin provinces during 1989-1990, and in Adana and Hatay provinces during 1990-1991 (Yücel 1994). The percentage of infested greenhouses with one and/or more pathogens was 33.4-69.2% for glasshouses and 46.8-100% for plastic houses in Antalya and Mersin provinces. The percentage of diseases appeared higher in plastic houses than glasshouses and this occurrence were similar for all species of the vegetables, including tomato, cucumber, eggplant and pepper. The percentage of infested plastic houses and tunnels were 25-72.7% in Adana and Hatay provinces. The diseases and pathogens detected were white mold, Fusarium wilt, early blight, grey mold, leaf mold and corky root (*Pyrenochaeta lycopersici*) on tomatoes grown in greenhouses.

VIRUS DISEASES OF TOMATO

From day to day, disease control due to virusal infection of tomatoes has gained utmost importance in agricultural production. The seriousness of the problem increases since no curative treatment exists for viral infections. Considering the monoculture agrarian practices, it is obvious to have higher crop losses due to the virus epidemics. In Turkey, tomatoes are grown both under protected conditions (greenhouse and plastic-house) and in the open field. Hence, crop losses due to virus diseases are significant, especially under protected conditions.

The control of viruses as pathogens is correlated with our knowledge of their biological properties allowing us to discover the proper diagnostic tools to apply. It is therefore, the study of virus diversity, introduction of advanced diagnostic tools and the use of data outcomes from those studies that would help to control virus infections of vegetable cultures in order to decrease the disease threshold under ecologically unsafe limits.

In the last two decades, studies were conducted mainly on the determination of viruses exist in Turkish tomato culture. As a result of those works, the presence of *Cucumber mosaic cucumovirus* (CMV), *Tobacco mosaic tobamovirus* (TMV), *Potato X potexvirus* (PVX), *Potato Y potyvirus* (PVY), *Tomato mosaic tobamovirus* (ToMV), *Tomato spotted wilt tospovirus* (TSWV), *Tomato ringspot nepovirus* (ToRSV), *Tomato black ring nepovirus* (TBRV) and *Tomato yellow leaf curl begomovirus* (TYLCV) were diagnosed.

In a study, DOT-ELISA method was used in order to determine Y (yellow) and Z (zinnia) strains of CMV by using a nitrocellulose membrane (Ertunç 1988). The efficiency of indirect and DAS-ELISA methods were compared by using crude and purified plant saps, as well. The conclusion of this study was that indirect ELISA could be used as a DOT-ELISA assay since it gave superior OD reactions than DAS-ELISA.

In another study, hybrid and standard tomato seeds derived from several organizations were used in order to identify the incidence of ToMV. The infection rate by ToMV was found as *c*. 70% in the standard seeds and *c*. 40% in the hybrids (Erkan *et al*. 1991). In general, tomato seeds of this study were free from ToMV for about 53%.

Unevenly distributed rings with line patterns and rosetting rinds (corky-bark) are usual symptoms limited to epidermal tissues on tomato fruits infected by ToMV. The leaves of these plants also show mosaic symptoms. A set of herbaceous test plants were used in order to obtain a virus culture while electron microscopy (EM) and serology were also applied in order to diagnose the causal agent. Test plants were symptomatic after 2-8 days from inoculation. The purified virus culture was collected as 36-40 mg/kg. However, viral particles were observed as rod-shaped and 18 X 300 nm under EM. Serology was applied by an agar double diffusion test and it was found serologically related to ToMV. Naturally, the causal agent was reported as ToMV (Güldür *et al*. 1991).

Yorgancı and Erkan (1991) observed some different symptoms than the usual ones in Mustafakemalpasa and Turgutlu districts. Upward shaping and anthocyan formation in lower plant leaves, yellow-green spots, narrowed and deformed appearance on the upper leaves, an necrotic spots on the fruits were some of those syndromes. Those tomato plants were partially or totally dead. To identify the problem, a set of test plants and EM work were used. Finally, CMV was determined as the causal agent of the syndromes.

Nogay (1991) studied the reaction of 12 hybrid tomato varieties against TMV infection. None of the varieties was found to be resistant to TMV. However, those varieties were grouped as less, medium and highly sensitive to TMV.

TYLCV was defined by obtaining antiserum, extracting DNAs and conducting electrophoretic analysis of the DNAs. The first attempt to characterize TYLCV found native isolates to be members of subgroup I (Yılmaz *et al*. 1991).

Another experiment was conducted in order to evaluate candidate plants resistant to TYLCV (Abak *et al*. 1991). A total of 7 tomato plants previously determined as resistant in other countries were used. *Lycopersicon peruvianum* "C.M.V. sel INRA", *L. hirsitum* "LA 1777" and "H2" lines were found to be sufficiently resistant to TYLCV under native conditions.

Spot Hybridization Technique was applied for the first time in tomato against TMV by using thee purified isolates. This process was found to be a very sensitive and reliable analytical method and was recommended for the detection of other viruses (Talas *et al*. 1991).

In a survey of the greenhouse vegetable production areas of Muğla province, Fidan (1993) sampled symptomatic plants and analyzed them using ELISA. Results indicate that tomatoes were infected with TSWV, ToRSV and TBRV. Fidan continued to survey Izmir and Manisa provinces and found TSWV infection in tomato plants by ELISA and mechanical inoculation tests (Fidan 1994). Following these surveys, Fidan investigated Izmir and Muğla provinces for the vegetables grown in greenhouses (Fidan 1995). Mechanical inoculation and ELISA tests were performed in order to determine the agents of the symptomatic plants. As a result of biological tests, TMV and a mixed infection of ToMV+PVX were observed. Where ELISA was used, TSWV, TRSV and TBRV were detected.

The most common viruses for tomato crops in Turkey were reported as ToMV, TYLCV, CMV and PVY by Güldür and Yılmaz (1994).

Tomato isolates of Bursa province were sampled and diagnosed biologically and serologically. ELISA tests were positive against TMV and PVX while test plants showed TMV and CMV symptoms as mixed infection (Özgöz *et al*. 1995).

A total of 13 tomato fields were sampled along the Adana-Mersin road; plants showed wilting and necrotic spotting symptoms (**Fig. 1G**). Isolates were inoculated into a set of test plants and serologically analyzed by DAS-ELISA. The presence of TSWV was found for the first time in the Mediterranean region of Turkey in this study (Güldür *et al*. 1995). The same methods were also used in order to find the causal agent of symptomatic tomato plants grown in the open in Sanliurfa province of South-East Anatolia region (Güldür 1997). This was the first report of TSWV in the province.

Güldür and Yılmaz (1998) also reported the presence of TYLCV in the South-East Anatolia region for the first time.

Seed-borne viruses of vegetables were also investigated by DAS-ELISA. Seeds were obtained from several organizations which produced or marketed the seeds (Gümüş *et al*. 2001). The rate of virus infections was 4.65%, 2.32% and 72.09% for TBRV, TMV and ToMV, respectively.

A total of 21 tomato cultivars derived from the tomato processing or seed producing companies were studied for their reactions against virus infections in greenhouse conditions. Resistance of those seeds was also evaluated by DAS-ELISA. They were completely resistant to infection by ToMV-, CMV- and PVY-positive cultures of native origin. However, at the end of the experiment, Primiton 712 appeared to be resistant to ToMV, UG 209, TP 0136 and Alexia F1 appeared to be resistant to CMV, and Golf and Alexia F1 appeared to be resistant to PVY (Erkan *et al*. 2001).

Virus-like symptoms were observed in tomato fields of Isparta province in 2000-2001. Those plants were collected and further analyzed by ELISA. As a result, isolates were infected with CMV and TMV at 31.81% and 22.72%, respectively (Yardımcı and Culal 2002).

A survey was conducted on the greenhouse districs of Uzundere, Torsum, Ispir, Olur, Ilica (Erzurum) and Yusufeli (Artvin) in the Eastern Anatolian region in Turkey during 2000-2001 (Bostan *et al*. 2002). Tomato leaves showing mosaic, bronzing, chlorosis, malformation, and rolling and also plants of bushy appearance were collected. Samples were analyzed by DAS-ELISA and resulting incidence of TMV was found to be 1.73%, 1.76%, 1.41%, 1.62%, 2.48% and 1.02% in Uzundere, Torhum, Ispir, Olur, Ilıca and Yusufeli, respectively. The rate of ToMV was around 0.18% and 1.45% for the Yusufeli and Ilica samples, respectively. However, TSWV was only detected in Ilica samples at 0.22%. No infection by TRSV, PVX and CMV was reported.

The sensitivity and reliability of several methods were compared for the detection of ToMV utilizing seeds and cotyledon leaves from tomato (Yılmaz *et al*. 2003). Materials were collected from variable organizations or business, namely those of Razan/Petoseed, Roquetero FA 180/Hazera, Fantastic/Hazera, Tomato F1 Belmonty/Enza Zaden, Falkon/MAY, Domato Mandur/Agromar, Tomato M74 F1/Agrotec and 73-33 RZ/Rijk Zwaan. No infection of ToMV was found from the seed coats by ELISA while it tested positive by ELISA, dsRNA and RT-PCR when cotyledon leaves of germinated seeds were used.

To determine seed-borne vegetable viruses, samples were collected for the pea, pepper, bean, squash, melon, lettuce and cucumber, including tomato seeds from the seed companies. Mechanical inoculations to a set of herbaceous plants, agar double-diffusion and ELISA tests were carried out. ELISA was found to be the best method to detect viral infections of seed samples. Nevertheless, agar double-diffusion tests, mechanical inoculations and planting the seeds were found applicable to some virus-seed combinations as well (Gümüş *et al*. 2004).

Methods applied to detect virus infections were compared. Techniques such as biological and serological methods (ELISA, immunodiffusion) and genome-based methods (total RNA, dsRNA analysis, PCR and electrophoresis) were used. Tomatoes grown on the Çukurova plane were analyzed by these comparative methods against ToMV. Virus infection was detected by the methods used, but in a low virus titer; ELISA was found insufficient to detect ToMV, which was possible by PCR. Therefore, ELISA and PCR were recommended to be used in combination (Yılmaz *et al*. 2004).

In 2003 and 2004, tomatoes grown in the open in Canakkale province were surveyed for the presence of TSWV. A total of 200 plants from 99.2 ha showing TSWV-like symptoms were sampled. Nine plants found to be positive through ELISA were further analyzed by DTBIA for comparison. Those nine plants were also positive by DTBIA. Pink-reddish coloration on a nitrocellulose membrane of the infected samples was also observed under binocular at 10X magnification (Turhan and Korkmaz 2006).

Şefik and Sökmen (2007) carried out a study on the temporal and spatial spread of TSWV by thrips in tomato fields. Vector species, *Thrips tabaci* Lindeman and *Frankliniella intonsa* Trybom, were investigated. The relationship between the incidence of TSWV and the flight activity of thrips within the tomato fields were reported as statistically significant ($P<0.01$). The TSWV isolates obtained from tomatoes were determined as being transmissible by *T. tabaci* from tomato and tobacco to tomato by biological, serological and molecular methods.

To determine the presence of TSWV, symptomatic plants of greenhouse-grown tomatoes and some weeds were sampled in the 2005-2006 growing season in Denizli province. Forty-three out of 71 were TSWV-positive by ELISA. Host plants *Nicotiana tabaccum* cv. 'Samsun', *N. rustica* L., *N. glutinosa* L. and *Datura stramonium* L. were observed with necrotic local lesions, chlorotic and necrotic spots and rings on inoculated leaves together with systemic mosaic, necrotic patterns, leaf deformation and stunting in general. Weeds as the reservoir of TSWV were also investigated. Ten weed species belonging to nine families were tested by ELISA, seven of which were found to be infected by TSWV (Özdemir *et al*. 2007).

Another study was performed to determine virus diseases of tomatoes in Muğla province in 2002-2004 growing seasons. TMV, ToMV, CMV, TSWV, TYLCV and PVY infections were investigated by ELISA from 19 different greenhouses where IPM was applied and routinely observed. Seeds and the seedlings were tested first and were initially found to be free from these viruses. However, throughout the cultivation period, some virus-like symptoms were observed and further analyinsist by ELISA detected the infection with TMV, CMV and TSWV at 3.0, 3.85 and 2.56%, respectively. A total of 53 tomato samples were found to be infected with TYLCV in molecular hybridization technique with variable whiteflies in the infected greenhouses (Kaya *et al*. 2007).

PHYTOPLASMA DISEASES OF TOMATO

In western Anatolia, tomatoes grown for the industry in Yenişehir (Bursa province) were found to be heavily infected with a phytoplasma disease "stolbur -Candidatus Phytoplasma" (Yorgancı *et al*. 1991). *Hyalesthes obsoletus*, known to be the vector for stolbur, was determined not to be significant for the province and no correlation was found between the vector and the epidemiology of the disease. However, it was hypothetically thought that vectors such as *Empoasca* spp. and other members of *Cicadellidae* spp. could be responsible for vectoring the disease. Due to this, some practices were recommended to control the vector and the planting time, which was the 15th of May in the province.

To determine the transmission of stolbur disease in tomatoes, a study was carried out in Çanakkale province by grafting, dodder and seed (Afat and Korkmaz 2004) in which the incidence of the disease was also determined. A total of 29 fields from 312 ha were observed during 2002 growing season and 1200 plants among 312,000 were found to be infected with stolbur. The infection rate was 0.38% in the surveyed areas. The disease incidence was 3.6% and 1.3% in Halileli and Gümüşcay districts, respectively, while no infection was found in Gülpınar, Tuzla and Kösedere districts of Çanakkkale. Twenty four infected plants out of 25 were graft-transmitted while 6 out of 7 were dodder-transmitted. No seed transmission was detected in this experiment. As a result, the symptoms of stolbur disease were observed only in old plants by grafting and by dodder-transmitted ones.

BACTERIAL DISEASES OF TOMATO

Stem and pith necrosis diseases

Several yield-limiting bacterial diseases in tomato have caused considerable concern among commercial tomato growers in Turkey. The important ones are stem and pith necrosis, caused by *Pseudomonas* spp. and soft rot disease by *Erwinia* spp. Several names such as tomato stem necrosis, pith necrosis and stem rot have been used to describe the general pathological symptoms of the disease exhibited on all above ground parts of plants including stems, petiole, leaves and fruits.

The occurrence of this syndrome of tomato was first observed in the Mediterranean and the Aegean regions of Turkey in the early 1990s. Following this report, it has spread out and caused severe damage to tomato plants in glasshouses, high tunnels, and recently fields wherever a high level of relative humidity and stress conditions were observed. Based on external disease symptoms in the Mediterranean and Aegean regions of Turkey in 2003, the average disease incidence caused by *Pseudomonas* and *Erwinia* species has been noted as 15-20% and 50-60%, respectively (Aysan *et al*. 2006).

Pith necrosis disease of tomato in Turkey caused by six different *Pseudomonas* species including *P. viridiflava*, *P. cichorii*, *P. corrugata*, *P. mediterraneae*, *P. fluorescens*, and an unidentified *Pseudomonas* sp. has been determined in many commercial greenhouses since the early 1990s (Aysan 2001; Ustun and Saygili 2001; Sahin *et al*. 2004; Saygili *et al*. 2004; Basim *et al*. 2005; Saygili *et al*. 2005). So far *P. viridiflava* (Aysan *et al*. 2004), has been known to be the most widespread species associated with stem necrosis in Turkey.

Spots on the stem, lesions on the petiole and fruit stalk, hollowing and browning of the pith, and discoloration of the vessels are defined as typical symptoms of the disease. Pith necrosis, caused by *Pseudomonas* species, is characterized by yellowing and wilting of the lower leaves, various sizes of irregular dark brown-black lesions on the stem, peduncle and leaf stalks, adventitious roots on the cracked stem, brown discoloration of the pith, ad sometimes no external symptom. Stem necrosis, caused by soft rot *Erwinia* species, is characterized by wilting of the whole plant, water-soaking areas on the stem, hollowing of the pith, browning of the vascular tissue and maceration in stem and fruits (Aysan *et al*. 2005).

All of the *Pseudomonas* species causing pith necrosis on tomato were Gram-negative, rod-like with one or more polar flagella. All were strictly aerobic bacteria, which induces a hypersensitive reaction in tobacco. LOPAT tests differ for all of these species (Aysan *et al*. 2006; Saygili *et al*. 2006). In addition, polyclonal antiserum for indirect-ELISA was produced and used for identification of *P. viridiflava* (Aysan *et al*. 2004). *P. corrugata* and *P. mediterranea* can be differentiated by specific PCR, the assimilation of *meso*-tartrate, 2-ketogluconate, and histamine (Catara *et al*. 2002). *P. corrugata* and *P. mediterranea* are non-fluorescent, but other *Pseudomonas* species are.

The disease is associated with low night temperatures, high nitrogen, and high humidity (Ustun *et al*. 2006). A high level of nitrogen fertilization, extensive irrigation and extreme temperature differences between day and night have been shown to increase significantly the susceptibility of host plants to the disease. The pathogens of stem and pith necrosis require an impaired host and favorable environmental conditions to cause the disease. The spread of the pathogens in greenhouses may occur by contaminated equipment during pruning and harvesting. The bacteria enter through wounds and natural openings. The epidemiology of pith necrosis on tomatoes is incomplete. *P. viridiflava* may survive as epiphytic on some weeds (Aysan and Uygur 2005), in association with infected debris and seeds and provide inoculum for the next growing seasons (Yildiz *et al*. 2004). Soil, infected debris, seeds and alternate hosts for soft rot Erwinia are the probable source of inocula (Aysan *et al*. 2004a; Cetinkaya-Yildiz and Aysan 2004).

Chemical treatments have not been developed for this syndrome. Some effective antagonists have already been isolated in Turkey (Aysan *et al*. 2003), and biological control as an alternative strategy may be used in the future. Tomato cultivars used in Turkey are susceptible to plant pathogenic bacteria (Ustun and Demir 2001). Sanitation, use of pathogen-free seed and seedlings, and environmental controls are extremely important. Good management practices, such as proper nutrition, good soil drainage, and ventilation in greenhouses should be followed. Excessive nitrogen and high humidity, especially in glasshouse and high tunnel culture, should be avoided. Diseased plant debris should be removed from the growing area.

Bacterial canker

Bacterial canker caused by *Clavibacter michiganensis* subsp. *michiganensis* (Smith) Davis *et. al*. is one of the most destructive diseases of the fresh market and processing tomato and it is responsible for important economics losses in tomato-growing areas in both field and greenhouses of Turkey. The pathogen was detected for the first time in the central Anatolia region by Bremer and Özkan (1950); since then it has been reported from the North Eastern Anatolia (Bremer *at al*. 1952), the Marmara (Karahan 1965) and the Aegean (Saygili 1977) regions as declared by Tokgönül (1998). In addition, the disease occured in the Eastern Mediterranean (Çınar 1980), the Western Mediterranean (Basim 2002; Basim *et al*. 2004) and in Eastern Anatolia (Sahin *et al*. 2002). The strains have been identified following the amplification of a 614 bp DNA fragment by a PCR test (Dreier *et al*. 1995), fatty acid methyl ester analysis (FAME) and Sherlock Microbial Identification System software (Microbial ID, Newark, DE) by Basim *et al*. (2004) and Sahin *et al*. (2002). *Clavibacter michiganensis* subsp. *michiganensis* and *Xanthomonoas axonopodis* pv. *vesicatoria* have been detected by multiplex PCR in a single PCR tube by Özdemir (2005).

Water-soaked, dark brown to black lesions on the leaf margins and stems, vascular discoloration, one-sided wilting, tip die-back and open stem cankers are reported as typical symptoms of the disease (**Table 1, Fig. 1H**). In another study, Özdemir (2005a) observed bird eye symptoms on proces-sing tomato (var. NDM 447) fruits.

In disease management studies, Tokgönül (1998) reported that solarization treatment has little effect in plastic tunnels and greenhouses. But at the same location, the effect of a second solarization increased by 55%. Soil samples obtained from tomato growing areas in the Eastern Mediterranean region were examined and *Actinomycetes* and fluorescent *Pseudomonas* were isolated. These antagonistic strains were reported as being hopeful for controlling the pathogen (Tokgönül and Çınar 1999; Cetinkaya-Yildiz and Aysan 2007).

Bacterial speck

Bacterial speck disease of tomato, caused by *Pseudomonas syringae* pv. *tomato*, was detected for the first time in the Aegean (Saygili 1975) and the Mediterranean (Çınar 1977) regions of Turkey in the end of the 1970's. Since then, serious outbreaks of the disease have occurred in commercial nurseries (Aysan *et al*. 2004b) and many tomato greenhouses and fields located in all regions of Turkey (Sahin 2001; Basim *et al*. 2004a). Incidence of the disease was 5-25% in 2004 (Aysan *et al*. 2004b; Basim *et al*. 2004a). The disease is characterized by lesions on cotyledons, speck lesions with a yellow halo on leaves, large brown areas on the stem, and small lesions on fruits. It is not systemic. There is no resistant or tolerant local cultivar to the bacterium (Çınar 1978; Karaca and Saygili 1982; Çökmüş 1984). Only cv. 'Ontario 7710' (Canadian cultivar) is resistant to the disease except for race 1. The occurrence of *Pseudomonas syringae* pv. *tomato* race 1 in Turkey was detected for the first time in 1998 (Aysan *et al*. 1998). This race is pathogenic on all local tomato cultivars and on cv. 'Ontario 7710'.

Pathogens may survive on infected debris in soil and seeds over the next growing seasons in the Mediterranean region of Turkey (Aysan *et al*. 1997). *Pseudomonas syringae* pv. *tomato* was also isolated from some seed lots that represent an important inoculum source (Aysan and Çınar 2002).

Chemical treatments, especially copper ammonia, has been used for controling this disease (Özaktan *et al*. 1991). Soil solarization is an alternative control strategy for suppressing the pathogen in soil. Soil solarization alone was as effective as 43%. In addition, combination of soil solarization, copper compounds and seed treatments was as effective as 79% compared to control plots in greenhouse conditions (Erkilic *et al*. 1994). Biological control by Plant Growth Promoting Rhizobacteria (PGPR) (Özaktan *et al*. 2001; Aslan and Özaktan 2004), and antagonists (Aysan and Çınar 2002a), and induced resistance studies with BABA (Baysal *et al*. 2004) were reported to be promising methods.

OTHER PATHOGENS

Parasitic weeds

Orobanche spp. (broomrape) was reported to effect tomato cultivation in the Marmara region where intensive production is being conducted (Nemli *et al*. 1989; Demirkan 1993). The researchers noted that this parasitic weed was the most destructive pathogen of tomato in the region, and that *Orobanche* spp. also destroys tobacco fields.

Orobanche aegyptiaca/ramosa complex was defined as broomrape species effecting tomato cultivation in Turkey. Research conducted by Orel-Aksoy and Uygur (2003) revealed that greenhouses in the Eastern Mediterranean region in which extensive tomato cultivation under protected conditions is being done, were highly contaminated with *Orobanche aegyptiaca/ramosa* complex, and that the contamination ratio was 27.72% among greenhouses, with 0.42 broomrape shoots per tomato plants. Another study to determine insect species for use in biological control of *Orobanche* spp. in the Eastern Mediterranean region was conducted by Aksoy *et al*. (2006). The researchers detected 101 samples belonging to 7 different insect species from lentil and broad bean fields. However, they did not find any insect from broomrape plants within greenhouses where tomatoes were grown. The authors linked this situation to the use of pesticides in the greenhouses (Aksoy *et al*. 2006). Another study conducted to examine yield loss of greenhouse-grown tomatoes revealed that tomato fruit weight was reduced by 24.18% due to *O. ramose* damage (Orel-Aksoy 2003).

Root-knot nematodes

Root knot nematodes, mainly *M. javanica* and *M. incognita*, were reported from tomato-growing areas both under protected conditions and open fields in Turkey (Elekçioğlu *et al*. 1995; Göçmen and Elekçioğlu 1996; Devran *et al*. 2002). The identification, disease ratios, chemical control and effect of solarization applications on root knot nematodes of tomato are well examined in Turkey.

CONCLUDING REMARKS AND FUTURE PROSPECTS

As a Mediterranean country, tomato is one of the major crops cultivated and processed in Turkey. Due to the availability of climatic conditions, many diseases cause yield losses in tomato. In general the growers have to be aware of the chemical control measures against diseases. However, there are scarce resources of resistant tomato cultivars against viral, bacterial and fungal disease agents. More research has to be carried out to develop resistant cultivars. In Turkey, a complete picture of virus strain diversity present in the field, as well as their harmfulness, which is crucial for analysis and prevention of plant virus epidemics, has not yet been drawn completely. The spread of viruses in agricultural ecosystems also needs to be analyzed.

Up-to-date information on species diversity of pathogens infecting tomatoes in the open field and under protected conditions needs to be obtained for Turkey. Molecular and biological characteristics and their phylogenetic relationships have to be further established.

Integrated Pest Management practices and their applications to growers and to technical staff need to be improved through demonstrative practices and training meetings. On top of these, possible new emergence of diseases has to be examined carefully.

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