Occurrence of Fusarium wilt caused by *Fusarium oxysporum* on strawberry transplants in Aydın Province in Turkey

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Abstract Samples of strawberry transplants were randomly collected from 47 growers in Aydın province of Turkey. A total of 26 *Fusarium oxysporum* isolates were identified by morphological characterization, sequence analysis of factor-1 alpha gene, and pathogenicity tests on strawberry, cucumber and tomato seedlings. To our knowledge, this is the first report of the presence of *F. oxysporum* in strawberry transplants in Turkey.

Keywords *Fragaria ananassa* · Fusarium wilt · *Fusarium oxysporum* f. sp. *fragariae*

Turkey is the fourth largest strawberry producer in the world, with an annual production of 372 thousand tones (FAOSTAT 2015). Recent studies indicated that *Macrophomina phaseolina* and *Fusarium* spp. were the major fungal pathogens isolated from the crown of dead or dying strawberry plants in Aydın province where 13 % of Turkey's strawberry production takes place (Benlioglu et al. 2014). During two cropping seasons 2009/10 and 2010/11, samples of strawberry transplants from 47 growers were randomly collected and examined for the presence of *Fusarium oxysporum*. After observation of longitudinal sections of transplants, fungal isolations were made aseptically on Potato Dextrose Agar (PDA) plates from internal vascular and cortical tissues of the crowns exhibiting a brown-to-orange-brown discoloration.

Fusarium-like colonies with light purple mycelia and orange reverse colony colours (Fig. 1) were sub-cultured on carnation leaf agar, and observed for microscopic conidial characteristics after obtaining single-spore cultures (Leslie and Summerell 2006). Twenty-six out of 73 *Fusarium oxysporum*-like strains exhibiting identical morphological characteristics were selected randomly for further identification tests. Macroconidia were 3 to 5 septate, straight to slightly curved, gently tapered and curved at the apical end (15.7 to 35.4×2.9 to 4.3 μm). Microconidia were oval ellipsoid, 0-septate and formed abundantly on short monophialides (6.1 to 12.5×2.1 to 3.6 μm) (Fig. 2). Pathogenicity tests were conducted in a growth chamber on 4-week-old strawberry transplants propagated from runners (cv. Camarosa), 4-week-old tomato (cv. Supermarmande) and cucumber (cv. Çengelköy) plants. Spore suspensions (10^5 conidia per ml) for each of 26 isolates were prepared and the roots of 5 plants each were dipped in each spore suspension for 15 min and each plant was transplanted into plastic pot containing sterilized peat. Plants were maintained at 24 ± 2 °C with a daily 16-h photoperiod of fluorescent light. Control plants were soaked in water prior to planting. Within 8 weeks, all inoculated strawberry plants exhibited wilting and decline symptoms (Fig. 3) including root rot and vascular discoloration of the crown. All treated tomato and cucumber plants, including control plants did not show any disease symptoms, and vascular discoloration was not observed when longitudinal or transverse cuts were made on the main stems or crown. The pathogenicity test was conducted twice. The fungus was successfully reisolated from the crown of inoculated strawberry plants and identity confirmed as before. Pathogenic *Fusarium oxysporum* strains were detected in 33 of 47 growers with an average incidence of 10.03 % and 4.25 % in the cropping seasons 2009/10 and 2010/11, respectively.

Morphological identification was confirmed by amplification and sequencing of a portion of the translation elongation

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Fig. 1 Fungal growth of *Fusarium oxysporum* on PDA

factor-1 alpha (TEF-1 α) gene. Genomic DNA was extracted from 26 pathogenic isolates of *Fusarium* and amplified using ef1 and ef2 primers (Geiser et al. 2004). Comparative sequence analysis with GeneBank revealed that all 26 isolates showed identity (99 to 100 %) to the *F. oxysporum*. Eleven out of 26 *F. oxysporum* strains also showed 99 % identity to *Fusarium oxysporum* f.sp. *fragariae* that is previously reported pathogen of strawberry in many countries in the world (Paynter et al. 2014). Four representative *F. oxysporum* strains were submitted to GeneBank with accession numbers (KJ776744 to KJ776747). After identification, all of 26 *F. oxysporum* isolates were deposited in the culture collection of the Plant Protection Department, Agricultural Faculty of Adnan Menderes University, Aydin, Turkey.

Although *Fusarium oxysporum* in strawberry has been previously reported in Erzurum province of Turkey (Durak and Demirci 2014), to our knowledge this is the first report of the occurrence of *F. oxysporum* f. sp. *fragariae* in strawberry transplants in Turkey. Recent studies indicated that

Fig. 2 Microconidia produced in false heads on short monophialides of *Fusarium oxysporum* under 20 $\times$ objective

Fig. 3 Pathogenicity test on strawberry plants (cv Camarosa), **a** Control and **b** Inoculated with *Fusarium oxysporum* f. sp. *fragariae*

M. phaseolina and *Fusarium* spp. were the primary reasons leading to death of strawberry plants in Aydin province and soil solarization did not effectively control these soilborne pathogens (Benlioglu et al. 2014). Our results are particularly important because *F. oxysporum* f. sp. *fragariae* has recently been considered as one of the most serious fungal threats to strawberry cultivation in Australia (Golzar et al. 2007; Fang et al. 2012), United States (Koike et al. 2009, 2013), Spain (Arroyo et al. 2009), Korea (Nagarajan et al. 2004) and China (Zhao et al. 2009), and it can also threaten strawberry fruit yield and transplant production in Turkey.

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